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CUMBERLAND PLAIN ASSESSMENT REPORT

PART 8: SUPPORTING DOCUMENTS

PREPARED FOR THE NSW GOVERNMENT DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

Part 8 – Contents

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2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document A – EPBC agreement and ToR

ENVIRONMENT PROTECTION AND

***BIODIVERSITY CONSERVATION ACT 1999* (Cth)**

Part 10 Strategic Assessment

Section 146 agreement

Strategic Assessment of the impacts of actions taken under
the *Cumberland Plain Conservation Plan*
on matters protected by Part 3 of the EPBC Act

between

THE COMMONWEALTH MINISTER FOR THE ENVIRONMENT

and

THE STATE OF NEW SOUTH WALES

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1. Parties

1.1 The parties to this agreement are:

the Commonwealth Minister for the Environment

and

The State of New South Wales, represented by the Minister for Planning and the Minister for the Environment.

2. Definitions

2.1 Unless the context indicates otherwise in this agreement, the definitions, meanings and terms in the EPBC Act apply to this agreement including its attachments.

2.2 In this agreement:

agreement means this strategic assessment agreement entered into between the **parties** on the date the last party executes this agreement, and includes any attachments.

attachment means an attachment to this agreement.

Commonwealth Environment Department means the Commonwealth Department with responsibility for administering the EPBC Act from time to time.

Commonwealth Minister means the Commonwealth Minister with responsibility for administering the EPBC Act, and includes a delegate of the Minister.

DPE means the New South Wales Department of Planning and Environment.

EPBC Act means the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

Impact means an impact as defined under section 527E of the EPBC Act and includes impacts from an event or circumstance as a result of implementation of the Plan on areas outside the strategic assessment area.

Impacts to which this agreement relates means the impacts of actions under the Plan on any matter protected by a provision of Part 3 of the EPBC Act.

OEH means the New South Wales Office of Environment and Heritage.

Parties means the parties to this agreement as set out at clause 1.

Plan means the *Cumberland Plain Conservation Plan* which will be prepared pursuant to clauses 4 and 6 of this agreement and which constitutes a 'policy, plan or program' pursuant to section 146 of the EPBC Act. The actual name of the Plan may change prior to submission for endorsement under the EPBC Act.

Protected matter means a matter protected under Part 3 of the EPBC Act.

State means the State of New South Wales.

Strategic assessment area means the indicative area of the Cumberland Plain as shown in the map at **Attachment 1**. The final strategic assessment area will be agreed between the State and Commonwealth.

Strategic Assessment Report means the report describing and assessing the impacts of actions under the Plan on protected matters, as contemplated by section 146(2)(a) of the EPBC Act, and prepared under clauses 5 and 6 of this agreement.

Supplementary Report means a report which includes:

a) a summary of all the public comments received; and

b) sets out how comments have been addressed through modification/s to the Plan or Strategic Assessment Report, if any, following public exhibition of the draft Strategic Assessment Report and draft Plan.

Terms of Reference means the terms of reference for the Strategic Assessment Report prepared under clause 5 of this agreement.

In this agreement references to the singular include the plural.

3. Context and scope

3.1 Under the Western Sydney City Deal, the Commonwealth, the State of NSW and a number of local councils have committed to working together to improve the lives of the people of Western Sydney through better transport, improved housing supply and affordability, better access to jobs and improved environmental outcomes.

3.2 The Parties acknowledge that the Cumberland Plain of Western Sydney has important environmental values that must be considered alongside the economic and social benefits of development of the region, and that a landscape approach to planning may benefit the environment.

3.3 The Parties agree to reduce duplication and streamline regulatory processes through alignment of a strategic assessment under Part 10 of the EPBC Act with an application for biodiversity certification under the NSW *Biodiversity Conservation Act 2016*. This may include conducting parallel public consultation periods and producing consolidated assessment documentation that satisfies regulatory processes of both jurisdictions.

3.4 The Parties agree to undertake a strategic assessment of the impacts of actions under the *Cumberland Plain Conservation Plan* (the Plan), currently being prepared by the State of NSW, on all matters protected under Part 3 of the EPBC Act.

3.5 The Plan will aim to provide for development over approximately 38 years within the boundary of the strategic assessment area. The Plan may include consideration of residential, commercial and industrial developments, and supporting infrastructure including major transport corridors for future roads.

3.6 The Parties agree to share information and work collaboratively throughout the strategic assessment.

4. Development of the Plan

4.1 The Parties agree that the State will develop a Plan that will seek to maximise conservation of protected matters that occur within, or adjacent to, the agreed strategic assessment area through a landscape approach to environmental conservation.

4.2 The Plan will include, but is not limited to, the identification of areas for development and commitments and outcomes for conservation of protected matters in the agreed strategic assessment area.

4.3 The Plan will include an implementation framework that describes how the commitments for conservation of protected matters set out in the Plan will be achieved. This implementation framework will address the following:

a) how outcomes and commitments for protected matters will be documented, delivered and adequately resourced throughout the life of the Plan; and

b) a framework for adaptive management, review of the effectiveness of the implementation in meeting the objectives for protected matters over time, and provision of a 5 yearly assurance report.

4.4 The Plan may include additional content relating to other responsibilities of the State.

4.5 The Plan will clearly identify and address protected matters separately from other State matters and ensure that, to the extent consistent with applicable NSW laws, the 'avoid, mitigate and offset' hierarchy of principles has been applied.

4.6 The State agrees to consult with interested stakeholders on the development of the draft Plan.

5. Terms of Reference for the Strategic Assessment Report

5.1 Pursuant to section 146(1B)(b) of the EPBC Act, the Parties agree to the preparation of Terms of Reference for a Strategic Assessment Report on the impacts of actions under the Plan on protected matters.

5.2 The State must make available for public comment, by notice, the draft Terms of Reference for the Strategic Assessment Report. The State must ensure that, at a minimum, the notice:

a) is posted on the DPE or OEH website;

b) is published in a national newspaper and a state daily newspaper circulating in NSW;

c) mentions:

i. that the draft Terms of Reference are available for public comment;

ii. the provision of the EPBC Act that requires the draft Terms of Reference for the Strategic Assessment Report to be published (i.e. section 146(1B)(b)(ii));

iii. where and how copies may be obtained in an electronic and hard copy form without charge or at a reasonable cost;

iv. contact details for obtaining further information, including reasonable access for persons with special needs; and

d) invites public comment on the draft Terms of Reference for the Strategic Assessment Report for a period of at least 28 calendar days that is specified by the Commonwealth Minister and set out in the notice.

5.3 The Commonwealth Environment Department will make the notice and draft Terms of Reference available electronically on the Commonwealth Environment Department's website.

5.4 The Parties may directly notify any party they think may have an interest in the draft Terms of Reference of the notice in clause 5.2.

5.5 Following consideration by the State of the public comments on the draft Terms of Reference and the making of any revisions by the State, the State will submit to the Commonwealth Minister:

a) any revised draft Terms of Reference; and

b) a copy of all public comments relating to the draft Terms of Reference; and

c) a document summarising whether and how the public comments have been taken into account in the revised draft Terms of Reference.

5.6 If the Commonwealth Minister is satisfied that the revised draft Terms of Reference will provide for a strategic assessment report that adequately addresses the impacts to which this agreement relates, the Commonwealth Minister will notify the Parties that the Terms of Reference can be finalised.

5.7 On receipt from the Commonwealth Minister of a notification under clause 5.6, the Parties must finalise the Terms of Reference.

6. Publication of the Plan and Strategic Assessment Report

6.1 Once the Terms of Reference for the Strategic Assessment Report have been finalised in accordance with clause 5.7, the State must prepare a draft Strategic Assessment Report in accordance with this agreement and the finalised Terms of Reference.

6.2 The State will provide the draft Plan and draft Strategic Assessment Report to the Commonwealth Environment Department for comment prior to both documents being released for public comment under clauses 6.4 - 6.6.

6.3 The Commonwealth Environment Department will assist the State toward ensuring that the draft Strategic Assessment Report adequately addresses the impacts to which this agreement relates by providing comments on the draft Plan in a timely manner.

6.4 Following the completion of the process set out in clauses 6.2 - 6.3 of this agreement, the State must, by notice, make the draft Strategic Assessment Report and draft Plan available for public comment. The State must ensure that, at a minimum, a notice:

a) is posted on the DPE or OEH website;

b) is published in a national newspaper and a state daily newspaper circulating in NSW

c) mentions:

i. that the draft Plan and draft Strategic Assessment Report are available for public comment;

ii. where and how copies may be obtained in an electronic and hard copy form without charge or at a reasonable cost;

iii. contact details for obtaining further information, including reasonable access for persons with special needs;

iv. the address to which public comments should be provided; and

d) invites public comment for a period of at least 28 calendar days that is specified by the Minister in the notice.

6.5 The Parties may separately notify any person, of the notice under clause 6.4 and of the availability of the draft Plan and draft Strategic Assessment Report.

6.6 The Commonwealth Environment Department will make the draft Plan and draft Strategic Assessment Report available electronically on its website.

6.7 Following consideration of any public comments received, the State will prepare, and then submit to the Commonwealth Environment Department for further comment:

a) a copy of all public comments;

b) a revised draft Strategic Assessment Report that takes account of the public comments received (if any);

c) a revised draft Plan that takes account of the public comments received (if any); and

d) a Supplementary Report.

6.8 The Minister is to direct the Commonwealth Environment Department to assist the State in ensuring that the revised draft Strategic Assessment Report adequately addresses the impacts to which this agreement relates by providing comments in a timely manner. The comments provided by the Commonwealth Environment Department may include recommended modifications to the draft Strategic Assessment Report, the draft Plan or both.

6.9 Following consideration of the Commonwealth Environment Department's comments, the State must finalise the revised draft Strategic Assessment Report and the revised draft Plan.

6.10 The State must then submit the following documents to the Commonwealth Minister:

a) the Strategic Assessment Report; and

b) the Plan; and

c) the Supplementary report.

7. Consideration of the Strategic Assessment Report and the Plan

7.1 Following receipt of the Strategic Assessment Report and the Plan in accordance with clause 6 of this agreement, the Commonwealth Minister may make recommendations to the State about the Plan (including recommendations for modification of the Plan).

7.2 The Commonwealth Minister may request any additional information he or she considers necessary in order to consider whether the Strategic Assessment Report adequately addresses the impacts to which this agreement relates.

7.3 If the Commonwealth Minister makes recommendations about the Plan, the State may:

a) seek clarification from the Commonwealth Minister on the recommendations;

b) modify the Plan to give effect to the Commonwealth Minister's recommendations; or

c) modify the Plan in a manner that has the same effect as the modifications recommended by the Commonwealth Minister.

7.4 If the State modifies the Plan in response to the Commonwealth Minister's recommendations, the State must submit to the Commonwealth Minister for consideration:

a) the modified Plan; and

b) a summary of how the Minister's recommendations were given effect.

7.5 Following receipt of the modified Plan, the Commonwealth Minister may request any additional information he or she considers necessary in order to consider whether the impacts of actions under the Plan on protected matters have been adequately addressed.

8. Endorsement of the Plan

8.1 The Commonwealth Minister may endorse the Plan if satisfied that:

a) the Strategic Assessment Report adequately addresses the impacts to which this agreement relates (that is, impacts of actions under the Plan on protected matters); and

b) either the recommended modifications to the Plan, or modifications having the same effect, have been made.

8.2 In determining whether or not to endorse the Plan, the Commonwealth Minister may consider the extent to which the commitments for the protection and management of protected matters are enforceable and achievable over the life of the Plan.

8.3 In determining whether he or she is satisfied that the Strategic Assessment Report adequately addresses the impacts to which the agreement relates, the Commonwealth Minister must have regard to the extent to which the Plan meets the objectives of the EPBC Act, including how the Plan:

i. protects the environment, especially those aspects of the environment that are protected matters under Part 3 of the EPBC Act;

ii. promotes ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;

iii. promotes the conservation of biodiversity;

iv. provides for the protection and conservation of heritage;

v. promotes a cooperative approach to the protection and management of the environment; and

vi. assists in the co-operative implementation of Australia's international environmental responsibilities.

8.4 If the Plan is endorsed by the Commonwealth Minister, the State must make the Strategic Assessment Report, Plan and (if relevant) Supplementary Report, publicly available electronically through an official website for the life of the Plan.

8.5 The Parties acknowledge that the endorsement of the Plan itself does not constitute any approval for the taking of actions under Part 10 of the EPBC Act.

9. Approval of actions

9.1 If the Commonwealth Minister endorses the Plan, the Commonwealth Minister may then approve the taking of an action, or class of actions, in accordance with the Plan. The effect of this approval decision is that any actions or class of actions approved under section 146B would not need further approval by the Minister under the EPBC Act if taken in accordance with approval and any conditions attached to the approval decision.

9.2 The Parties agree that an approval holder (or holders) will be named for any approval of actions, or classes of actions, granted under section 146B of the EPBC Act.

10. Environmental information management

10.1 The Parties agree to work cooperatively and share information, to the fullest extent practical, so as to avoid duplication of work in undertaking the strategic assessment pursuant to this agreement, subject to meeting requirements under the EPBC Act. To deliver upon this objective the Parties commit to the following open access requirements:

a) Information is accessible and reusable by the community, business, government and other stakeholders.

b) Information is published under an Open Licence (preferably Creative Commons Attribution licence), and available in the public domain.

c) Information is published and described in a way that maximises discovery and reuse, preferably online, and in open formats.

d) Information is published at the highest resolution and accuracy available.

e) Information is released electronically at no cost to users or, if other formats are required, at minimal cost.

f) The Parties agree to restrict information access only where necessary to adequately manage sensitive or confidential information.

10.2 The Parties agree to develop and maintain a Data Management Plan to record the key pieces of data and information generated to support the decision for this strategic assessment.

10.3 Parties will endeavour to jointly explore new approaches and internationally recognised standards to inform the strategic assessment to achieve best practice environment impact assessment and effective and transparent monitoring and reporting.

11. Governance arrangements and dispute resolution

11.1 The Parties agree to use best endeavours to establish agreed timelines within one month of the signature of this agreement for deliverables and arrangements to ensure adequate communications to progress the strategic assessment. This may include preparation of joint or individual project plans. The Parties agree to use reasonable efforts to resolve by negotiation any problem that arises between them in the course of carrying out this agreement (dispute).

11.2 A party will not terminate this agreement as a result of a dispute until the following process has been exhausted:

a) If there is a dispute between the Parties concerning this agreement, either party may give written notice of the Dispute to the other party which will state that it is a notice under this clause and will specify the details of the dispute concerned.

b) Management representatives of each of the Parties will endeavour in good faith to agree upon a resolution of the dispute.

c) Should management representatives fail to reach a resolution within 14 business days of receipt of a notice of dispute (or another timeframe agreed in writing between the Parties), the dispute will be taken to senior executive service (SES) or equivalent representatives of each of the Parties.

d) SES representatives will endeavour in good faith to agree upon a resolution of the dispute.

e) Should the SES representatives fail to resolve the dispute within 10 business days (or other time frame agreed in writing between the Parties), the dispute will be taken to the:

i. relevant Deputy Secretary of the Commonwealth Environment Department, and

ii. relevant Deputy Secretary, DPE; and

iii. Chief Executive, OEH,

who will endeavour to reach agreement regarding the dispute.

12. Variation

12.1 The Parties may vary this agreement by written agreement only to the extent that the varied agreement is consistent with the provisions of the EPBC Act.

12.2 Any variation to this agreement shall be published on the DPE or OEH website.

13. Termination

13.1 This agreement may be terminated at any time by written notice from either Party, except where the termination relates to a Dispute and the procedure at clause 11 has not been followed.

14. General

14.1 Any notice given by a party under this agreement must be in writing and hand delivered or sent by pre-paid post or email to the appropriate representative at the specified address. The appropriate representative for each Party is:

i. relevant Deputy Secretary, DPE (Deputy Secretary, Policy and Communications, GPO Box 39, Sydney NSW 2001) and Chief Executive, OEH (PO Box A290, Sydney South 2000), and

ii. Assistant Secretary of the Branch managing the strategic assessment within the Australian Government Department of the Environment and Energy (Assistant Secretary, Assessments and Waste, Environment Standards Division, GPO Box 787 Canberra ACT 2601).

14.2 Notwithstanding any other provision of this agreement, the Parties may disclose information about this agreement, including personal information, where required or permitted to be disclosed by law.

SIGNED for and on behalf of the
COMMONWEALTH OF AUSTRALIA
represented by

The Hon Melissa Price MP

Minister for the Environment

Signature

Date 12/11/18

SIGNED for and on behalf of the
STATE OF NEW SOUTH WALES
represented by

The Hon. Anthony John Roberts MP

Minister for Planning

Signature

Date 18/10/xviii

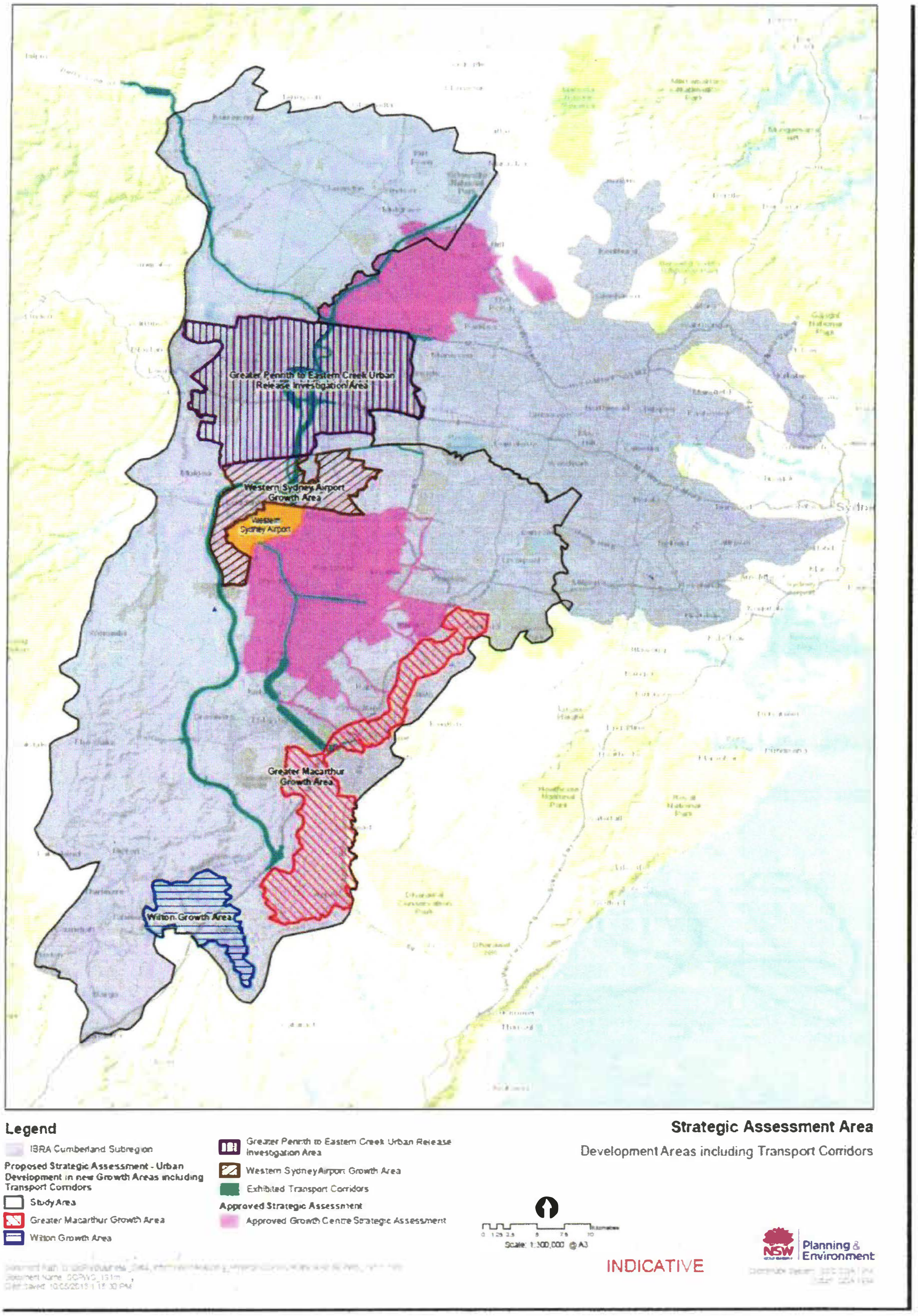
The Hon. Gabrielle Cecelia Upton MP

Minister for the Environment

Signature

16.10.18
Date

ATTACHMENT 1: INDICATIVE MAP OF STRATEGIC ASSESSMENT AREA



Terms of Reference for the Strategic Impact Assessment Report for the Cumberland Plain Conservation Plan

1. PURPOSE OF THE STRATEGIC IMPACT ASSESSMENT REPORT

1.1. The purpose of the Report is to assess the impacts of actions taken under the Cumberland Plain Conservation Plan (Plan) on all matters protected by Part 3 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) ('protected matters').

2. DESCRIPTION OF THE PLAN BEING ASSESSED

2.1. The Report must describe the Plan:

1. The Report must provide a summary outlining its overall purpose, key elements, spatial extent, and timeframes, including how long the Plan will be in effect.
2. The Report must provide details about the key elements, including:
   a. The conservation commitments and outcomes to be delivered for protected matters.
   b. The actions likely to be taken under the Plan over the short, medium and long term.
   c. The legal and administrative frameworks to implement the Plan and the persons and authorities responsible for implementation, including:
      i. How the Plan has been developed and its legal standing under New South Wales law.
      ii. The relationship of the Plan to other relevant polices, plans, guidelines, commitments, regulations and legislation including existing approvals under Commonwealth legislation for the Western Sydney Airport and the Western Sydney Growth Centres.
      iii. Management, approval and funding arrangements for implementing the Plan.
3. The Report must describe the need and justification for the Plan including the environmental, social and economic drivers for its development.
4. The Report must describe the decision-making framework used in considering alternatives and developing conservation outcomes of the Plan. It should identify where alternative options that have been evaluated to reach the final Plan have been published.
5. The Report must describe how the principles of ecologically sustainable development (ESD) (as set out in section 3A of the EPBC Act) are considered and promoted in the development of the Plan.

3. DESCRIPTION OF THE PROTECTED MATTERS IMPACTED BY THE PLAN

3.1. The Report must describe the nature of the environment within the strategic assessment area, and other areas outside the strategic assessment area that may be impacted by actions taken under the Plan. This must include (at a minimum):

1. A description of historical and current land use.
2. The extent and quality of native vegetation present including detailed mapping of ecological communities and habitat for threatened species listed under the EPBC Act.
3. The nature of the environment, including ecosystem processes and threatening processes.
4. A description of the landscape context for key environmental matters, including connectivity, habitat fragmentation and ecological processes.
5. A spatial map of areas that are already protected for environmental purposes, including Bio-banking and Biodiversity Stewardship sites.

3.2. The Report must identify and describe each protected matter that may be impacted directly, indirectly and cumulatively by actions taken under the Plan, including (at a minimum):

1. Key sites, and where relevant, key habitats for protected matters.
2. Important populations of protected matters, including the consideration of the importance of both small and large areas of habitat, and their position within the landscape.
3. Areas likely to be important for maintaining ecological processes (for example, habitat connectivity) for protected matters.
4. Condition of protected matters, including where relevant, seasonal and annual variability, and their likelihood to alter over time.
5. Key threatening processes.

4. ASSESSMENT OF THE IMPACTS OF THE PLAN ON PROTECTED MATTERS

4.1. The Report must describe and assess the likely impacts of actions taken under the Plan on all protected matters.

4.2. The Report must describe the method used to understand likely impacts on all protected matters of actions taken under the Plan. The level of the assessment will be proportionate to the level of likely risk to each protected matter. The method must:

1. Be appropriate for assessment at a strategic scale.
2. Rely on the best available information.
3. Discuss uncertainty, including reference to the technical data and information relied upon.

The Report must identify the data used in the assessment, any limitations it may have, where (or if) the data is available and where it can be accessed, including publicly accessed.

4.3. Describe and assess separately the likely impacts (if any) of actions taken under the Plan on the environment on Commonwealth land (as defined in section 528 of the EPBC Act).

4.4. The Report may also consider protected matters that are potentially eligible for listing as a result of inclusion in a final priority assessment listing held by the Commonwealth, or a recommendation to the Commonwealth Minister for listing by the Threatened Species Scientific Committee prior to the Report being submitted.

4.5. The Report must include an analysis of the likely adverse impacts of actions of the Plan on protected matters. This must include (at a minimum) consideration of:

1. Information on the following :
    a. Number and size of populations/important populations.
    b. Extent (in hectares) of suitable habitat.
    c. Extent (in hectares) and condition of protected matters.
    d. Landscape connectivity and ecological processes.
    e. Heritage listing and values.
2. How impacts on protected matters will be avoided through land use planning and other measures, and what mitigation measures will be implemented to reduce impacts, including a description of the mitigation measures and how unavoidable impacts will be offset.
3. Potential indirect and cumulative impacts.

4.6. The Report must include an analysis of the conservation benefits (beneficial impacts) of the Plan, including:

1. How protected matters will be conserved, protected and managed within the Strategic Assessment Area and other areas related to the Plan.
2. The adequacy of the conservation measures under the Plan in protecting and managing protected matters, including the effectiveness of implementation and funding arrangements and who will be responsible for delivering on commitments.
3. How proposed conservation measures involving environmental offsets meet the principles of the *Environment Protection and Biodiversity Conservation Act, Environmental Offsets Policy, 2012*.

4. How landscape connectivity has been maintained and improved, which may include opportunities for strategic restoration of key corridors and areas adjacent to sites with high biodiversity values.
5. How adaptation to reasonable climate change scenarios has been considered.

4.7. The Report must consider the extent to which the impacts on protected matters of actions taken under the Plan meet legislative obligations under the EPBC Act, including but not limited to:

1. Consistency with Australia's international obligations, including the Ramsar Convention.
2. Consistency with recovery plans (section 146K of the EPBC Act).
3. Regard to objectives, conservation actions and other relevant information in conservation advices (section 146K of the EPBC Act).
4. Consistency with World Heritage management plans (sections 316 and 321 of the EPBC Act) and National Heritage place management plans (sections 324S and 324X of the EPBC Act).

The Report may also consider other Commonwealth policy guidelines on protected matters.

4.8. The Report must include justification for key methods used in the assessment, including summaries of independent peer review processes and where the review/s are available to the public.

5. EVALUATION OF THE OVERALL OUTCOMES OF THE PLAN

5.1. The Report must evaluate the overall commitments and outcomes for protected matters taking into account likely impacts on protected matters from actions taken under the Plan.

5.2. The evaluation must include:

1. The extent to which protected matters are represented in areas to be protected or managed under the Plan or in existing protected areas in the IBRA bioregion/subregion.
2. The extent to which the areas to be protected or managed under the Plan or existing protected areas in the IBRA bioregion/subregion will ensure the long-term viability of each protected matter.
3. Whether there will be serious and irreversible impacts on any protected matter.
4. An assessment of how the Plan meets the endorsement criteria set out in the Agreement at clause 8.

5.3. The evaluation may also include consideration of:

1. The extent to which the conservation measures under the Plan facilitate adaptation of biodiversity to climate change and address any significant vulnerabilities of protected matters under reasonable climate change scenarios.
2. The likely effectiveness of the conservation measures under the Plan in protecting and managing protected matters and any risks and uncertainties.

6. ADDRESSING UNCERTAINTY AND ADAPTIVE MANAGEMENT

6.1. The Report must identify key uncertainties and risks associated with implementing the Plan, responses to these and proposed adaptations to changing circumstances. Key uncertainties may include:

1. Knowledge gaps in scientific understanding and responding to new knowledge.
2. Assumptions made in assessing potential impacts and benefits.
3. How changes to State and Commonwealth legislation, policies, plans and advice is to be accounted for in the management of the areas impacted by the Plan.
4. Effectiveness or capacity to ensure the Plan is implemented.

6.2. The Report must describe and assess the adequacy of the procedures proposed in the Plan to ensure an adaptive approach to implementation of the Plan. This must include:

1. How the results of monitoring will be used to understand the effectiveness of conservation outcomes for protected matters and improve implementation.
2. How new information relating to protected matters and biodiversity, including legislative changes, may be assessed and accounted for in implementation of the Plan.

7. MONITORING AND REPORTING AND AUDITING

7.1. The Report must describe and assess the adequacy of the monitoring programs, regular review, public reporting and independent auditing processes proposed in the Plan to:

1. Ensure conservation commitments and outcomes for protected matters contained in the Plan are delivered.
2. Enable implementation of the Plan to adapt where monitoring demonstrates delivery of the conservation actions are not leading to the predicted conservation outcomes.
3. Enable implementation of the Plan to adapt to changed circumstances, where there are risks to protected matters.

7.2. The Report must identify and analyse the likely circumstances and procedures that may result in the review or modification of implementation plans proposed to deliver on commitments and outcomes for each protected matter as described in the Plan, or abandonment of the Plan.

8. INFORMATION SOURCES

8.1. The Report must identify the sources of information and data relied upon including the reliability and currency of the data.

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document B – Peer review report

Excellence in your environment

niche Environment and Heritage

Western Sydney Strategic Assessment
Independent Peer Review

Prepared for Department of Planning and Environment | 25 March 2019

Document control

Project number	Client	Project manager	LGA
4771	Department of Planning and Environment	Rhidian Harrington	Numerous

Version	Author	Review	Status	Date
D1	Rhidian Harrington, Evelyn Craigie	Simon Tweed, Amanda Griffith	Draft 1	13 March 2019
Rev0	Rhidian Harrington, Evelyn Craigie	Tom Holden (Open Lines)	Final 0	15 March 2019
Rev1	Rhidian Harrington	Laura Torrible (DPE)	Final 1	18 March 2019
Rev2	Rhidian Harrington		Final 2	25 March 2019

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List of Tables

1. Introduction

Niche Environment and Heritage Pty Ltd (Niche) have been commissioned by NSW Department of Planning and Environment (DPE) to undertake an independent peer review of the Western Sydney Strategic Assessment. Specifically Niche were engaged to address Section 4.8 of the EPBC Terms of Reference, which requires that:

> *The Report must include justification for key methods used in the assessment, including summaries of independent peer review processes and where the review/s are available to the public*.

1.1 Background

The NSW Government has identified four Growth Areas and approximately 200 kilometres of Transport Corridors to support planned future growth in Western Sydney over the next 38 years (see

Figure 1). These initiatives are identified under a number of strategies including:

- A Metropolis of Three Cities - The Greater Sydney Region Plan (Greater Sydney Commission, 2017b)
- Future Transport 2056 (Transport NSW, 2017)
- Western Sydney City Deal (2018).

The four Growth Areas are:

- Wilton Growth Area
- Greater Macarthur Growth Area
- Western Sydney Aerotropolis Growth Area
- Greater Penrith to Eastern Creek Urban Release Investigation Area.

The NSW Department of Planning and Environment (DPE) is pursuing the relevant State and Commonwealth statutory environmental approvals required for development of the Growth Areas and Transport Corridors. As part of this approval process, DPE is preparing the Draft Cumberland Plain Conservation Plan (the Plan). The Plan will outline both the program of development works proposed for authorisation under relevant legislation, and commit to environmental measures that will contribute to the maintenance or return of ecological function on the Cumberland Plain in response to the proposed development.

The Plan is being drafted to meet State and Commonwealth statutory requirements for assessment of impacts on threatened species and ecological communities. DPE will seek approval for the Plan under the:

- Biodiversity certification provisions (Part 8) of the NSW *Biodiversity Conservation Act 2016* (BC Act)
- Strategic assessment provisions (Part 10) of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

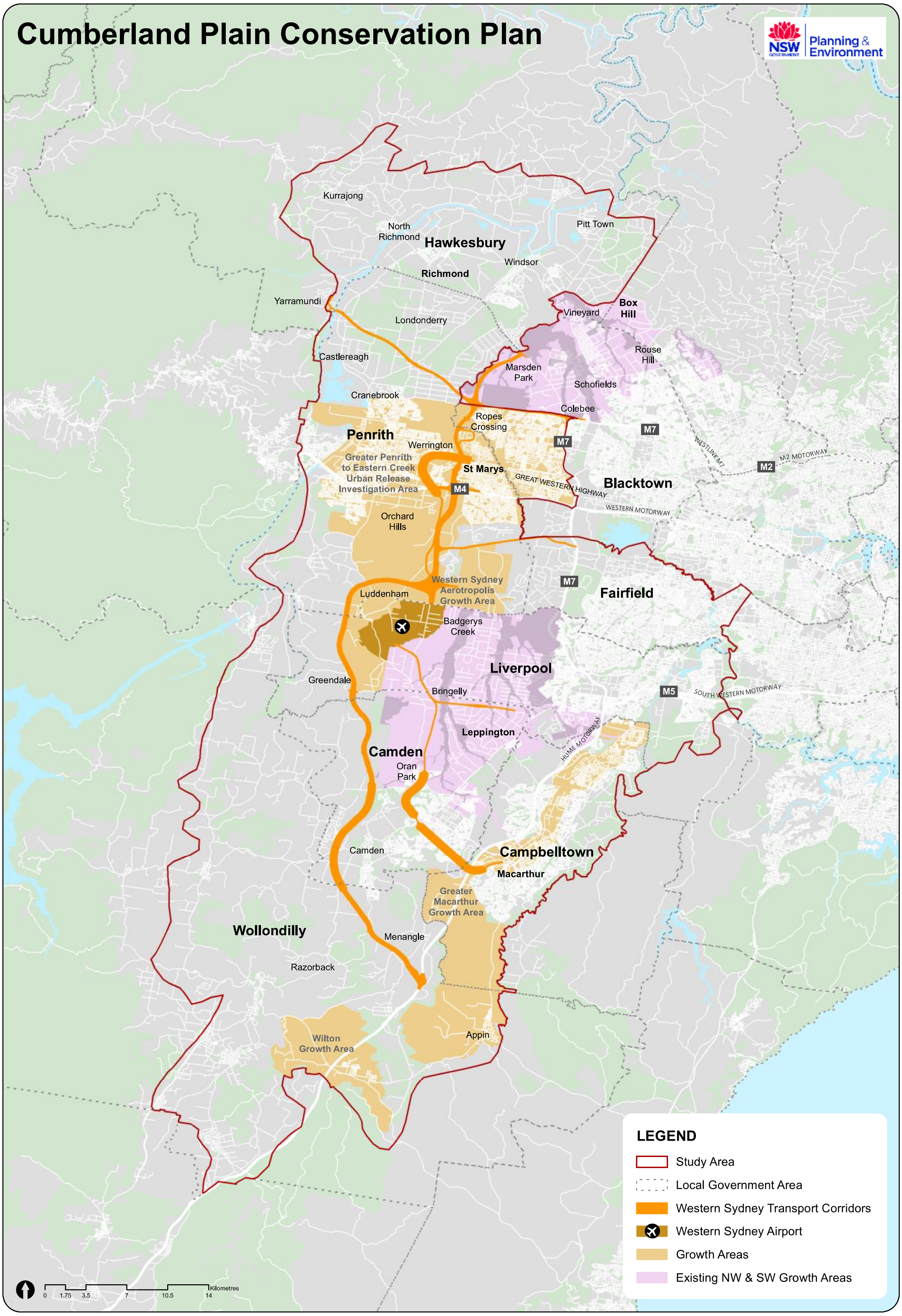

Figure 1. Map of the strategic assessment area

1.2 Scope of impact assessment within the Draft Cumberland Plain Conservation Plan

The scope of impact assessment within the Plan under the BC Act and EPBC Act is different (see Table 1). This relates to both:

- The components of the proposed development that is being assessed for approval
- The impact assessment requirements under each piece of legislation.

Table 1. Impact assessment requirements of the BC Act and the EPBC Act

Legislation	Impact assessment requirement	Comments
BC Act	Address provisions of the legislation and regulations under the relevant approval pathway within the Act.	The Plan is being assessed as a strategic application for biodiversity certification under Part 8 of the BC Act. The relevant regulatory provisions need to be met.
	Use of the Biodiversity Assessment Methodology (BAM)	The BAM is the detailed impact assessment method that is required under the BC Act
	Consider the guidelines for planning authorities for proposing conservation measures in strategic applications for biodiversity certification (Draft Version 7)	The Guidelines "*provide guiding principles for demonstrating that the conservation measures proposed for a strategic application for biodiversity certification adequately address impacts on biodiversity values under section 8.7 of the BC Act*" The Guidelines need to be addressed
EPBC Act	Address and meet relevant provisions of the legislation and regulations	The Plan is undergoing strategic assessment under Part 10 of the EPBC Act.
	Address the terms of Reference for the Strategic Impact Assessment Report for the Cumberland Plain Conservation Plan	The Terms of Reference specify the requirements for the Strategic Assessment Report
	Consider relevant statutory documents in the impact assessment process.	The EPBC Act requires that certain statutory documents be considered in the impact assessment process. For example, these include recovery plans, threat abatement plans, and conservation advices
	Consider EPBC Act policies and guidelines	The Australian Government has published a range of EPBC Act policies and guidelines which need to be considered in the impact assessment process

The assessment approach under Part 10 of the EPBC Act is different for the Transport Corridors that occur outside the Growth Areas compared with the other proposed development components. Table 2 shows the assessment approach for the proposed development components under Part 10 of the EPBC Act.

Table 2. Assessment approaches under Part 10 of the EPBC Act

Proposed development component	Assessment approach
Four growth areas	Detailed assessment of impacts on Commonwealth protected matters on the basis of the BAM and in accordance with the Terms of Reference
Sydney Metro Stage 1	
Transport Corridors within the growth areas	
Transport Corridors outside the growth areas	High level, risk-based assessment of protected matters and likely effectiveness of proposed avoidance, mitigation and offset measures to meet an improve or maintain scenario

1.2.1 EPBC Act Terms of Reference

The Terms of Reference for the Strategic Impact Assessment Report (SIAR) are part of the Strategic Assessment Agreement between the NSW and Australian Governments. They set out the information requirements that the impact assessment component of the Plan needs to address for matters protected under the EPBC Act.

The Terms of Reference broadly require the impact assessment to:

- Describe the Plan being assessed (clause 2)
- Describe the protected matters impacted by the Plan (clause 3)
- Assess the impacts of the Plan on protected matters (clause 4)
- Evaluate the overall outcomes of the Plan (clause 5)
- Address how uncertainty and adaptive management are considered in the Plan (clause 6)
- Describe the monitoring, reporting and auditing that will be implemented under the Plan (clause 7)
- Identify the information sources used to inform the impact assessment report (clause 8).

Clause 4.2 of the Terms of Reference outlines how the Plan should describe the methods used in the assessment:

"*The Report must describe the method used to understand likely impacts on all protected matters of actions taken under the Plan. The level of the assessment will be proportionate to the level of likely risk to each protected matter. The method must:*

1. *Be appropriate for assessment at a strategic scale*
2. *Rely on the best available information*
3. *Discuss uncertainty, including reference to the technical data and information relied upon*

The Report must identify the data used in the assessment, any limitations it may have, where (or if) the data is available and where it can be accessed, including publicly accessed."

The SIAR is designed to meet all of the Terms of Reference.

1.2.2 Key steps in the impact assessment

Despite the differences between the BC Act and EPBC Act processes, there are three common and key steps in the impact assessment:

- Step 1 – understand the environment
- Step 2 – understand impacts (and identify avoidance and mitigation measures)
- Step 3 – evaluate the outcome of the plan to adequately mitigate for any impacts and assess the benefits to the environment from the conservation measures.

1.3 Scope of the peer review

1.3.1 Peer review requirement

The peer review relates only to the strategic assessment under the EPBC Act. Section 4.8 of the EPBC Terms of Reference requires:

> *The Report must include justification for key methods used in the assessment, including summaries of independent peer review processes and where the review/s are available to the public.*

It is agreed that the term 'key methods' refers to technical methods for describing the protected matters impacted by the plan, such as methods used to collect data on protected matters and map or model the known or predicted occurrence of protected matters. The methods to be reviewed in this report include the assumptions underpinning all analyses and modelling, and the decisions about what datasets to include or exclude in the mapping and/or modelling processes.

We have been advised by DPE that the term 'key methods' does not include approaches to understand the likely impacts on protected matters of actions taken under the Plan, such as the approach to assessing direct impacts, indirect impacts, or cumulative impacts, or demonstrating how adaptation to climate change has been considered.

While the peer review is only required for the EPBC Act process, the results of the review will be of interest to the NSW Office of Environment and Heritage as part of the BC Act strategic biodiversity certification.

1.3.2 Methods for review

The following methods have been reviewed:

- The approach to determining the relevant Commonwealth matters for assessment ("the categorisation approach")
- The methodology for mapping EPBC Act-listed TECs, including any assumptions about correlations/ alignment between NSW Plant Community Types and EPBC Act TECs
- The knowledge-based method applied to mapping Category 1 EPBC listed threatened species
- The appropriateness and representativeness of the variables and datasets used for mapping habitat for 19 EPBC listed species using species distribution modelling
- The methods for identifying important populations of listed flora and fauna across the strategic assessment area for each species, and the application of the method for each species
- The evaluation method for determining the viability of the Southern Sydney koala population
- The Conservation Priorities Method, which is being used to identify priorities for offsetting.

1.4 Approach to the peer review

Niche was provided with details of the methods used to identify the range of protected matters prior to attending a workshop facilitated by Open Lines, which aimed to provide further information and opportunity for consultation with personnel involved. The workshop was held at DPE's Sydney office (Pitt Street) on 18th February 2019 and included detailed presentations by the lead author of each method:

- Tom Holden (Open Lines) – Chair and overview of EPBC impact assessment

- James Shepard (Biosis) - EPBC TEC mapping
- Rebecca Dwyer (Biosis) – Knowledge based mapping for EPBC Category 1 species
- Callan Wharfe (Biosis) - EPBC population mapping
- Peter Hemphill (Open Lines) - EPBC categorisation approach and Koala evaluation method
- Ascelin Gordon (RMIT) - Species distribution modelling
- Darren James (DAJ Environmental) and Ophelie Tinel (DPE) - Conservation priorities method

Dr Rhidian Harrington and Evelyn Craigie of Niche Environment and Heritage attended the workshop in their capacity as peer reviewers. CVs for Rhidian and Evelyn are provided in Annex 1.

Open Lines provided a detailed summary of the methods of each element in an agenda for the workshop but, apart from the *Western Sydney Strategic Plan – Species distribution Modelling* report (RMIT) and a section of the *Conservation Priorities Method for the Cumberland Plain Conservation Plan* report (DPE), no other reports were provided to the peer reviewers.

The workshop provided an opportunity to clarify any sections of the method that were unclear. Further information was provided following the workshop including updates to the method descriptions and GIS data. Where further information or clarification was required to inform the review, this was obtained directly from the creators/authors of the method.

2. Determining the relevant Commonwealth matters for assessment

2.1 Overview of method

Relevant Commonwealth matters for assessment within the Plan were determined by applying the 'categorisation method'. This involved identifying all matters with potential to be affected by the proposal within a 10 kilometre buffer around the boundary of the strategic assessment area, using the Protected Matters Search Tool, NSW Bionet, Atlas of Living Australia and the Commonwealth's Finalised Priority Assessment List (FPAL). Each matter identified on the list was then assigned to Category 1 (to undergo detailed assessment), or Category 2 (no further assessment).

If a threatened species or community met any of the following criteria, it was assigned to Category 1:

- The BAM process for the Growth Areas identified the species may be impacted
- The species was subject to a commitment in the Sydney Growth Centres Strategic Assessment Program Report
- A known important population occurs in the strategic assessment area
- The strategic assessment area contains >5% of all known records in NSW of a species since 1990 according to the Atlas of NSW Wildlife dataset
- The strategic assessment area comprises >5% or more of the mapped distribution of the species according to DoEE's current distribution mapping
- It is an FPAL species, and available information suggests it occurs in the strategic assessment area.

If a migratory species met any of the following criteria, it was assigned to Category 1:

- The strategic assessment area supports important habitat or an ecologically significant proportion of modelled habitat for a species
- The strategic assessment area contains >5% of all known records in NSW of a species since 1990 on the Atlas of NSW Wildlife.

The results of the threatened and migratory species categorisation were reviewed by two senior ecologists familiar with the area to confirm its accuracy.

All Ramsar Wetlands downstream of the study area and all world and national heritage and Commonwealth land in the study area were assigned to Category 1.

2.2 Data collection and categorisation

The approach is considered appropriate for determining matters for assessment at a strategic scale as it:

- Uses a precautionary approach, with the initial step aiming to capture all matters that may be of relevance within the strategic assessment area and within 10 kilometres of its boundary
- Uses appropriate criteria to categorise the matters for further assessment
- Aligns with standard methods used in ecological assessment for identification of matters for assessment
- Includes analysis and cross-checking that is independent of the source data and method outputs.

2.3 Details of the approach

2.3.1 Data collection/manipulation

The methods used to identify potential Threatened Ecological Communities (TECs) is considered appropriate as an initial filter as it captures all Plant Community Types in the strategic assessment area that may be TECs.

2.3.2 Assumptions

The categorisation method includes information from sources that are not specific to the area, e.g. EPBC Act recovery plans and conservation advice. In some cases, these sources may not include information relevant to the assessment area. This should be identified as a limitation, however, it is noted that area specific information was also used and results were reviewed by ecologists familiar with the area of investigation.

2.3.3 Datasets

The method uses the ecological databases that are commonly used in ecological assessment, supplemented by the results of recent studies undertaken in the Growth Areas and review by ecologists familiar with the area. This is considered to be appropriate as it:

- Incorporates the most up to date databases that are available at the required scale
- Is conservative and unlikely to exclude matters that require further assessment.

2.4 Components that require improvement

The reviewed methods are considered appropriate for the strategic assessment and no components requiring improvement have been identified. However, any limitations associated with the information sources should be identified within the strategic assessment, including whether they incorporate up to date information and the scale at which they are relevant.

3. Mapping for EPBC Act TECs

3.1 Overview of method

This section summarises the methods used to prepare the general vegetation map and the EPBC Act TEC map. The methods used to prepare the general vegetation map is not the subject of this review, however, as it underlies the EPBC Act TEC mapping, a brief summary is provided.

3.1.1 General vegetation mapping

Due to the different requirements for the BAM and the EPBC Terms of Reference, two methods were used to prepare the general vegetation map as follows:

- Within the Growth Areas, vegetation mapping commenced with a desktop study and subsequent updates based on data collected in the field in accordance with the BAM
- Within the Cumberland sub-region (outside the Growth Areas) vegetation mapping was based on the vegetation maps prepared by OEH:
    - *Remnant Vegetation of the Western Cumberland Subregion: 2013 update* (OEH 2013)
    - *The Native Vegetation of the Sydney Metropolitan Area: Version 3.0* (OEH 2016).

The desktop study included analysis of:

- Recent Nearmap imagery at 15 centimetre resolution
- NSW Landuse polygons from DPI
- NSW soils datasets at 1:100,000 from the OEH data portal
- NSW geology datasets at 1:250,000 from the DPE data portal
- Processing multispectral aerial imagery at 60 centimetre resolution into NDVI imagery
- Amalgamating previous native vegetation mapping undertaken by Biosis and others across the Growth Areas
- Combining two existing OEH maps of native vegetation within the Cumberland sub-region (OEH, 2013, 2016b) into a single layer and clipping the layer to the Growth Area boundaries
- Creating a Canopy Height Model using 1 metre LiDAR data from various projects contained within Biosis' GIS database (data ranged from six years to nine years old)
- Processing the Canopy Height Model into amalgamated canopy polygons for vegetation over 1 metre in height.

The draft maps were then updated based on the results of field survey (in the Growth Areas only), which included rapid assessment ground-truthing and plots in accordance with the BAM.

It is considered the datasets, methods for data collection and assumptions associated with the general vegetation mapping are appropriate and provide the most suitable base for mapping of EPBC Act TECs.

3.1.2 EPBC Act TEC mapping

All TECs with the potential to occur in the strategic assessment area were identified based on the Protected Matters Search Tool and Plant Community Types (PCTs) identified during the general vegetation mapping.

The method used to map EPBC Act TECs within the Growth Areas is summarised as follows:

1. Identify PCTs that correlate with an EPBC Act TEC and thereby identify specific areas that may comprise an EPBC Act TEC
2. For each potential area of EPBC Act TEC, apply criteria related to:
    a. distribution and patch size class
    b. projected foliage cover (where relevant to the TEC threshold criteria)
    c. elevation (where relevant)

3. Map vegetation polygons that meet the above criteria as candidate TEC polygons
4. Apply condition class criteria to candidate polygons within which BAM plots have been undertaken, and assign the polygon as the TEC, or remove it as the TEC
5. Apply condition class criteria to candidate polygons within the Growth Areas but external to the development footprint, i.e. areas within the Growth Area were BAM plots were not undertaken, and assign a potential category to the polygon (high, moderate and low potential and not TEC)
6. The methods and outputs were reviewed by the DoEE.

The method used to map EPBC Act TECs external to the Growth Areas is summarised as follows:

1. Identify PCTs that correlate with an EPBC Act TEC and thereby identify specific areas that may comprise an EPBC Act TEC
2. Apply distribution and patch size criteria and remove polygons that did not meet the criteria
3. Apply condition class criteria, based on condition classes associated with the two source maps (OEH 2013 and OEH 2016)
4. Analyse draft maps to remove areas with discrepancies such as cleared land and assign a potential category to the polygon (high, moderate and low potential and not TEC).

3.2 General Approach

3.2.1 Data collection/manipulation

The general approach is considered appropriate for assessment of EPBC Act TECs at a strategic scale as it:

- Incorporates all TECs that have potential to occur in the strategic assessment area, including one TEC that is proposed for listing
- Is repeatable across the entire strategic assessment area
- Has established rule sets that incorporate all relevant attributes for each TEC, as described in the DoEE's Species Profile and Threats Database (SPRAT) and discussion with DoEE
- Relies on the best available information, including the most recent iterations of all input data
- Allows for updates to be incorporated
- Is adjusted to account for the different levels of accuracy in vegetation mapping available across the strategic assessment area
- Includes analysis and cross-checking that is independent of the source data, model outputs and other input information.

3.2.2 Assumptions

The method incorporates numerous assumptions, largely associated with the data used in the GIS model. This is necessary in the absence of field collected data and has been adequately discussed and justified for each point where an assumption is made. Where it was possible to reduce the level of uncertainty involved, for example through a cross check of results by GIS and ecology practitioners, this has been undertaken and explained.

It is considered that further details of all datasets used in the project are required. Information such as whether the data is based on a desktop study or field verification, and methods used to capture the data.

3.2.3 Datasets

The method has incorporated the best available information as it:

- Incorporates the results of extensive recent field survey where possible
- Incorporates the most up to date datasets that are available at the required scale
- Has updated the data where possible
- Has considered a wide range of data and its suitability to the assessment.

3.3 Details of the approach

3.3.1 Data collection/manipulation

The methods used to identify potential TECs is considered appropriate as an initial filter as it captures all PCTs in the strategic assessment area that may be TECs.

TEC mapping in the Growth Areas

Further filtering by patch size, canopy cover, native vegetation patch size, soil and elevation (in areas for which field data is available) is appropriate as it incorporates the factors that determine whether vegetation meets the criteria to be a TEC (as described in SPRAT) and for which data is available and can be accurately interrogated. The GIS interrogation of the data, coupled with independent review by an ecologist, is considered appropriate and would achieve as much accuracy as possible without field verification.

For patches where BAM data is not available, the method does not identify areas of TEC but rather, categorises the candidate TEC polygons according to their potential to be a TEC (High, Moderate, Low and Not TEC). This is appropriate as it accounts for greater uncertainty in the model and is likely to overestimate the areas of potential TEC, rather than underestimate. This conservative approach is appropriate for a strategic level assessment where comprehensive field surveys have not been conducted.

TEC mapping – Cumberland Plain

The reduced filtering undertaken for TECs in the Greater Cumberland Plain (patch size and condition only) is appropriate as it accounts for the increased reliance on data that has not been validated in the field.

This method also categorises the candidate TEC polygons according to their potential to be a TEC (High, Moderate, Low and Not TEC). This is appropriate as it accounts for the reliance on data that has not been validated in the field and is also likely to provide a conservative estimate of the TECs in the area. This is appropriate for a strategic level assessment where comprehensive field surveys have not been conducted.

3.3.2 Assumptions

The assumptions associated with the method are clearly stated and considered appropriate. They comprise factors that can reasonably be assumed based on known data, such as presence of hollows and species composition. The assumptions are also inclusive, i.e. the required features for a polygon to be a TEC are assumed to be present (for polygons that remain after the filtering process), rather than absent, thereby resulting in an approach that is likely to provide a conservative estimate of the TECs in the area. This is appropriate for a strategic level assessment.

3.4 Components that require improvement

The method is considered appropriate for the strategic assessment and components requiring improvement have not been identified. However, further details associated with the input data should be included to provide the reader a more complete understanding of the limitations of the method. This includes details of the extent and dates of field validation undertaken for the source mapping.

4. Mapping of EPBC species

Section 3.2 of the Terms of Reference requires the SIAR to describe for the strategic assessment area the protected matters that may be impacted directly, indirectly and cumulatively by actions taken under the Plan. Habitat for Commonwealth listed Category 1 species was mapped within the Cumberland sub-region using either:

- Species Distribution Modelling (SDM) where species data is adequate, or
- Assumed presence using a knowledge-based method (KBM)

In some cases, a map was prepared for a Commonwealth listed Category 1 species within the Growth Areas in accordance with the BAM because the Commonwealth species is also a NSW listed candidate species credit species. Under the BAM, candidate species credit species were mapped within the Growth Areas using:

- An expert report in accordance with section 6.5.2 of the BAM, or
- Assumed presence using a knowledge-based method (KBM)

Where a map was prepared for a Commonwealth listed Category 1 species within the Growth Areas in accordance with the BAM, that Growth Areas map was integrated into the Cumberland sub-region map and formed the basis of the assessment of impacts on that species within the Growth Areas.

4.1 Species Distribution Modelling

Species Distribution Modelling (SDM) was undertaken for Commonwealth listed Category 1 species within the Cumberland subregion where adequate species records were available to develop a model. SDMs were developed for 19 Commonwealth listed Category 1 species (6 fauna species and 13 flora species). The assessment will use SDMs for 15 of those species.

SDMs are statistical models used to estimate the relationship between species records at sites and the environmental and/or spatial characteristics of those sites. Once this relationship has been estimated, the statistical model can be used to predict other locations in the landscape where the species is likely to occur.

The models were developed using the software 'Maxent'.

Data required for the modelling included:

- Species records obtained from BioNet. During a review of the records, various errors were identified. Ecologists were engaged to review the records and exclude those with errors.
- Twenty-one environmental predictors that were used to establish the relationships between species records at sites and the environmental and/or spatial characteristics of those sites. These included:
    - Native vegetation (PCTs)
    - Soil type
    - Mean annual temperature
    - Mean annual radiation
    - Number of days per year with minimum temperature less than 2 degrees
    - Latitude
    - Distance to streams
    - Topographic position.

An approach was developed to account for the different levels of bias likely to be present in the species records. This resulted in the development of three maps for each species with different assumptions regarding bias in the records, depicting the likelihood of occurrence for each species. These three maps were then combined to produce a single Species Distribution Model for each species with three classes of occurrence for each species:

- Unlikely to occur – none of the three models predicted the species to occur
- Potential to occur – at least one of the three models predicted the species to occur
- Likely to occur – all three of the models predicted the species to occur.

It is considered that the datasets and their interrogation, which was used to feed into the SDM, are the most appropriate and suitable of methods available at this spatial scale for predicting species distribution. The covariates (environmental predictor layers) used in the modelling were reviewed for each species and are considered to be appropriate.

4.1.1 Details of approach

Data collection/manipulation

The general approach is considered appropriate for modelling species distribution at a strategic scale as:

- The way in which the BioNet species record data was interrogated by an ecologist and filtered based on a 100 metre accuracy criteria would have adequately excluded records that were spatially inaccurate
- The environmental predictors used for each species were appropriate and used appropriate data and the best data available
- Biases in data (i.e. BioNet data is not random) is accounted for as best is possible by using three different models with different assumptions regarding bias
- Interpretation of the model's outputs (i.e. "unlikely to occur", "potential to occur" and "likely to occur") provide a very conservative approach which is likely to overestimate species occurrence
- Includes analysis and cross-checking that is independent of the source data, model outputs and other input information.

The exclusion of Koala records from within the 10 kilometre buffer region due to a large number of records in the buffer region skewing the model to predict reduced occupancy within the Cumberland Subregion appears appropriate. As is exclusion of records not within native vegetation due to them representing dispersing males.

The report rightly notes that the predicted distribution for the Green and Golden Bell Frog should be approached with caution. The fact that the model excluded areas without vegetation means that small waterbodies within the Subregion would not be captured, even if frogs had been recorded there.

Assumptions

The method appears to incorporate numerous assumptions, and although some of these are referred to throughout the report, it is considered that further details are required. It is recommended that a separate section of the report list all assumptions and discuss their implications to the modelling.

Datasets

The method has incorporated the best available information as it:

- Incorporates the most up to date datasets that are available at the required scale, although it is recognised that vegetation and soil data contained errors that could not be rectified and that vegetation data did not extend across the whole buffer area
- Has interrogated the data and excluded it when inaccurate
- Has considered a wide range of data and its suitability to the assessment.

4.1.2 Summary

In general, the approach used for generating the species distribution models would over-predict the habitat for a species. Errors in data (particularly vegetation and soil) may have resulted in associations with these variables that were artefacts, thus over-predicting species distribution. However, the use of "likely to occur" and "potential to occur" regions limits the likelihood of over-prediction in this regard.

Other factors that may have resulted in over-prediction include the highly fragmented and modified habitat within the Subregion, which means patches of habitat that contain the appropriate predictors for a species may be too isolated or degraded for that species to occur.

Although over-predicting a species distribution is acceptable from a precautionary approach care must be taken that this approach is not transposed to offset sites, as it will predict false occurrence. It is noted though that all offset sites would be surveyed prior to being secured. Consideration must also be made of the offsetting requirements from over-predicting species distribution as this will have significant cost implications, and could result in offsets being provided unnecessarily. Over-prediction may also prevent development in areas of limited conservation value.

Despite the potential issues with data error and over-prediction of species distribution, the interrogation of the data, coupled with independent review by an ecologist, is considered appropriate and would achieve as much accuracy as possible without field verification.

4.1.3 Components that require improvement

The approach is considered appropriate for the strategic assessment and components requiring improvement have not been identified. However, further details associated with the assumptions of the model should be included to provide the reader a more complete understanding of the factors affecting the outcomes of the model.

The *Western Sydney Strategic Plan – Species Distribution Modelling* report has numerous typographical errors, but these have not been detailed in this report.

4.2 Knowledge-based mapping method

Where adequate species records were not available, Commonwealth listed Category 1 species within the Cumberland subregion were mapped on the basis of assumed presence using a knowledge-based method. The method is the same method applied to NSW-listed candidate species credit species within the Growth Areas. It was based on the following steps:

STEP 1: IDENTIFICATION OF POTENTIAL HABITAT

Potential habitat for each species was identified and mapped using the Western Sydney Strategic Assessment Vegetation Mapping undertaken by Biosis for the project. Each species polygon was initially mapped using the relevant PCT and condition class identified in BioNET.

The potential habitat was then refined using scientific literature, including the following spatial and non-spatial data resources:

- Atlas of NSW Wildlife (BioNet)
- Commonwealth SPRAT database
- OEH Threatened Biodiversity Data Collection
- Cumberland Plain Recovery Plan (OEH 2011)
- Other recovery plans/conservation advices
- NSW Threatened Species Profiles Database
- BirdLife Australia shorebird data
- Hydrological modelling derived from LiDAR data
- Topographic information, including height and slope, obtained from LiDAR data
- The altitude above sea level and slope
- Soils data digital atlas of Australian soils

STEP 2: UNDERTAKE FIELD SURVEYS

Letters were sent by DPE to all landholders within the development footprints of the Growth Areas to request access. Due to a limited response, Biosis also undertook door knocking to request access for targeted surveys.

Targeted surveys for threatened flora and fauna were undertaken within the 'development footprint' where access was provided by landholders. Due to time restrictions of the project, it should be noted that targeted fauna surveys were not undertaken in accordance with the relevant survey guidelines, and were only used to identify potential habitat for relevant species.

STEP 3: INTEGRATE RESULTS FROM TARGETED SURVEYS

The results from the targeted surveys were incorporated in two ways:

- Any areas where a species was not recorded (and where surveys were considered sufficient) were removed from the potential habitat polygons
- Any areas where a species was recorded were integrated into the mapping.

STEP 4: ASSUMED PRESENCE IN POTENTIAL HABITAT

Given the limitations in access and survey, species were assumed to be present in all areas of potential habitat.

4.2.1 Details of approach

Data collection/manipulation

The general approach is considered appropriate for mapping of EPBC Act species habitat at a strategic scale as it:

- Interrogated species record data using an expert ecologist and removed any inaccurate records

- Used appropriate data and the best data available, including updated Western Sydney Strategic Assessment Vegetation Mapping undertaken by Biosis for the project
- Assumed presence of a species if potential habitat was present and survey of the habitat patch was insufficient to determine presence
- Used an appropriate approach for determining candidate species that would be impacted
- Used appropriate assumptions and criteria for determining potential habitat
- Includes analysis and cross-checking that is independent of the source data and other input information
- Used a conservative approach so that despite insufficient survey effort compared with the government guidelines species habitat would be over-estimated.

More details and justification are required on the exclusion of habitat based on patch size, particularly for species where a patch size of 1,000 hectares was used (i.e. Spotted-tailed Quoll, Satin Flycatcher, Oriental Cuckoo, Horsfield's Cuckoo, Spectacled Monarch and Rufous Fantail). It is considered that use of such a large patch size, particularly for highly mobile species such as birds, will exclude areas of potential habitat that could be utilised by these species.

More details and justification is required with respect to the exclusion of records for some species that are earlier than the lifespan of the species. For example, records for the Regent Honeyeater were restricted to those post 2008 to account for the 10 year lifespan of the species. It is considered that the exclusion of these records, particularly for highly mobile species, will exclude areas of potential habitat that could be utilised by those species.

Assumptions

The assumptions associated with the method are clearly stated and considered appropriate for a strategic level assessment, except for the issues discussed above in the *Data collection* section.

It's important these assumptions are presented in the report.

Datasets

The method has incorporated the best available information as it:

- Incorporates the most up to date datasets that are available at the required scale, including updated vegetation mapping
- Has interrogated the data and excluded it when inaccurate
- Has considered a wide range of data and information relevant to the species habitat requirements, and its suitability to the assessment.

4.2.2 Summary

In general, the approach used for the knowledge based method would over-predict the habitat for a species. However, it is considered that some data refining approaches, such as exclusion of habitat based on patch size and the exclusion of records older than the lifespan of the species, may result in suitable habitat being excluded for some species.

Although over-predicting a species distribution is acceptable from a precautionary approach care must be taken that this approach is not transposed to offset sites, as it will predict false occurrence. It is noted though that all offset sites would be surveyed prior to being secured. Consideration must also be made of the offsetting requirements from over-predicting species distribution as this will have significant cost implications, and could result in offsets being provided unnecessarily. Over-prediction may also prevent development in areas of limited conservation value. However, it is noted that detailed surveys would be completed prior to areas being developed.

Despite the potential issues with data error and over-prediction of species distribution, the interrogation of the data, coupled with independent review by an ecologist, is considered appropriate and would achieve as much accuracy as possible without significantly more effort with respect to field verification.

4.2.3 Components that require improvement

The approach is generally considered appropriate for the strategic assessment. However, the exclusion of habitat based on patch size needs to be explained and justified in detail and, where it might result in suitable habitat being excluded for some species, an alternative approach used.

4.3 Important populations

The term 'important populations' refers to a concept applied under the EPBC Act to inform the assessment of impacts of actions, such as urban development, on matters of national environmental significance. Important populations are defined in the Commonwealth's Significant Impact Guidelines (Policy Statement 1.1) (DoE, 2013) as:

> *Any population of a vulnerable species which meets the definition of an important population in the Commonwealth's Significant Impact Guidelines (Policy Statement 1.1) as follows:*
>
> *'A population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:*
>
> - *key source populations either for breeding or dispersal*
> - *populations that are necessary for maintaining genetic diversity, and/or*
> - *populations that are near the limit of the species range'*.

For the purposes of the SIAR, important populations are also defined as including any population of an endangered or critically endangered species. Under the EPBC Act, all populations of an endangered or critically endangered species are considered to be important for the survival and recovery of the species.

The following steps were undertaken to identify and map important populations for critically endangered, endangered and vulnerable Commonwealth listed Category 1 matters:

- Step 1: Development of criteria for defining important populations for vulnerable Commonwealth listed Category 1 matters. The criteria and rationale for each criteria is provided in Table 3
- Step 2: For each species, BioNet records were analysed to define biological populations of the species. This analysis was undertaken by ecologists at Biosis with knowledge and expertise in the ecology of each species. Where gene flow between two records is considered likely, the records were assigned to the one population. The ecologists took the following factors into account in determining whether gene flow is likely between records:
    - Distance between individual flora records
    - The presence of features or barriers that might limit demographic or genetic exchange
    - Pollinator type and seed dispersal mechanism (where known)

- The continuity of patches of vegetation.

- Step 3: For critically endangered and endangered Category 1 matters:
    - Describe and map each population (including identifying population sizes).
- Step 4: For vulnerable Category 1 species:
    - Collate the required data on each species as per the data sources in Table 3
    - Apply the criteria in Table 3 to each species, using GIS analysis where necessary
    - Describe and map each population (including identifying population sizes).

Table 3. Criteria for identifying and mapping important populations of vulnerable Commonwealth listed Category 1 species

	Criteria	Rationale	Data sources
1	Any population of a species identified as potential Serious and Irreversible Impacts (SAII) entity under the NSW BC Act	SAII entities have been identified under the NSW BC Act and meet one or more of the following principles: • Species in rapid rate of decline • Very small population size • Very limited geographic distribution • Unlikely to respond to management and therefore irreplaceable • Populations of SAII entities therefore make a significant contribution to the conservation of the species.	• Threatened Biodiversity Data Collection
2	A population identified or inferred in a Commonwealth conservation advice, recovery plan, final determination, or other relevant policy document as being important	Consistent with the EPBC Act Policy Statement 1.1 (DoE, 2013).	• Recovery plans • Conservation advices • Final determinations
3	A population that is a site-managed species or iconic species targeted for conservation under the NSW Saving our Species program	Species targeted by the Saving our Species program have been prioritised for conservation effort under a program that aims to maximise the chance of securing the greatest number of species in the wild. Therefore populations targeted under the NSW Saving our Species program could comply with the following EPBC important population criteria: • Key source populations either for breeding or dispersal • Populations that are necessary for maintaining genetic diversity, and/or • Populations that are near the limit of the species range'.	• Save our Species program conservation projects database
4	A population associated with a commitment made under the Sydney growth	These populations have been previously identified for conservation, have had significant resources attributed to their conservation and are subject to existing commitments under the Sydney growth centres	• Sydney Growth Centres Strategic Assessment: Program Report (DOP, 2010)

	centres conservation program	conservation program and should therefore be considered important.	• NSW *Threatened Species Conservation Act 1995* Order to confer biodiversity certification on the State Environmental Planning Policy (Sydney Region Growth Centres) 2006
5	Any population of a species that contains more than 20% of the total population (total number of mature individuals in the species) or 20% of the Area of Occupancy (AOO)* of that species	Significant contribution to the conservation of the species. Loss of any population that contains 20% or more of the total population or Area of Occupancy is justification for change in status from Vulnerable to Endangered under IUCN and EPBC Act criteria (IUCN 2012).	• BioNet, site specific surveys
6	Any population of a species where the species has less than 10 known subpopulations	These are species that have very few populations. All known populations therefore make a significant contribution to the conservation of the species. Loss of any population of such a species would be significant.	• BioNet, site specific surveys
7	Any population of a species that is a large population in the context of the ecology of that species, in the opinion of expert ecologists	Large populations are important from a genetic perspective. They typically will have sufficient genetic diversity, increased evolutionary potential, reduced inbreeding effects and increased probability of long term viability and persistence.	• BioNet, site specific surveys
8	Any population of a species within a conservation reserve (regardless of the number of plants or size, etc)	These populations are important because they are more likely to be effectively managed and have a greater chance of persistence due to their occurrence in a conservation reserve, and therefore make a significant contribution to the conservation and recovery of the species. Conservation reserve refers to those that meet IUCN protected area categories I-IV.	• BioNet, site specific surveys • National parks estate data • BioBank site data
9	Any population of a species that is important for maintaining the Extent of Occurrence (EOO)^ of that species	Maintaining the full range of a species has a greater chance of retaining the variation within the species (a primary aim of biodiversity conservation). Populations at the extent of occurrence or that are outliers to the more general distribution are likely to contain genetic difference or capacity to persist in different environmental conditions that will provide the species ability to cope and respond to changes in the environment, such as climate change.	• BioNet, site specific surveys • Commonwealth database profiles/distribution mapping

*AOO is defined as the area within a species 'extent of occurrence' which is occupied by a taxon, excluding cases of vagrancy. The measure reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats.

^Extent of occurrence is defined as the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a species, excluding cases of vagrancy.

4.3.1 Details of approach

Data collection/manipulation

The general approach is considered appropriate for determining important populations at a strategic scale as it:

- Interrogated species record data using an expert ecologist and removed any inaccurate records
- Used appropriate data and the best data available
- The criteria used for identifying and mapping important populations was appropriate and comprehensive
- Used appropriate assumptions for determining populations of individual species
- Includes analysis and cross-checking that is independent of the source data and other input information
- Used a conservative approach so that despite quality of data methods for determining populations were unlikely to be overlooked.

More details and justification is required with respect to the exclusion of populations for some species that are earlier than the lifespan of the species. For example, records for the Regent Honeyeater were restricted to those post 2008 to account for the 10 year lifespan of the species. It is considered that the exclusion of these records may exclude records that could contribute towards a population of that species not being considered. However, it is noted that only three species were not considered to have important populations within the Subregion.

Assumptions

The assumptions associated with the method are clearly stated and considered appropriate for a strategic level assessment, except for the issues discussed above in the *Data collection* section.

It’s important these assumptions are presented in the report.

Datasets

The method has incorporated the best available information as it:

- Incorporates the most up to date datasets that are available at the required scale
- Has interrogated the data and excluded it when inaccurate
- Individual records have been interrogated by an expert ecologist.

4.3.2 Summary

In general, the approach used for determining important populations is adequate and conservative. However, it is considered that some data refining approaches, such as the exclusion of records older than the lifespan of the species, may exclude records that could contribute towards a population of that species not being considered.

4.3.3 Components that require improvement

The approach is generally considered appropriate for the strategic assessment. However, for the species that have been determined not to have important populations within the subregion AND have had records excluded based on the lifespan of the species, a detailed discussion of the implications of the approach needs to be provided.

5. Southern Sydney Koala population viability evaluation method

5.1 Background and context

There are a significant number of koalas within and adjacent to the southern portion of the strategic assessment area.

These koalas are thought to be in recovery, with research indicating clear increases in the area of habitat occupied by koalas in the locality over recent years. The koalas in the area are subject to a range of existing threats, in particular increasing road kill along Appin and Picton Roads. They will also be subject to direct impacts as a result of development within the Greater Macarthur and Wilton Growth Areas (noting that significant avoidance of impacts has occurred), and potential indirect impacts associated with proximity to new urban areas and roads.

However, the Cumberland Plain Conservation Plan (the Plan) also provides a significant opportunity to:

- Protect and manage large areas of habitat for the population
- Restore and improve key habitat corridors
- Manage and reduce threats
- Improve the information base for the population to assist in ongoing adaptive management

5.1.1 Terminology

The koalas within and adjacent to the southern portion of the strategic assessment area are currently being referred to as the "Southern Sydney koala population".

However, it is noted that koalas within this locality may in fact comprise two ecologically and genetically distinct koala populations (the Southern Tablelands koala population, and the Campbelltown koala population).

It is known that the Campbelltown koala population is important as it is free from Chlamydia. Conversely, the Southern Tablelands population is known to contain virulent strains of Chlamydia.

It is thought that these two koala populations may have originally been separated due to low population numbers, yet as populations expand, they may now be increasingly exposed to contact with each other.

The locations of the boundaries between each population are difficult to determine and further research is required as part of this assessment to identify them. It is noted that the true locations of the boundaries between the populations may be unknown and therefore there is a potential that the assessment approach may need to account for uncertainty in this regard.

Therefore, the terminology "Southern Sydney koala population" may be subject to change in the future, depending upon further consideration of whether the assessment area encompasses one or two koala populations, the likely location of the boundaries between the koala populations (if known), or whether the boundaries of the koala populations are unknown.

The Plan defines a [draft] outcome for the Southern Sydney koala population that it aims to deliver. It is:

> *"Key areas of habitat for iconic and distinctive threatened species such as koala are protected and managed".*

5.1.2 Regulatory context

Koalas are listed as vulnerable under both the EPBC and BC Acts. The key instruments considered for the assessment included:

- Approved Conservation Advice for *Phascolarctos cinereus* (DSEWPC, 2012)
- EPBC Act referral guidelines for the vulnerable koala (Department of the Environment, 2014)
- Recovery plan for the koala (*Phascolarctos cinereus*) (DECC, 2008)
- State Environmental Planning Policy No 44 – Koala Habitat Protection
- Securing the koala in the wild in NSW for 100 years: Saving Our Species Iconic Koala Project 2017-2021 (OEH, 2017)
- NSW Koala Strategy (OEH, 2018)
- Conserving koalas in Wollondilly and Campbelltown LGAs (OEH, 2018).

5.2 Overview of approach

This section summarises the approach to the evaluation methods for determining the viability of the Southern Sydney koala population.

Open Lines is preparing a detailed impact assessment for the Southern Sydney koala population. This is based on addressing the terms of reference for the EPBC strategic assessment through:

- Understanding the background to koalas and the regulatory context for the assessment
- Understanding the baseline information for the species within the strategic assessment area
- Analysing the efforts to avoid and minimise impacts
- Analysing the direct and indirect impacts to koalas as a result of development under the Plan
- Assessing the proposed mitigation and management measures within the Plan
- Assessing the proposed conservation measures within the Plan
- Assessing potential cumulative impacts on koalas within the strategic assessment area
- Carrying out a detailed evaluation of the outcome for the species against the statutory and policy requirements. This will be done using the method that is the subject of this peer review (described below)

Open Lines are working with Associate Professor Mathew Crowther who is providing expert advice on the assessment.

5.2.1 Information sources

In addition to the documents listed above, the information sources in Table 4 were considered.

Table 4: Information sources for the impact assessment

Source	Description
Literature on the ecology of the population	The ecological characteristics of the koala population in the locality have been intensively studied over the last few decades. Research efforts have included government research (conducted by the Saving Our Species program administered by OEH), numerous academic publications and a PhD thesis.

	From this body of research, information specifically about the Southern Sydney koala population is available regarding: • Koala home range sizes and densities (OEH, 2018a; Ward, 2002) • Potential population size (Biolink, 2016; OEH, 2018a; Ward, 2002) • Population trends (Biolink, 2016, 2018b) • Preferred feed tree species (OEH, 2018a; Phillips & Callaghan, 2000; Sluiter, Close, & Ward, 2002; Ward, 2002) • Habitat connectivity requirements (Biolink, 2018a) • Population genetics (Kjeldsen et al., 2018; Lee, Zenger, Close, Jones, & Phalen, 2010) • Key threats (Phillips, 2016) This targeted literature is complemented by a broader body of research relating to koala populations and ecological characteristics across the range of the species. The available literature and resources provide a solid foundation with which to understand the key characteristics and conservation needs of the Southern Sydney koalas.
Species records	Koala records within and adjacent to the study area have been accessed from the NSW BioNet Atlas database. The BioNet Atlas contains species records within the study area which were obtained during recent research conducted by the Saving Our Species program, and therefore is considered a resource containing contemporary knowledge of koala distributions within the area. BioNet records have been used in research to assess population trends (Biolink, 2016, 2018b) and identify koala roadkill locations and hotspots (OEH, 2018a). BioNet records have also been used to conduct Species Distribution Model mapping as part of the current assessment process.
Cumberland Plain wide species distribution model	A Species Distribution Model (SDM) has been prepared to predict the occurrence of koala habitat within the Cumberland subregion. The SDM supports environmental impact analysis within the Growth Areas, such as through providing information about the relative importance of habitat within each Growth Area, and providing indicative information about the availability of habitat for offsetting.
Habitat and corridor mapping	Comprehensive mapping of koala habitat within the study area has been undertaken, first by OEH within the Greater Macarthur and Wilton GA, with the methodology then replicated by Biosis for the whole of the Cumberland subregion. This habitat mapping is based upon: • Mapping Plant Community Types (PCTs) to a fine resolution across the study area, and using coarser resolution data across the wider subregion • Classifying each PCT as either 'high', 'medium' or 'low' quality habitat for koalas, and from this identifying 'principal' and 'supporting' koala habitat • Identifying movement corridors, and categorising corridors into 'primary', 'secondary' and 'tertiary' corridors • Identifying important koala habitat based on species polygons Habitat mapping provides insight into the relative importance of vegetation areas for supporting koalas, and enables avoidance, mitigation and conservation measures to be appropriately targeted to ensure the best possible outcomes for koalas within the locality.
Mapping of habitat critical to the survival of the species	Mapping of habitat critical to the survival of the species is currently being undertaken in accordance with the *EPBC Act referral guidelines for the vulnerable koala* (Department of the Environment, 2014). The mapping process is based on scoring

	criteria and considers the following key parameters in determining the value of koala habitat: • Koala occurrence • Vegetation composition • Habitat connectivity • Existing threats • The value of the potentially impacted koalas to the recovery of the wider koala community Each attribute is assigned a score based on whether or not certain parameters are met for each of the above attributes. If an area of habitat equals or exceeds a score of 5, then the habitat considered to be habitat critical to the survival of the species. The purpose of this mapping is to identify the presence of habitat which is of significant conservation value to koalas, such that appropriate avoidance, mitigation and conservation measures may be taken during environmental assessment.
Habitat connectivity analysis around Greater Macarthur and Wilton	Biolink Ecological Consultants were engaged by OEH to conduct an analysis of habitat connectivity across the Wilton Growth Area and the southern portion of the Greater Macarthur Growth Area. The purpose of the assessment was to assess the current habitat connectivity of the area, and then model the projected changes in habitat connectivity following development within the Growth Areas and upgrading of Appin Road. The results of this assessment provide insight into relative the accessibility of different patches of koala habitat within the Growth Areas, and enables assessment of the potential fragmentation impacts of different development scenarios.

It is considered that the datasets and literature considered as part of the assessment are appropriate and comprehensive, and provide the most suitable base for meeting the objectives. Although only in draft form, the Campbelltown City Council Comprehensive Koala Plan of Management should be considered.

5.2.2 Key gaps

Open Lines identify two key knowledge gaps which remain for koalas within the assessment area, which may impact upon the environmental assessment methodologies used to determine the viability of the Southern Sydney koala population, and whether the outcome in the Plan has been met. These gaps are as follows:

Demographic statistics for the koalas within the study area

Key demographic information (such as the birth rates, mortality rates, and mortality causes) are currently not available for the Southern Sydney koala population. This lack of information is considered to impede the capacity to immediately conduct an accurate Population Viability Analysis (PVA) model, which is a well-recognised methodology to assess a population’s viability.

Open Lines consider it may be possible for a PVA to be conducted in the future, once further background work has been undertaken to consolidate all available information for the koalas within the study area, and then further survey work is undertaken to obtain information which is otherwise not available.

Boundaries of koala populations within the study area

Open Line identify that further work is required as part of the assessment process to ensure that the best available knowledge has been accessed, to identify the locations (and porosities) of boundaries between the Campbelltown and Southern Tablelands koala populations.

It is noted that the Campbelltown koala population is currently free of Chlamydia, whereas the Southern Tablelands population is known to contain virulent strains of Chlamydia.

It is noted that potential proximity and subsequent connectivity between the Campbelltown and Southern Tablelands koala populations is of conservation concern, and that it has the real potential to significantly impact upon the projected the viability of the Campbelltown koala population.

5.2.3 The evaluation method for review

The evaluation method is based on posing a series of evaluation questions:

1. Will the Plan deliver the desired outcome of the Plan and ensure viability of koalas?
2. How does the Plan address the OEH principles?
3. How does the Plan consider the EPBC Act referral guidelines?
4. Has the Plan had regard for the Conservation Advice?

Question 1: Will the Plan deliver the desired outcome of the Plan and ensure viability of koalas?

The current draft koala outcome in the Plan is:

> *Key areas of habitat for iconic and distinctive threatened species such as koala are protected and managed.*

In addition to analysing this outcome, Open Lines considered it important to look at the current and future viability of the Southern Sydney Population. Predicting the performance of the Plan against this framework has its challenges. In particular, the assessment relies upon a clear and measurable definition of viability.

Viability has been defined as the ability of the koala population to persist and avoid extinction. There are a number of key factors which have been identified as influencing a population's viability:

- Extent and quality of habitat
- Landscape connectivity
- Level of threat
- Genetic variation
- Population size and demographics
- Stochastic events.

Population Viability Analysis was not used as much of the input data was not available and it was considered that the model's predictions might be inaccurate and result in inappropriate conservation actions. Further it was considered that if the Koala population responded in ways not predicted this would undermine scientific and public confidence in the process.

Instead population viability will be analysed through considering the factors which influence a population's viability, and through assessing whether any of these factors will be negatively affected in a significant manner such that the viability of the population could be undermined.

To this end, the following approach is proposed by Open Lines to analyse whether the Plan will achieve the desired outcome. It is based on considering each of the factors that drive viability and includes:

- Step 1 avoidance of impacts: Calculate the avoidance of impacts to koala habitat as a result of planning decisions in the Greater Macarthur and Wilton Growth Areas through:
    - Calculating available habitat in each Growth Area broken down by primary, secondary and tertiary corridors
    - Calculating avoidance of habitat for biodiversity reasons
    - Calculating avoidance of habitat for other reasons (e.g. topography).
- Step 2 extent and quality of habitat: Calculate the net change in the extent of quality of habitat as a result of development, restoration and offsetting through:
    - Calculating the total current extent of habitat broken down by primary, secondary and tertiary corridors
    - Calculating the future extent of habitat once the Plan has been implemented. This will include areas to be restored.
- Step 3 landscape connectivity: Analyse changes to landscape connectivity through:
    - Reviewing the findings of the GIS-based GAPCLoSR undertaken by Biolink
    - Analysing the projected changes to primary corridors.
- Step 4 level of threat: Analyse changes to the level of threat to the population through:
    - Roadkill:
        - Assessing current roadkill records
        - Assessing projected decline of roadkill events with proposed wildlife fencing and/or crossing structures
        - Assessing changes in koala movement patterns as a result of proposed wildlife fencing
    - Dogs:
        - Assessing the likely increase in dog density and associated dog predation of koalas under projected development scenarios
    - Disease:
        - Assessing the likely current and projected connectivity between the Campbelltown (disease free) and Southern Tablelands (diseased) koala populations, under current conditions ('do nothing' approach) and under projected development scenarios.

- Step 5 genetic variation: consider possible changes to the genetic variation of the population through:
    - Assessing current available literature regarding the genetic diversity of the local koala populations
    - Assessing the likelihood of koala populations or sub-populations becoming genetically isolated as a result of the proposed development
    - Assessing the severity of the risk posed by low genetic diversity to koala population viability, noting that some of the most heavily populated and expanding koala populations within Australia are populations with very low genetic diversity.
- Step 6 population carrying capacity: analyse possible changes to the carrying capacity of the population through:
    - Habitat loss (either through land clearing, or through isolation of otherwise viable habitat patches)
    - Alteration of habitat quality through long-term environmental changes such as climate change.

Given the lack of data available to feed in to the PVA it is agreed that using PVA at this time may provide inadequate or false outputs and that it should not be used. It is considered the proposed approach to assessing Koala viability through measuring changes to the extent and quality of Koala habitat, connectivity, threats, genetic variation and carrying capacity is appropriate and the best possible approach, in light of the absence of suitable data for PVA. It is agreed that the use of carrying capacity rather than Koala numbers is a better approach as it takes into consideration habitat loss and alteration, whereas measuring Koala numbers would be time consuming expensive and potentially of low accuracy, and may not reflect true carrying capacity due to delayed changes to populations from changed habitat.

Question 2: How does the Plan address the OEH principles?

The following outlines the evaluation approach for determining how well the Plan addresses the principles outlined by OEH.

- Principle 1: Avoid new residential development within core koala habitat and primary corridors:
    - As per Step 1 for Question 1
- Principle 2: Separate residential development and koala populations to minimise ongoing threats from domestic dogs and vehicles:
    - Assessing the suite of management measures which are proposed to separate residential developments from koala populations in terms of:
        - Which measure/s will be implemented
        - Where each measure will be implemented

- Whether there are any areas or gaps in which no measures are implemented at the interface of koala-urban habitat, and whether the localised lack of mitigation measures represents a significant threat to koalas
- Whether there are sufficient provisions for long-term monitoring and maintenance for each measure
- Whether the proposed measures to be implemented are supported by appropriate scientific data to indicate their effectiveness in achieving their desired outcomes

- Principle 3: Identify critical revegetation zones that will augment and strengthen core habitat and corridors:
  - Assessing the location/s of proposed rehabilitation and/or revegetation areas with regards to the locations of important habitat
  - Assessing whether proposed revegetation areas contribute to strengthening important habitat, and/or widening/filling in gaps within existing corridors
  - Assessing whether revegetation targets key priority areas identified by OEH, which are as follows:
    - "The highest priority in the Wilton GA is in the south- east section, where core koala habitat surrounds and almost fully encloses cleared land at the start of the primary corridor along Allen's Creek (Allen's corridor)."
    - "the length of the eastern side of the [Greater Macarthur] GA, to the east of Appin Road, directly adjacent to the Georges River corridor… Other areas include areas to the east of the Ousedale-Mallaty corridor to complete a corridor connection (on both ends) for a secondary corridor currently connected to a primary corridor at one end."
  - Where revegetation is located outside of areas highlighted as priority revegetation areas by OEH, the associated justification of the environmental benefits of the proposed revegetation is to be examined.
- Principle 4: Identify koala road kill hotspots requiring road kill mitigation fencing and/or underpasses to allow safe passage of koalas:
  - Assessing the locations of road kill hotspots which have been identified by OEH with regards to proposed locations of wildlife fencing and/or crossing structures. An assessment will be made as to whether the locations of the proposed fencing/crossing structures are likely to:
    - Reduce roadkill at roadkill hotspots
    - Result in changes in species movements across transport infrastructure through the wider locality
  - Assessing whether adequate provisions have been made for long-term maintenance and monitoring of fencing and/or crossing structures

- In the event of other and/or additional measures being proposed, available literature and/or expert advice will be assessed to consider the likely effectiveness of proposed measures in achieving desired outcomes.

It is considered that if the Plan addresses the principles as outlined it would result in the viability of the southern Sydney Koala population(s) would be maintained. With respect to Principle 3 and 4, revegetation and mitigation measures outside the Growth Areas could still benefit the southern Sydney Koala population(s), including inside the Growth Areas, and should be considered and discussed in the evaluation.

Question 3: How does the Plan consider the EPBC Act referral guidelines?

The evaluation will consider if and how the Plan has had regard for the objectives of the guidelines:

- Promote avoidance and mitigation of impacts on the koala
- Promote a clear, consistent and transparent approach for making decision on whether an action is likely to result in a significant impact on the koala
- Promote streamlined decision-making and approval processes
- Promote the recovery of the koala.

Additional considerations posed by the guidelines will also be evaluated:

- Potential impacts to habitat critical to the survival of the species
- Implementation of mitigation and management measures to protect the species.

It is considered the evaluation would adequately consider the EPBC Act referral guidelines.

Question 4: Has the Plan had regard for the Conservation Advice?

The koala Conservation Advice is a brief and broad document which is intended to provide generalised advice to both management/approval bodies and proponents with regards to conservation information and requirements for koalas in Queensland, New South Wales and the Australian Capital Territory.

The Advice acknowledges that the ecological characteristics and conservation requirements of Koala populations vary significantly across the range of localities covered by the Advice. Therefore, the Advice states that in many cases, local and regional research and Koala management plans may provide far more detail and may be more applicable at local and regional scales.

The evaluation will consider if and how the Plan has had regard for the Conservation Advice. This includes analysis of how the Plan relates to:

- Identified threats
- Research priorities
- Priority management actions.

It is considered the evaluation would adequately have regard for the Conservation Advice.

5.3 Summary

It is considered that with the data available that the evaluation method is appropriate for a landscape-scale assessment and would adequately assess the viability of the southern Koala population. It is agreed that due to poor data availability using PVA at this time may provide inadequate or false outputs and that it should not be used. The evaluation method's consideration of landscape issues such as connectivity and landscape-scale threats such as roads and disease means it is appropriate and the best possible approach, in light of the absence of suitable data for PVA.

The evaluation method addresses the terms of reference and has regard for conservation advice and EPBC Koala guidelines.

The peer review by Associate Professor Mathew Crowther and input from relevant government authorities such as the Commonwealth Department of Environment and Energy and NSW Office of Environment and Heritage have provided a robust audit mechanism.

5.4 Components that require improvement

The evaluation method is considered appropriate for a strategic assessment and components requiring improvement have not been identified. Although it is a complex method with many influencing and interactive factors, which will be difficult to interpret and synthesis, it is still considered more appropriate than a PVA and or a simpler method.

Use of a PVA in the future should be considered, but only if the current method is determined to be deficient or producing outputs that don't meet realities, and if sufficient data can be collected or becomes available. The effort required to collect data adequate for PVA over such a large area is significant, and will be extremely expensive, so should not be considered lightly.

6. Conservation priorities method

6.1 Overview of method

The Conservation Priorities Method aims to determine and prioritise conservation methods for the Cumberland Plain study area. To offset the impacts associated with development of the Growth Areas and transport corridors, it identifies areas suitable for conservation through establishment of Biodiversity Stewardship Sites or National Park Reserves. The method combines spatial data with an analysis of constraints and opportunities. Constraints with respect to establishment of offset sites include land where conservation measures are already required and urban/industrial zoned land. Opportunities include large areas of vegetation in good condition, and proximity to protected/important land such as national parks or riparian areas.

Offset requirements were determined by applying a ratio matrix that applies an offset ratio to all impacted entities based on their conservation status and condition. In accordance with the matrix, the offset ratio increases as conservation significance increases (i.e. from not listed through to critically endangered under the EPBC Act and/or BC Act) and as the condition of vegetation improves.

6.2 Legislative requirements

The project will comprise a strategic application, allowing greater flexibility in application of the offsetting requirements of the BC Act and EPBC Act. Nonetheless, the method aims to address the offsetting requirements of the BC Act and the offsetting principles stated in the OEH Draft Guidelines and EPBC Act Environmental Offsets Policy.

It is considered the method adequately addresses the above requirements and principles as it targets the vegetation and species that will be impacted by the development, aims to improve or maintain biodiversity values, emphasises important biodiversity areas such as national parks and aims to establish in-perpetuity protection for the offset areas.

6.3 Data sources and manipulation

The datasets used in the method are considered appropriate as they can be consistently applied across the study area and comprise the most up-to-date information regarding biodiversity values, development and land use.

The categorisation of constraints and opportunities is appropriate and successfully prioritises potential offset sites across the study area. The method favours privately owned land, which is likely to involve difficulties with landowner involvement and cooperation at this scale. However, the method prioritises offset sites, thereby providing alternative options if difficulties are encountered.

7. Conclusion

Niche were commissioned by DPE to undertake an independent peer review of the Western Sydney Strategic Assessment to meet the EPBC Terms of Reference. The review was based on a workshop held at DPE's Sydney office on 18th February 2019 where the authors of each method provided detailed presentations and an agenda for the workshop that summarised the details of each method of the assessment.

This peer review has summarised the methods for each component of the assessment and then provided comments on the adequacy of the data and method used, and whether there can be improvements. In general it is considered the datasets, methods for data collection and assumptions associated with the methods are appropriate for a strategic assessment and most components do not require improvement. However, in general, details associated with the input data and assumptions should be included to provide the reader a more complete understanding of the limitations of each method.

The methods used are generally conservative and unlikely to under-represent the presence or distribution of any threatened ecological community or species. In fact, the methods used in most methods are likely to over-predict distribution and it is important these approaches are not transposed to the offset component of the assessment as they may predict false presence in future offset lands. However, it is noted that all offset sites would be surveyed prior to establishment. Some species records are excluded from consideration based on patch size and this approach may exclude areas of potential habitat that could be utilised by some of these species.

Despite some potential issues with data error and an overly conservative approach, the interrogation of the data, coupled with independent review by suitably qualified ecologists, is considered appropriate for a strategic assessment and would achieve as much accuracy as possible without significantly more effort with respect to field verification.

Annex 1 – Curriculum Vitae

CV

Rhidian Harrington

BSc (Hons), MSc, PhD

Director and Ecologist

niche Environment and Heritage

"My goal is to develop the best environmental consultancy in Australia: an organisation that staff are proud to be a part of and that clients partner with to achieve sustainable and efficient project outcomes."

- Founding director of Niche Environment and Heritage
- Over 25 years' experience as an ecologist and project manager
- Design, implementation and delivery of large complex ecological projects
- Extensive experience with road and mining projects, and offsetting
- Biodiversity Assessment Method (BAM) - Accredited Assessor under the NSW *Biodiversity Conservation Act 2016*
- Vice President, Environmental Institute of Australia and New Zealand (EIANZ)

Career overview

Rhidian is a professional ecologist and project manager with over 25 years' experience working across a diverse range of industry sectors and environments. Rhidian has been the senior scientist and project manager on many major projects, including environmental assessments, management plans and mitigation design, particularly for linear infrastructure and large mining developments.

Rhidian has experience in flora and fauna survey, federal and state offsetting schemes and project management for environmental approvals projects. Rhidian has conducted ecological work throughout Australia (NSW, VIC, QLD, SA and the NT) as well as overseas in southern Africa and Pakistan. He is experienced in the application of state and federal legislation which relates to the conservation of threatened species and communities, and related planning instruments. Rhidian has acted as an expert witness in the NSW Land and Environment Court. Rhidian is an Accredited BAM Assessor under the NSW BC Act.

Employment history

2009–present	Director and Ecologist, Niche Environment and Heritage
2003-2009	Manager/Senior Ecologist, Biosis
2002-2003	Project Officer, Black-eared Miner Recovery Team, La Trobe University
2002–2002	Scientific Writer, Institute for Land and Food Resources, Melbourne Uni
2000–2001	Zoologist/Project Manager, Melbourne Enterprises International Ltd
1998–2002	Research Assistant/Demonstrator, University of Melbourne
1995-1996	Research Assistant, Botswana National Parks
1997-1998	Lecturer/Demonstrator, University of the Witwatersrand, South Africa
1992-1992	Research Assistant, Australian Centre for Tropical and Freshwater Research (ACTFR), James Cook University

Skills

- Project management
- Ecology assessments for major projects
- Ecological survey and monitoring
- BioBanking and BAM assessments
- Offsetting strategies and BDAR's
- Stewardship Site Assessments
- Biodiversity offset brokerage
- Impact minimisation (mitigation)
- Expert witness and peer review
- Government agency consultation and advocacy
- Strategic planning and advice
- Regulatory compliance
- Quality assurance

Flagship projects

Key offsetting projects that Rhidian has project managed

Brimbin New Town; Biodiversity Certification Assessment, 2013-2014

Hunter Valley Operations (Rio Tinto); Upper Hunter Strategic Assessment, 2013-2015

Wambo Coal Mine; Upper Hunter Strategic Assessment, 2013-2015
Boggabri Coal Mine; Independent audit of EBPC Act offsets, 2013
Transport for NSW; review of offsetting guide and calculator; 2015-2016
O'Donnelltown'; Biodiversity Stewardship site assessment; 2018
Edgeworth (NSW) residential development; offset strategy; 2016-2017
Austen Quarry Stage 2 Extension; BioBanking assessment and offset strategy; 2016-2017
'Piney Range'; BioBank site assessment; 2016-2017
Mt Thorley Warkworth Mine; biodiversity areas; bird assemblage monitoring; 2016
Warkworth Mine; offsets vegetation and habitat monitoring; 2014, 2015 and 2016
Chinese Theme Park; BioBanking assessment; 2014-2015
Oxley Hwy to Kempsey Pacific Hwy Upgrade; Biodiversity Offset Management Plan, 2014-15
Hunter Expressway; BioBanking assessment; 2013
West Wallsend residential development; SIS and offset strategy, 2012-2013
Caroona Coal Project; Fauna, aquatic ecology and offsetting assessment, 2013-2015
Hunter Valley Operations; Ecological assessment and offset strategy, 2012-2013
Warkworth Mine; Biodiversity offset strategy, 2013
Warkworth Mine; Local offsets vegetation and habitat monitoring program, 2014-2015
Warkworth Sands Woodland Restoration Plan, 2013
Vickery Coal Mine; SSD ecological assessment and offset strategy, 2011-2014
Tarrawonga Coal Mine; BioBanking Assessment, 2010-2011

Other offsetting projects Rhidian has been involved in

'Glenhaven'; BioBank site assessment; 2016
'Blackjack Mountain'; BioBank site assessment; 2014-2015
Tahmoor South Coal Mine; Ecological assessment and offset strategy, 2013-2014
Balranald Mineral Sands Project; Ecological assessment and offset strategy, 2013-2014
Marys Mount Quarry; Ecology assessment, Koala PoM and BioBanking assessment, 2013-14

Major road projects that Rhidian has project managed

Outer Suburban Arterial Roads Program; Technical Due Diligence Advisor – Ecology, 2017
Toowoomba Second Range Crossing; Technical Due Diligence Advisor – Ecology, 2014-2015
East West Link; Technical Due Diligence Advisor - Ecology, 2013-2014
Hunter Expressway; Project Ecologist, 2004-2009
Pacific Highway Upgrade: Tintenbar to Ewingsdale; Environmental Assessment, 2004-2009
Pacific Highway Upgrade: Woodburn to Ballina; Environmental Assessment, 2006-2008
Oxley Highway Upgrade: Species Impact Statement, 2004-2006
Pacific Highway Upgrade: Moorland to Herons Creek; Environmental Assessment, 2004-2006
Pacific Highway Upgrade: F3 to Raymond Terrace; Environmental Assessment, 2004-2006
Pacific Highway Upgrade: Ballina Bypass modification; Environmental Assessment, 2007-2008
Central Coast Highway Upgrade: Carlton to Matcham Road; EA, 2008-2009
Central Coast Highway Upgrade: Matcham Road to Ocean View Drive; EA, 2008-2009
Central Coast Highway Upgrade: Woy Woy Road Intersection at Kariong; EA, 2009
Princes Highway Upgrade: Tomerong Bypass; Environmental Assessment, 2011
Terrigal Drive Upgrade (two separate projects); Environmental Assessment, 2011
Picton Road Upgrade: Reverse Curves Stage 2; Environmental Assessment, 2012
Princess Highway Upgrade: Nowra Bypass; threatened species assessments, 2012
Pacific Highway Upgrade: Wyong Town Centre Study; Environmental Assessment, 2012
Shortland to Sandgate; Threatened species surveys and assessments, 2013
Federal Environment Department Linear Infrastructure Mitigation panel, 2007

CV

Evelyn Craigie

BSc (Zoology), MEM

Senior Ecologist

niche Environment and Heritage

"I aim to find innovative solutions that maximise environmental benefits and progress sustainable development."

- Accredited BAM Assessor under the *Biodiversity Conservation Act 2016*
- 14 years' experience in the private and public sectors, including both State and local government
- Experienced in application of environmental and planning legislation and negotiating solutions to ecological issues
- Experience in flora and fauna field survey
- Member of Ecological Consultants Association of NSW

Career overview

Evelyn's career experience includes 10 years in ecological consulting and four years in the public sector. Evelyn's recent experience in development assessment at State and local government has given her a comprehensive working knowledge of environmental and planning legislation and valuable insight into the complexities of environmental planning, the development process and experience in stakeholder liaison.

Evelyn's experience in ecological consulting includes project management, planning and carrying out of field survey. Evelyn has prepared numerous high quality reports that are clearly written and comprehensible to all readers including clients, government agencies, site workers and the general public.

Employment history

2018 –present	Senior Ecologist, Niche Environment and Heritage.
2015 – 2018	Ecologist, Central Coast Council
2014 – 2016	Planning Officer, NSW Department of Planning and Environment
2011 – 2014	Senior Ecologist, Environmental Resources Management Pty Ltd
2004 – 2011	Ecologist, AECOM

Skills

- Comprehensive understanding of environment and planning legislation
- Flora and fauna survey
- Biobanking Assessment Methodology
- Stakeholder liaison and negotiation
- Project management
- Clear written communication

Flagship projects

Prepare Biobank Agreements on behalf of NSW Office of Environment and Heritage (OEH) (2018)

Evelyn has reviewed four applications to establish Biobank Sites and prepared the associated Biobank Agreements on behalf of OEH. This included a comprehensive review of all submitted documents to ensure compliance with the Biobanking Assessment Methodology, liaison with the applicant and OEH and preparation of the Biobank Agreement.

Reports in accordance with Biodiversity Assessment Method (2018)

Evelyn has undertaken survey and reporting in accordance with the Biodiversity Assessment Methodology (BAM) for Part 4 development applications, including development projects and stewardship site projects. Field survey included quadrats in accordance with the BAM and targeted threatened flora survey. Evelyn managed the process through to submission to local government and provided advice to the client with respect to meeting offset obligations.

Mobile: 0488 224 810 **Email**: ecraigie@niche-eh.com

Review of Biodiversity Reports on behalf of Bayside Council (2018)

Evelyn reviewed the biodiversity reports for a Planning Proposal on behalf of Bayside Council. Evelyn was able to draw on her previous State and Local government experience to ensure all biodiversity aspects of the proposal were adequately addressed.

Review of Flora and Fauna Assessments for Planning Proposals, Part 4 Development Applications and State Significant Development (2014 – 2018)

Evelyn assessed numerous ecological reports In her previous roles as a development assessment officer at the Department of Planning and Environment and Central Coast Council. Projects ranged from single dwellings to residential and industrial subdivisions and re-zonings. These roles provided Evelyn with a comprehensive working knowledge of planning and environmental legislation and experience in guiding projects through the complexities of the development application process.

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Development and activity approvals
Rehabilitation
Stakeholder consultation and facilitation
Project management

Environmental offsetting
Offset strategy and assessment (NSW, QLD, Commonwealth)
Accredited BAM assessors (NSW)
Biodiversity Stewardship Site Agreements (NSW)
Offset site establishment and management
Offset brokerage
Advanced Offset establishment (QLD)

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document C – Expert reports

Supporting document C – Contents

Expert report – *Acacia bynoeana*

Expert report for *Acacia bynoeana* (Bynoe's Wattle), Dr Steven Douglas, February 2019

ECOLOGICAL
SURVEYS & PLANNING

Expert Report For

Acacia bynoeana

(Bynoe’s Wattle)

Strategic Assessment for the Cumberland Plain Conservation Plan

Greater Macarthur, Greater Penrith to Eastern Creek, Wilton, and Western Sydney Aerotropolis Growth Areas

Prepared for NSW Department of Planning & Environment, February 2019

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Table of Contents

Acacia bynoeana on the edge of a roadside cutting. © S. Douglas

1. Introduction

1.1 Purpose of the Expert Report

An Expert Report may be prepared under s.6.5 of the Biodiversity Assessment Method (BAM) in place of undertaking a threatened species survey of sufficient extent, intensity and duration as would otherwise be necessary to comply with the BAM. Use of an Expert Report may be beneficial where it is highly unlikely that a species may occur within a study area; where survey cannot meet BAM specifications; and/or the reliability of detecting the species is low. In respect of *Acacia bynoeana*, insufficient survey extent; constraints on the effectiveness of survey; and unreliability of detection due to aspects of the species' ecology are the primary reasons for preparing an Expert Report.

The purpose of this Report is to provide an assessment of the current status and conservation requirements of *Acacia bynoeana* within the four priority Growth Areas of Greater Macarthur (GMGA); Wilton (WGA); Greater Penrith to Eastern Creek (GPECGA); and Western Sydney Aerotropolis (WSAGA)to determine whether:

a) The species is unlikely to be present and would thus require no further assessment; or
b) The species is known or likely to be present, and the Expert Report must provide estimates of potential habitat within Growth Areas and development footprints as part of the biocertification process.

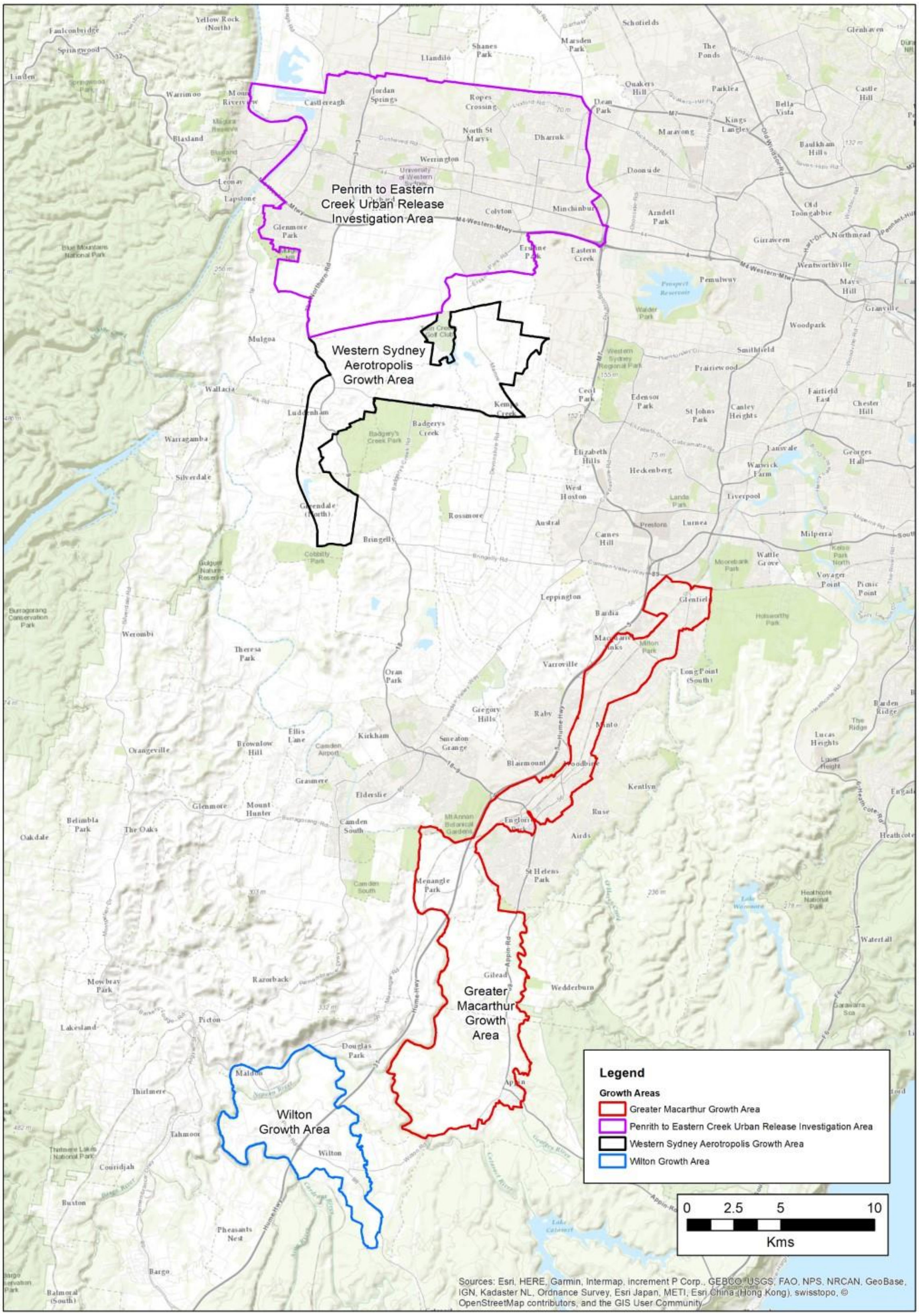
1.2 Project context

The NSW Government is identifying areas for future urban land use and associated infrastructure in western Sydney. The four priority Growth Areas are all located in the Cumberland Subregion under the Interim Biogeographic Regionalisation for Australia (IBRA) (SEWPaC, 2012).

As part of the planning for these areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify land use outcomes. A strategic assessment of this Plan is underway, and this Expert Report will assist in determining the extent and quantum of impacts of the proposed urban growth on *Acacia bynoeana*.

Acacia bynoeana (Bynoe's Wattle), Putty Road © S. Douglas

1.3 Study area



Map 1. Growth Areas subject to this Expert Report

Greater Penrith & Eastern Creek Growth Area (GPECGA)

A large portion of this Growth Area is already urbanised, with several areas of industrial land use. Significant rural and peri-urban areas remain in the central north, the centre, and the southwest. Large areas of remnant vegetation are present in the far north (former Australian Defence Industries site, now in part Wianamatta Regional Park), and the Orchard Hills Defence facility. Mining of alluvium for sand and soil continues in the far northwest of the area in the Penrith Lakes locality.

The area has been extensively cleared because of its relatively arable terrain, based mainly on shale and alluvium. Some of the remaining vegetation is associated with the much less arable to infertile Castlereagh Woodlands and its older, leached and mineralised alluvium and shale-derived soils. Strips of remnant vegetation are present along some of the larger watercourses such as Eastern and South Creeks. Significant parts of the study area are or were flood-prone, and this has influenced the retention of vegetation in some affected areas.

Western Sydney Aerotropolis Growth Area (WSAGA)

This Growth Area adjoins the Greater Penrith to Eastern Creek area, extending south to the locality of Greendale, west of Bringelly. It is currently largely rural, with villages at Luddenham and Kemps Creek. Most rural areas are pastoral, but there are significant areas of more intensive rural use, including poultry and egg production, a large dairy and associated fodder cropping, and some market gardens and enclosed fruit and vegetable production. Quarrying occurs at the localities of Badgerys Creek and Kemps Creek.

This Growth Area is extensively cleared but retains native vegetation in areas where rural uses were constrained by steeper terrain, flooding along streams, or unsuitable soils.

Greater Macarthur Growth Area (GMGA)

The GMGA occurs in southwestern Sydney on predominantly shale soils that have been heavily cleared for agriculture and urban or industrial use. The northernmost section has long-established urban and commercial / industrial land use, while the southern section is largely rural (pastoral, minor cropping), with some villages and primarily subsurface mining (e.g. coal and coal seam gas). It extends from urban Glenfield in the north, to the rural village of Appin in the south.

In the southernmost section, geological uplift and erosion have exposed infertile sandstone terrain along gullies and valleys. Much of that terrain remains naturally vegetated because it is unsuited to agriculture, however it occupies only a small percentage of the total area of this heavily-cleared region. Between the infertile sandstone valleys and the relatively arable shale plateau and hills is a geological and ecological transition zone. Whilst much of the vegetation of the shale terrain has been cleared, a greater area of vegetation remains on the transition zone, primarily in the south. Both the shale and transition zones support Critically Endangered ecological communities that are potential habitat for some threatened plant and animal species.

Wilton Growth Area (WGA)

The Wilton Growth Area is the most southerly of the four Western Sydney Growth Areas dealt with in this Report. It extends from the village of Douglas Park in the north, to the village of Wilton in the south. It is primarily rural (pastoral) area with some more intensive agriculture, significant but mostly underground mining (primarily coal), and some long-established villages. The Hume Motorway dissects this Growth Area.

The pattern of clearing and vegetation retention is broadly similar to that of Greater Macarthur, with the majority of remnant vegetation associated with infertile but biodiverse sandstone gullies and the Nepean River gorge, and with associated transition into the heavily cleared shale landscapes.

1.4 Justification for the use of an Expert Report

An Expert Report for *Acacia bynoeana* is required as part of the threatened biota assessment for the Cumberland Plain Conservation Plan because:

1) Survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH, 2016) for field traverses due to limitations on land access, particularly in the GMGA;
2) Survey quality was constrained by drought conditions. Whilst this species is perennial, under sufficiently severe drought and associated total grazing pressure (livestock, if relevant; native species; feral species), it can be suppressed such that it only remains apparent (but likely undetectable) as rootstock and as seed bank. Drought was a major limitation on survey effectiveness in this instance. A known location of the species was visited by fellow botanist, Robert Miller, but could not be detected, even though the habitat was still in place. This suggests that the surveys for this species will have under-detected it because of drought and associated increased grazing / browsing pressures;
3) Survey effectiveness was further constrained by parts of the study area having been long-unburnt. This can create an unnaturally dense shrub layer that limits access and that also creates conditions likely to suppress the species such that it may retreat to the seedbank until favourable conditions return (post-fire or equivalent disturbance).

Surveys associated with biocertification of the study areas and earlier projects in those areas have been insufficient to reliably determine the presence and extent of the species. An Expert Report is required to provide an assessment of the likely presence, location, and significance of occurrences of the species in those areas.

1.5 Credentials of expert

I have worked as an ecologist since the mid-1990s, primarily in the Greater Sydney region, but also in the ACT, Central Coast, southern NSW (coast, tablelands and slopes), throughout Victoria and into eastern South Australia. I have primarily been self-employed, with a mix of government, private, and corporate clients, and have also worked as a subconsultant to larger firms, including two university-based consultancies. I have also worked directly for the NSW NPWS, and more recently for OEH (Native Vegetation Information Science). A summary of my credentials as required under the BAM is provided below as Table 1. I was approved by OEH as a species expert for *Acacia bynoeana* under s.6.5 of the BAM in November 2018

Table 1. Credentials of Dr Steven Douglas as Expert in relation to *Acacia bynoeana*

BAM section	BAM requirement	Details
s.6.5.2.8 (g)	Name of expert	Dr Steven Douglas
s.6.5.2.3 (a)	Expert's qualifications	Bachelor of Science (Plant Ecology, Land Management, Resource & Environmental Management), Macquarie University, 1993. Master of Environmental Planning, Graduate School of Environment, Macquarie University, 1996. Doctor of Philosophy, Australian National University, 2008. Graduate Certificate of Information Literacy, ANU, 2006. BAM Accredited Ecologist, 2018.
s.6.5.2.3 (b)	History of experience in ecological research and survey method for the relevant entity	Review of BioNet and incorporated NSW Herbarium database records of *A. bynoeana* (DPE, 2018). Provision of expert witness evidence in relation to *Acacia bynoeana* (QUBE proposal, Moorebank; included assessment of adequacy of biobanking arrangements) L&EC 2017/81889 (2017-18). Discovery and documentation of new population of *Acacia bynoeana* in Penrose State Forest, including management advice to Forestry Corporation and monitoring (2015-on-going). Rediscovery and documentation of 'lost' 1960s 'Bundanoon' records of *Acacia bynoeana* in Morton National Park (2012-13). Acknowledged by OEH for contribution to the 2009 Draft Recovery Plan for *A. bynoeana*. Consultant to OEH in its review of the current, 2014 Draft Recovery Plan for *A. bynoeana*. On-going advice to OEH to maintain currency of this Plan. Preparation of species management profile for Hornsby and later Gosford LGA Threatened Biota Management Plans (1999 and 2001). Surveys, documentation and recommendations for threatened species including *Acacia bynoeana* as part of the Landcom ESD report (Total Environment Centre, 1999). Successfully nominated species for upgrade from Vulnerable to Endangered under Threatened Species Conservation Act 1995 (1998). Numerous historic surveys in northwest and western Sydney including Hills Shire, Hornsby Shire, Blue Mountains City, Hawkesbury and Penrith LGAs (1994-2000) as evidenced by BioNet and NSW Herbarium records.

s.6.5.2.3 (c)	Resumé detailing projects pertaining to the survey of the relevant entity	See Appendix 1. Relevant surveys and works listed above. Penrose SF population survey used OEH-compliant transects. Minor survey of potential habitat at locality of Kemps Creek for DPE Expert Report. Meandering transect used.
s. 6.5.2.3 (d)	Employer's name and period of employment (if relevant)	Self-employed ecological consultant, 1996 to present (continuous other than for periods of study). Employed by OEH as contracted staff from November 2015 to July 2018 (Wingecarribee Shire vegetation map, South Coast Regional vegetation map, Review of mapping issues for TECs).
s.6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant entity	Profiles prepared for this species in threatened biota management plans for Hornsby and Gosford Councils. Successful nomination to NSW Scientific Committee to upgrade species' conservation status. Consulted by DECCW on this and other threatened flora species of the region as part of a data review for the purposes of the Biobanking Tool (2006). Consulted by OEH in PAS2 and SOS reviews of this species. Current member of SOS project panel. Engaged by Forestry Corp to advise on management of this species in Penrose SF. Approved as a BAM species expert for *Acacia bynoeana* by OEH in November 2018.

2. Species information

2.1 Description

"Bynoe's Wattle is a semi-prostrate shrub to a metre high. The (adult) phyllodes ('leaves') are shiny, stiff and narrow, 1.5 - 5 cm long and 1 - 3 mm wide…" (OEH, 2017 online species profile). "Decumbent shrub to 0.3 (-0.5) m tall" (Cowan, 2001 in Flora of Australia on-line). "Decumbent shrub to 0.5 m high" (Kodela, 2012 in PlantNET on-line).

The species is best described as having a range of growth forms from prostrate to decumbent to erect, depending on habitat and disturbance history. The tallest plants occur in the lower Hunter / Lake Macquarie regions and can reach 1 metre high; the lowest-growing plants occur primarily on shallow and infertile soils derived from Hawkesbury, Narrabeen, or rarely, Nowra Sandstones and associated laterite, broadly south and west of Lake Macquarie and range from ground-hugging (<5 cm high) to ~20 cm high; and plants of 10 - 30 cm high occur on Paleogene-Neogene alluvium and associated laterite in the Castlereagh Woodlands (roughly in the centre of the species' distribution).

Driscoll (2006 in OEH, 2014) recognised what he considered to be a form of the species in Yengo National Park that was different to the many plants he'd seen in the north and north-east of the species' range. He stated that the Yengo plants have "a much shorter leaf length, sessile peduncles, and fewer flowers and anthers." I am cited in OEH (2014) as suggesting that Driscoll's comments about the Yengo plants are actually typical of the 'southern' populations (i.e. those south of the Lake Macquarie / Hunter area). Driscoll's work was largely in the far north of the species' range, and it is the northern occurrences that are atypical of the species as a whole, though there may be a cline of traits between the Central Coast and the Hunter district. The physical differences between the northernmost populations, and the more typical, much lower-growing plants that occur across most of the species' range is such that the recognition of two subtaxa has been suggested (Douglas, pers. obs. in OEH, 2014). Were a northern subspecies to be recognised, it would have a far smaller range than the typical form of the species, but it is apparently more abundant and potentially more fecund within that area of habitat than would be the typical form across the same sized area. Further research is required to clarify the taxonomic distinctions and any changes in conservation status that this might generate.

Acacia bynoeana in bud – handheld GPS unit for scale. Regenerating in slashed APZ, Penrose State Forest (© Forestry Corporation)

2.2 Ecology

"The single flower heads, on short hairy stems, appear anytime from September to March. Its seedpods are mature from September to January" (OEH, 2017).

Acacia species are generally self-incompatible, and the pollinators are likely to be small native bees and wasps (Bernhardt, 1987 cited in OEH, 2014).

Seed dispersal is most likely by ants seeking to collect the aril. Seeds are taken into the ant nest, and later discarded in a wide area around the nest (Whitney, 2002 and OEH, 2014). Seeds are likely to remain viable over many years in the absence of germination cues, with the species likely to develop a persistent, soil-stored seed bank, as is typical for most Acacias (NPWS, 2002, cited in OEH, 2014).

Driscoll (2006) states that the species is largely clonal and spreads vegetatively by underground stems. Consideration of stem thickness suggests that the plants are relatively long lived. The species is known to resprout following some forms of disturbance, including fire. It can survive in highly modified habitats such as slashed Asset Protection Zones, and road/trail verges.

Driscoll notes that most plants appear to be resprouts or other clonal growth, and that seedlings are rare. However, determining whether a plant is a seedling or a resprout can require some amount of excavation of the root and stem, which may be fatal. Most of Driscoll's assessments relate to populations in the northern part of the species' range, and they may not be representative of the species overall.

I have observed definitive seedlings of this species at Penrose (see below) on a disused fire trail. A BioNet record (Turner, 2005, Tadmore Rd, Cranebrook) also notes "one individual still with juvenile leaves at base, not seen on previous site visit so possibly recent recruit…". A search for the word 'juvenile' in BioNet records for this species within the Cumberland Subregion plus a 100 km buffer found only Turner's reference, though most records simply don't record details about the age of observed plants.

Plants are not always apparent and appear periodically, perhaps in response to local disturbance (Benson & McDougall 1996). The species is "cryptic, clonal and difficult to detect, particularly when not in flower" (OEH, 2014). It is described as "rather inconspicuus" by Fairley (2004).

Acacia bynoeana seedling showing juvenile (lobed) and adult (linear) leaves. (© Forestry Corporation).

2.3 Distribution and abundance

A range of publications, including on-line resources, provide different distributions for this species, largely as a result of there being significant changes to its known range over time. Some describe it as occurring 'near Wollongong' but this is a result of database errors, as the only legitimate records in that region are not at all near the city and are a considerable distance inland to the north and west within the Woronora Plateau. Many outdated sources list the northern limit as Morriset (Lake Macquarie region), and the southern limit as the Mittagong area (Southern Highlands, Central Tablelands). Neither remain accurate, with the species now accepted to occur substantially further north and south of those areas, as well as further west.

Current knowledge is that *Acacia bynoeana* is found from the Hunter District (North Rothbury) in the north, to the Southern Tablelands (near Goulburn) and South Coast hinterland (Colymea / Parma Ck), and west to just beyond the Blue Mountains (Bogee in the Captertee Valley, and Lithgow areas).

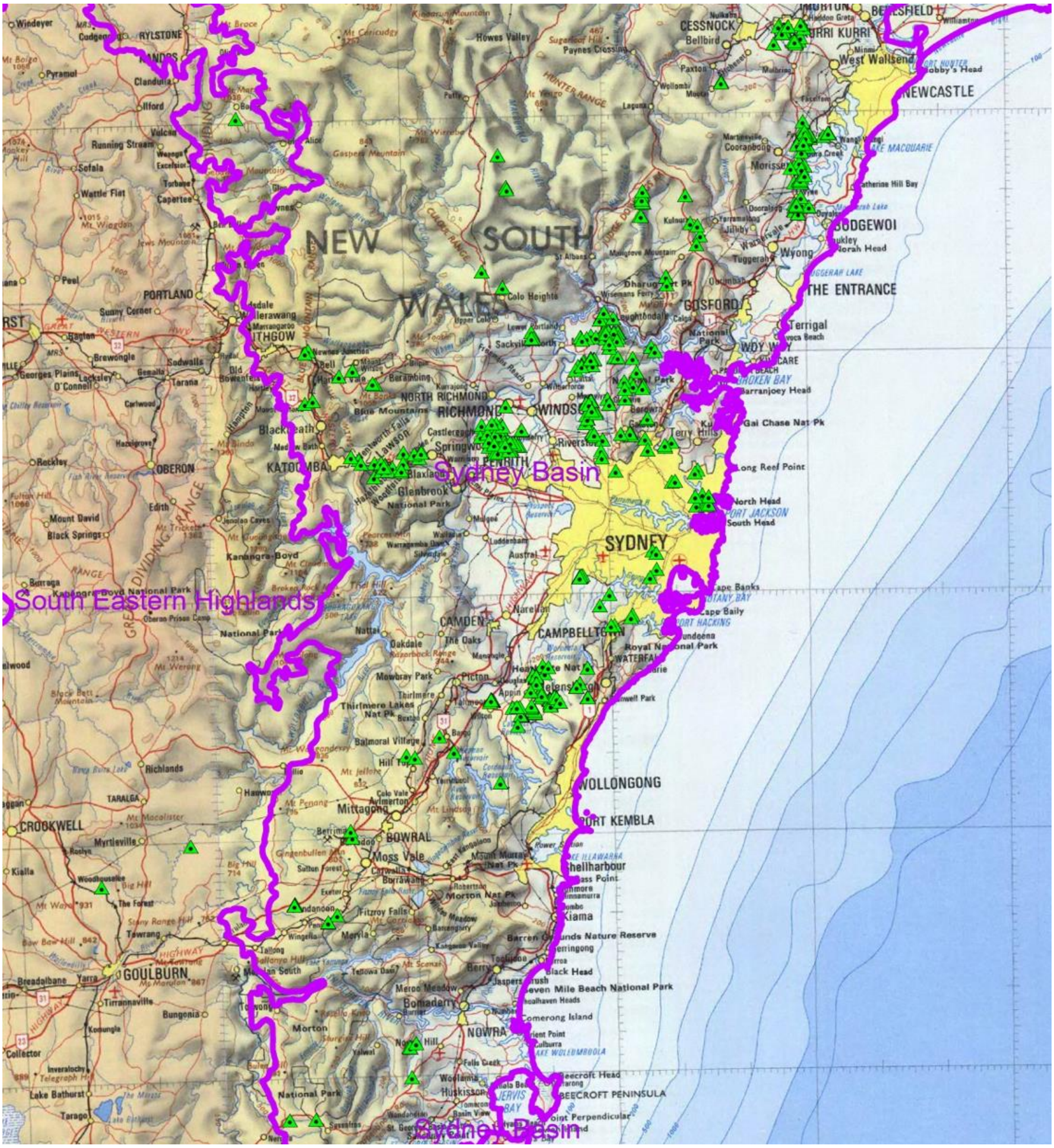
Based on cleaned BioNet data, this species is largely endemic to the Sydney Basin Bioregion, with the exception of three outliers: a record in Tarlo River National Park (part of an incomplete species list for that Park, with no co-ordinates available for this record, so potentially unreliable); a record north of Goulburn (in a vegetation sampling plot with accurate co-ordinates), both of which are within the South Eastern Highlands Bioregion; and another in the Capertee Valley (modern Herbarium specimen with sufficiently accurate co-ordinates), just within the South Western Slopes Bioregion[1].

Map 2 was generated from BioNet data and gives a generally accurate indication of the species' known range, but not the extent of potential habitat. Large areas of NPWS estate and Water NSW catchment lands have not been subject to the same level of survey effort as areas where pressure for land clearing is high or where activities such as underground mining have funded surveys in relation to surface works and subsidence concerns. The map shows an absence of records of the species between the urban areas of the Blue Mountains, and the Southern Highlands, despite there being extensive areas of potential habitat present. Similarly, there are very few records north from the Blue Mountains villages through Wollemi National Park, but again, the area contains significant areas of potential habitat.

As of 2006, the species was known from about 113 extant locations across 21 LGAs (Driscoll, 2006). The number of locations will have increased since that time, though known and unknown destruction of plants and perhaps populations is also likely in that time. The total *estimated* population size in 2006 was 1400 to potentially >6000, though counts were only made at 18 populations, and data indicates that 84 populations only support 1 plant. Two populations were known to support >400 individuals (another was known at that time but not to Driscoll), but 91% of all populations are estimated to support <100 individuals (Driscoll, 2006). Driscoll believes that most population data is very deficient, and that most sightings do not entail a sufficiently thorough census. I concur, as many records lack any population data. In one example provided by Driscoll and Bell, a population estimate of 9 changed to a count of >300 after systematic survey (with some allowance for clonality) (OEH, 2014). OEH has not published a more recent estimate of the number and size of populations, and the 2014 draft Recovery Plan had not proceeded to a final version at this time.

It is important to note that most population 'counts' are estimates because the species is partially clonal, so it is often not feasible to determine the number of actual individuals without genetic testing or potentially destructive sampling.

[1] The boundaries of Bioregions and subregions are often mapped very coarsely and can be misleading in some regards. In this instance, Steenbeeke (OEH / DPE, pers. comm.) states that the Capertee Valley primarily comprises Permo-Triassic deposits of the Sydney Geological Basin and should be included in the Sydney Basin Bioregion, not in the South Western Slopes Bioregion. He notes that the location of the *A. bynoeana* record in that area is on Permian Shoalhaven Group geology.



Map 2. Cleaned BioNet data (extracted 18/10/18)

The above map was generated from BioNet data and gives a generally accurate indication of the species' known range, but not the extent of potential habitat. Large areas of NPWS estate and Water NSW catchment lands have not been subject to the same level of survey effort as areas where pressure for land clearing is high or where activities such as mining have funded surveys. The map shows an absence of records of the species between the lower Blue Mountains and the Southern Highlands, despite there being extensive areas of potential habitat present. A recent record by Orme (not shown) from Joadja has begun to fill that gap. Similarly, there are very few records north from the Blue Mountains villages through to those north of Colo Heights and near St. Albans. Again, that area contains significant areas of potential habitat.

2.3.1 Reservation status

The NSW Scientific Committee (1999) states, "Most of the known sites (of *A. bynoeana*) are not reserved, although populations are known from several reserves including Marramarra National Park, Castlereagh Nature Reserve, Lake Macquarie SRA[2], Blue Mountains National Park". This information was updated by Driscoll (2006) who states that the species is known from 12 NPWS reserves (see Table 2). Five of these are State Conservation Areas that do not prohibit subsurface or surface mining, so do not provide the security that a National Park (NP) or Nature Reserve (NR) designation can.

At least one population (or part thereof) is reserved in a Biobanking offset site (Moorebank). However, that site was burnt in a very intense fire event in April 2017 during severe drought, and at this stage, the status of the *A. bynoeana* population there has not been documented. Part of the area had been burnt only 2-3 years prior to the arson event, which could result in extinction of this species in the affected area, depending on how fire affected the seedbank and how much, if any, successful recruitment occurs post-fire.

Steenbeeke (DPE, pers. comm.) suggests the species may be within the Westcliff Colliery 'managed offset'. Information about other reserved populations in Biobanking offset / stewardship sites was not available due to confidentiality constraints.

Table 2. Modified from Driscoll (2006) by DEE (2008) and for this report. *Best estimate.

Reserve	Records	Individuals*	Populations
Bargo SCA	1	2	1
Berowra Valley RP (now NP)	4	8	3
Blue Mountains NP	8	16	8
Castlereagh NR	4	8	1
Colymea SCA	1	2	1
Jilliby SCA	1	5	1
Ku-ring-gai Chase NP	4	8	4
Lake Macquarie SCA	1	1600	1
Maroota Ridge SCA	4	8	1
Marramarra NP	9	18	1
Wollemi NP	1	2	1
Yengo NP	10	94	1

[2] SRA = State Recreation Area. These were later replaced with the State Conservation Area designation, which has different planning and management parameters but is still a relatively low level of reservation.

Table 3. Additional NPWS reserves containing BioNet records of the species as of November 2018

Reserve	Records	Notes
Agnes Banks NR	1	No recent records despite intensive survey for associated species
Bargo River SCA	1	At edge of reserve
Dharawal NP	51	Detailed survey on and near firetrails and utility corridors. Number of populations much less than number of records
Dharawal SCA	2	One in reserve, one on roadside – may or may not be inside reserve
Morton NP	4	Two sets of two records, distant from each other
Parma Creek NR	1	Credible
Parr SCA	2	One site
Popran NP	1	Credible
Tarlo River NP	1	Dubious record in an incomplete species list for the reserve
Upper Nepean SCA	1	Credible
Werakata NP	3	One site, triplicated. Dubious, possible spatial error.
Wianamatta NR	7	One to three sites – some records with low spatial accuracy

In some instances, the number of records per reserve cited by Driscoll has since increased e.g. Colymea SCA (now 3 records not 1).

In its Final Determination to upgrade the species from Vulnerable to Endangered, the NSW Scientific Committee states, "Recent vegetation surveys in Royal National Park have not located the species. The species was also known from one site within Ku-ring-gai Chase National Park, but several subsequent searches of the site have failed to find any plants". BioNet data currently shows a duplicated, old record on the edge of Royal NP near Loftus, and 4 records in Ku-ring-gai NP. It is this record from Royal NP that has not been rediscovered. A review of cleaned BioNet data for the species in Ku-ring-gai Chase NP revealed 4 records: one by Auld in 1985 (the record referred to by the Scientific Committee); two by Foley in 1998, one of which is an apparent rediscovery of Auld's record, and the other at a nearby by separate site; and one by Foley in 2001 from a different population. Consequently, the statement in relation to the Ku-ring-gai Chase NP population by the Scientific Committee is now redundant. However, there are no records of the species at any of those sites since 2001, but this may be solely an artefact of no survey effort.

"Large populations are present in the Cessnock area of the Hunter Valley, but none of these are currently present in conservation reserves" (Bell & Driscoll, 2002). BioNet data indicates that these populations are near Ellalong and Kurri Kurri, and that one triplicated record may be within Werakata National Park, but they do not provide sufficient detail to verify this.

The species is also now known in considerable numbers (>100 apparent plants, but potentially far fewer individuals) within two sites in Penrose State Forest. Both are outside zones subject to plantation forestry, and the largest is wholly within a bushfire Asset Protection Zone. Whilst the APZ will be maintained to protect plantations, it is now managed with the conservation of *A. bynoeana* in mind, meaning that slashing is less frequent than has been the case; not as low to the ground (parts of the site are now bare due to historically intensive and low slashing); and timed to avoid flowering and seed production. Manual methods of vegetation suppression are also used between slashing events, and these target tree saplings and large shrubs. This practice likely favours *A. bynoeana* by reducing competition and shading through the maintenance of a derived low heathland in what would have been heathy to scrubby forest or woodland.

Additional populations may be reserved as a result of the pending declaration of several new Flora Reserves (deemed Koala Reserves, to be managed by NPWS) within State Forests. However, none were evident based on current BioNet data and Forestry Corporation tenure. Again, this may be a result of low or no survey effort. The species is likely to occur in at least two of the forthcoming Flora Reserves: Meryla and Jellore, both of which are in the Southern Highlands. It may also be present in the forthcoming Comleroy Flora Reserve northwest of Sydney.

The species is now known to occur in many more NPWS reserves than when it was gazetted as Endangered in 1999, or as reported in Driscoll's work of 2006, and by OEH (2014). However, the true size and viability of all such populations is largely unknown. There are also more records of the species, and some more information about apparent population sizes. However, the species remains inadequately conserved across much of its range, and most records either have no population data, or relate to a single plant.

2.4 Habitat

2.4.1 Geology and soil

Acacia bynoeana occurs primarily in heathland, scrub, woodlands and forests on Triassic and Permian primarily sandstone-derived soils (including but not limited to members of the Hawkesbury, Narrabeen & Shoalhaven Groups); the Wianamatta Shale / Hawkesbury Sandstone transition and often-associated Mittagong Formation; and on Paleogene-Neogene alluvium deposits of the Cumberland Plain and environs (*sensu* Martyn, 2018). Some occurrences are known from Quaternary and Cainozoic geologies (Driscoll, 2006), but these are a very small proportion across the species' range. The three geographically outlying records are apparently associated with older geologies that form the basement of the Sydney geological basin. Most occurrences are from sandstone plateaux, with the exception of those from parts of the Lake Macquarie and Hunter area, and those from the Castlereagh Forests and Woodlands of Western Sydney.

Associated Soil Landscapes include but are not limited to: Berkshire Park (Paleogene-Neogene alluvium); Faulconbridge, Bundeena, Gymea, Lambert, Somersby, Oxford Falls, Penrose, Penrose A, Soapy Flat, Nattai Tablelands (Hawkesbury Group); Lucas Heights, Hilltop (Mittagong Formation); Warragamba, Gorokan, Awaba (Narrabeen Group); Durran Durra (Ordovician Metasediments); Canobla Gap (Megalong Conglomerate and Berry Siltstone); Doyalson (Munmorah Conglomerate); Heddon Greta (Permian Branxton Formation). Other Soil Landscapes may be relevant towards the limits of the species' distribution but occur in areas without Soil Landscape maps or where the available data appears incorrect.

Altitude of known habitat ranges from 0-1000 m, though Driscoll (2006) believes that the species may be found at higher elevation subject to survey effort.

2.4.2. Associated vegetation communities and NSW TECs

The species "Seems to prefer open, sometimes slightly disturbed sites such as trail margins, edges of roadside spoil mounds and in recently burnt patches. Associated overstorey species include Red Bloodwood, Scribbly Gum, Parramatta Red Gum, Saw Banksia and Narrow-leaved Apple" (OEH, 2017). The listed overstorey species are only a subset of those that are relevant across the species' range, and are not representative, nor do they occur at all locations where the species is present.

OEH (2014) and the OEH Threatened Biodiversity Data Collection list the following Keith Vegetation Classes as being associated with *A. bynoeana*:

- Sydney Coastal Dry Sclerophyll Forests;
- Sydney Coastal Heaths;
- Sydney Hinterland Dry Sclerophyll Forests; and
- Sydney Sand Flats Dry Sclerophyll Forests.

The Threatened Biodiversity Data Collection indicates that *Acacia bynoeana* is potentially associated with 52 Plant Community Types (PCTs) across its range. Some of these are also associated with State and Commonwealth-listed Threatened Ecological Communities (TECs). Within the Growth Areas, relevant communities and NSW-listed TECs, excluding apparent errors, are shown in Table 4. The associated PCTs are treated by OEH as *potential* habitat, and the species may not actually occur in all of those communities.

Associations between a species and Vegetation Classes and PCTs in the Threatened Biodiversity Data Collection were determined by the species' Accountable Officer within OEH some years ago, and staff were required to take a relatively inclusive approach in accordance with the precautionary principle (Steenbeeke, pers. comm.). This may mean that for some species, Vegetation Classes and PCTs have been associated with them even though there is little or no empirical evidence to support that, but where the officer believed that these attributes credibly represent *potential* habitat. Given the limitations of vegetation mapping and that in most cases, survey effort for threatened species is incomplete across their range, such an approach is understandable.

It appears that in some cases, the associations with Vegetation Class and PCTs in the Threatened Biodiversity Data Collection may have been amended after the assignments described above, and that some more recent associations may be influenced by spatial errors in species' records and/or errors in or limitations of vegetation maps. The apparent association between *Acacia bynoeana* and PCT 1292 is apparent evidence of this, as this unit is a riparian scrub that is unsuitable habitat for this plant. Similarly, the association with PCT 849 is very likely unsound, as the species is not accepted to occur on Wianamatta Shale.

An assessment of the association between *A. bynoeana* and PCTs was undertaken to better understand the potential habitat for this species in terms of plant communities. The assessment is constrained by limitations of BioNet data and available vegetation maps. The assessment of the species' relationship with PCTs in and near the Cumberland Subregion used OEH vegetation maps that were publicly available at the time and did not use the updated vegetation maps produced within the Growth Areas. The information is used to generate 'species polygons' (maps of potential habitat) as required under the BAM. Whilst DPE required habitat associations to be graded i.e. strong to weak association with particular PCTs, only ungraded PCT association data was used to generate the 'species polygons'.

Some records of the species were seen to not be spatially associated with a PCT. This may be because:

- the record occurs in a site now cleared of native vegetation or too degraded to be captured by mapping;
- because the record is too spatially uncertain, so has been assigned generic co-ordinates, usually in a named town or suburb, and such settled areas often lack remnant native vegetation; and/or
- the record plots just outside an area of mapped vegetation because it is on a road verge, and even most GPS records are only accurate to 5m, meaning it could plot on the road, not on the vegetated verge.

To overcome this latter problem, those records were assigned a 10 m buffer so that they would associate with the nearest mapped vegetation polygon up to 10 m from the plotted location.

A further consideration is that survey effort for the species is not evenly distributed across the area subject to analysis. Some sites of potential habitat have had very little or no effort, often due to tenure constraints, yet others have had every apparent plant recorded (mostly in reserves or as part of ecological impact assessments). This creates very substantial biases in the data, which can create misleading weightings of association between the species and particular PCTs. Furthermore, most records do not include population data, such that a record might be for one plant or many. In short, this analysis is best used only for presence/absence i.e. whether the species has been recorded at a point that is mapped as a particular PCT, or not. Analysis beyond that is very constrained by deficiencies and biases in the datasets, especially in BioNet data.

The analysis of association with PCT in Table 4 below deals only with records in the Cumberland Subregion plus a 10 km buffer. Records that associate with a PCT when a 10 m buffer is used are included in the counts of sightings below and are not shown separately. Two analyses were undertaken: All records in the target area without regard to spatial Accuracy score; and only records in that area with Accuracy score of 100 m or better. The latter analysis is considered more reliable, but both sets of figures are provided. Sightings with Accuracy <=100 m are shown in square brackets **[ ]** and in bold text. Where available, the combined count of individuals associated with the records is provided in parentheses { }. Those counts relate only to records with Accuracy <=100 m. Where a record doesn't contain population data, it is assumed to relate to a single plant.

Only PCTs mapped in the Growth Areas are dealt with below. For PCTs outside the Growth Areas and within the 10 km buffer, only Coastal Sandstone Ridgetop Woodland (1777) is significantly associated with *Acacia bynoeana* (80 [71] {112} Very High).

Some PCTs can appear to have a greater or lesser association than is known or likely to be the case. This is evident for this species in that an uncritical review of the raw data would generate an association with this species and PCT 849, a form of Cumberland Plain Woodland that is not considered habitat for this species in any of the literature. The very few records that appear to be associated with that vegetation were more likely in Shale Gravel Transition Forest or Shale Sandstone Transition Forest, both of which can have a broad and indistinct ecotone with Cumberland Plain Woodland such that mapping of the boundary can be very difficult, even at quite a fine map scale.

Similarly, the raw data for PCT 1181 indicates a potentially Low to Moderate relevance as potential habitat, but this is likely to be influenced by spatial errors in the species' records and/or spatial and other limitations of the vegetation maps. At least some of the records associated with this sandstone-based PCT are more likely associated with PCT 1081, which may not have been accurately mapped. The association with 1181 is subsequently rated as Low probability/relevance as habitat.

Inclusion of PCTs 724, 725 and their derived shrubland state (808) as Very Low probability habitat in Table 4 would not ordinarily be supported by the methodology adopted here because there are no spatially credible records of the species from PCT 724 and only two from PCT 725. However, given the limitations of both survey data for the species (incomplete across its range, variable dependent on tenure/access, variable over time, variable in spatial accuracy, variable in quality, etc.) and of vegetation maps, inclusion of PCT 725 as potential habitat is in accordance with the precautionary principle and is made based on advice from Steenbeeke (DPE, pers. comm., relying on his field observations and his interpretation of habitat-related text associated with some records of the species). Steenbeeke also believes that 724 should be included as potential habitat, but I have not adopted that recommendation because there is insufficient evidence to support this, and I consider it unlikely to support the species, or at most, to be extremely low value habitat.

TABLE 4. Species records relative to mapped PCTs

PCT	PCT Name	Associated TECs (NSW BC Act)	% Cleared (VIS)	Sightings & Population	Relative association	Adjusted relative association#
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Shale Gravel Transition Forest (E)	75	1 **[0]** {0}	Probably nil	Nil
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Cooks River/Castlereagh Ironbark Forest (E)	95	4 **[2]** {4}	Very Low	Very Low
808	Derived shrubland on Tertiary Gravels of the Cumberland Plain	Shale Gravel Transition Forest (E) Cooks River Castlereagh Ironbark Forest (E)	75-95 inferred from 724/725	Not mapped	Very Low (inferred)	Very Low
849	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CE)	93	7 **[2]** {2}	Very Low	Nil
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Castlereagh Scribbly Gum Woodland (V) Castlereagh Swamp Woodland (E)	50	54 **[48]** {157}	High	High
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Not a TEC but some areas may be within Shale Sandstone Transition Forest (CE)	40	70 **[62]** {114}	Very High	Very high
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney	Not a TEC	20	17 **[10]** {71}	Low	Low
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (CE)	80	37 **[36]** {153}	High	Moderate

Description of PCTs associated with *Acacia bynoeana*

PCT 725

This community is not mapped in the WGA and GMGA, as the requisite geology is apparently not present. However, it may have been present to a minor extent in the far north of the GMGA because the presence of a very small area of 883 (below) indicates that there was at least one unmapped occurrence of Paleogene-Neogene alluvium.

This PCT is present to a very limited degree near the localities of Kemps and Badgerys Creeks in the WSAGA, and in the far central north of the GPECGA. It is restricted to Paleogene-Neogene alluvium/laterised shale, and this substrate is naturally rare and localised in those areas. Most occurrences in the GPECGA are within or near the currently gazetted and proposed portions of Wianamatta Regional Park, with only small patches occurring further east. It is part of the Cooks River/Castlereagh Ironbark Forest TEC.

PCT 883

This community is absent from the WGA, as the requisite geology is not present. It has been mapped only in the northern section of the GMGA as four small polygons in a section of infrequently-mown urban parkland adjoining a sporting facility. Whilst much of what little remnant vegetation remains, these polygons appear to be correctly ascribed to this community. However, aerial and ground-based photo interpretation indicates that much of the habitat within those polygons is likely to be too compromised to support this species, largely due to the nature of disturbance history and the severity of weed invasion (particularly African Love Grass). Engagement with Campbelltown Council as the land manager resulted in Council setting aside some areas from mowing. This increases the prospect for regeneration of *A. bynoeana*, but application of fire to stimulate regeneration is also likely to be necessary, especially in long-unburnt and long-unmown areas. The habitat value of the four polygons of 883 appears variable, but the ecology of *A. bynoeana* is such that it can persist in significantly compromised sites, such that these remnants are treated as potential habitat for the species.

PCT 883 has been mapped by OEH as two patches near the locality of Kemps Creek, only one of which is in the WSAGA, the other being just south of Elizabeth Drive. Fieldwork determined that the patch previously mapped within the WSAGA was incorrectly assigned and is better placed in one or two alternative PCTs (724/725). Based on the analysis shown in Table W, these two PCTs are very poorly associated with *A. bynoeana*, which may at least partially explain the absence of records of this species from this locality despite several surveys being undertaken there in association with recent land clearing applications.

OEH mapping shows four small patches of 883 in the central north of the GPECGA, three of which are within Wianamatta Regional Park. A few patches are mapped nearby at Llandilo on the northern border of the GPECGA. There could be additional very small patches within the GA that have not been correctly mapped due to the coarse resolution of soil and geology maps. The revision of OEH's map by Biosis has reduced this PCT's extent in the GPECGA to a single linear patch in the eastern portion of Wianamatta Regional Park. This PCT is extensive north from Cranebrook and is present within Castlereagh and Windsor Downs Nature Reserves. It is the most extensive community within what remains of the threatened Castlereagh Forests & Woodlands, partly because its soils are relatively infertile. It is a Vulnerable ecological community.

PCT 1081

This community is a form of 'shale sandstone transition forest' that was previously within the scope of the now circumscribed Shale Sandstone Transition Forest (SSTF) TEC. It has been independently assessed as a prospective threatened community, that whilst significantly reserved, is suffering on-going losses around Sydney, largely due to urban and peri-urban land use. It is a very significant habitat for *A. bynoeana* and several other threatened plant species.

This PCT is absent from GPECGA and WSAGA due to the lack of suitable geology. It is present as a very minor component of the northern GMGA (one site and three polygons) and as moderate component of the WGA. It is likely to have been naturally uncommon to rare in those areas and has probably not been heavily cleared there. It is not readily mapped with high reliability because of the broad ecotone with PCT 1395. Consequently, a precautionary approach is particularly necessary when dealing with areas mapped as PCT 1081, as some may be better classified as 1395 and therefore a Critically Endangered Ecological Community. It is also highly likely that 1081 is present but unmapped in areas that show 1395 immediately adjoining 1181, as the transition zone between the associated geologies is rarely as simple as most maps indicate.

PCT 1181

This community is mapped within the WGA and GMGA, but is generally outside the proposed areas of urbanisation, being associated with sandstone soils in gullies, valleys and steeper slopes. It is usually excluded from the proposed urban footprint because of its association with protected habitat along watercourses, and because of bushfire risk and steep, often rocky terrain. This PCT is not strongly associated with *A. bynoeana* habitat, and the association that is evident in the Bingara Gorge records may be an artefact of the vegetation mapping and of map scale. Most of those records are within vegetation mapped as 1395, with a small proportion close to or just over the boundary with 1181.

This PCT is not present in the GPECGA or the WSAGA due to the absence of associated geology.

PCT 1395

This community is the principal PCT of SSTF TEC and has a relatively moderately strong association with *A. bynoeana*. This community occurs on flat to gently sloping terrain, usually bordering cleared or highly modified rural land. This PCT is absent from the GPECGA and the WSAGA due to the lack of associated geology.

Even where proposed urbanisation does not involve clearing of SSTF, it can be increasingly threatened by urban encroachment in the form of bushfire hazard reduction works, recreational pressures, urban pollution e.g. nutrient-laden runoff, increased weed invasion from inappropriate landscaping/gardening, and increased predation of fauna by domestic pets.

2.4.3 Associated Commonwealth TECs

The Approved Conservation Advice for this species (DEE, 2013) contains significant errors that were brought to that agency's attention in 2016 but remain in its on-line publication as of November 2018. These include *incorrectly* associating *A. bynoeana* with the following nationally listed threatened ecological communities: Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion, White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland, Western Sydney Dry Rainforest and Moist Woodland on Shale, and Blue Gum High Forest in the Sydney Basin.

The Advice correctly associates the species with Shale Sandstone Transition Forest (this is essentially the same entity as the NSW TEC of the same name), and to a minor degree, the species can be found near but not in Temperate Highland Peat Swamps on Sandstone. The latter does not occur in the Growth Areas. Other nationally listed threatened ecological communities are also relevant but remain absent from the now-outdated text provided by DEE (2013). These are Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion; and at least on the basis of statistics, Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest. These are composite entities that each combine at least two NSW TECs. The species is strongly associated with Castlereagh Scribbly Gum Woodland but less so with Agnes Banks Woodlands.

2.4.4 Habitat condition

Degraded and significantly modified areas of the above-described PCTs can still be habitat for this species due to its ability to persist as woody rootstock and in the soil seed bank. Such modified sites may have reduced or no canopy and/or midstorey, and/or reduced understorey and some weed invasion. It is known to occur in highly modified sites such as slashed bushfire Asset Protection Zones, and road and trail verges, and in former small-scale quarries. Some forms of disturbance, even relatively severe forms that would be considered clearing of vegetation, appear to be beneficial to this species, within limits. This situation is recognised for numerous threatened plant species in and beyond the Sydney Basin Bioregion. It is believed to be related to the fact that modern fire regimes are likely to be significantly different to those prior to 1788, and that some native animal species that had a role in seed dispersal and understorey modification are now extinct, locally or entirely.

The condition of potential habitat for this species is not, in itself, a reliable indicator of the species' presence, and accordingly, **all condition states are considered in determining suitable habitat** i.e. intact, thinned, scattered, derived shrubland and, to a lesser degree, derived grassland.

3. Description of the study area

3.1 Landscape context and land use history

All of the Growth Areas have been significantly cleared for earlier activities, primarily timber production associated with opening areas for agriculture and pastoralism, minor areas of surface resource mining, and to varying degrees, for urban and commercial/industrial use. They are proposed to accommodate phased increases in urban land use, primarily within existing cleared or highly modified lands. Increased urban use is planned as a response to population growth.

3.1.1. Greater Macarthur Growth Area (GMGA)

The GMGA extends from Glenfield in the north to Appin in the south. It is largely within the Campbelltown LGA with the southernmost section within the Wollondilly LGA. The northern half comprises an urban renewal corridor centred on the Sydney to Main Southern railway line. It encompasses the existing industrial and residential suburbs of Glenfield, Macquarie Fields, Minto, Leumeah and Campbelltown. The GMGA is associated with extensively cleared, gently undulating shale terrain typical of the Cumberland Plain, and contrasts the sandstone gorges of the Woronora Plateaus across the Georges River to the east. The northern portion of the GMGA is already substantially urbanised, with remnant vegetation largely restricted to creek-lines or small patches associated with designated open space. Vegetated creek-lines include Bunbury Curran Creek, Bow Bowing Creek, Leumeah Creek, Fishers Ghost Creek and Spring Creek.

The more extensive southern half of the GMGA, south of Rosemeadow, comprises proposed urban land releases at Menangle Park, Mount Gilead and Appin. Menangle Park and Mount Gilead are subject to separate planning processes, so are not within the scope of this biocertification. In the north-west, Mount Sugarloaf (213 m AHD) forms the southern end of a hilly ridge on the Luddenham Soil Landscape above the Menangle floodplain that extends north to Denham Court, then to Cecil Hills and Prospect Hill. Some native vegetation persists, although it is often invaded by African Olive. The floodplain is dissected by Menangle Creek and its tributaries, including Nepean Creek, Woodhouse Creek and Leafs Gully.

The southern GMGA is primarily semi-rural and agricultural land, with creek corridors and some larger patches of remnant vegetation located between the Nepean and Georges Rivers. Geologically, the area comprises gently undulating hills on Wianamatta Shale intergrading via a shale sandstone transitional zone (can include the Mittagong Formation) with steeper and infertile terrain on Hawkesbury Sandstone along the rivers. Transitional and sandstone geologies are sometimes exposed along the smaller creek lines.

3.1.2. Wilton Growth Area (WGA)

The WGA is a relatively smaller area that occurs to the south of the GMGA, extending from the vicinity of Douglas Park in the north, Maldon in the north-west, and beyond Wilton in the southeast. The boundaries closely follow the Nepean River in the north and west, a tributary Allens Creek in the east, and the Cordeaux River in the south. Away from the Nepean River and gullies, a higher, gently undulating zone has been largely cleared for agriculture. The Woronora Plateau forms the southern boundary and includes the northernmost section of the large Upper Nepean State Conservation Area, with unreserved but closed areas of the Water NSW Special Area (Sydney water supply catchment) extending to the east and southeast. The Hume Motorway dissects the WGA roughly north to south, and Picton Road traverses it roughly northwest to southeast.

The WGA includes both shale, shale sandstone transition and sandstone environments. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The flatter shale terrain has soils of the Blacktown Soil Landscape, which is derived from Ashfield Shale (a member of the Wianamatta Group), and typically supported the now Critically Endangered Cumberland Plain Woodlands. Much of this area is cleared or modified for agriculture and hobby farms. It comprises native/exotic grassland with smaller areas of Derived Native Grasslands in relatively better condition. Areas above the gullies feature soils of the Lucas Heights Soil Landscape derived from the Mittagong Formation (a transitional bed between the Wianamatta and Hawkesbury Groups). These support variable shale sandstone transition woodlands and forest, some of which are also Critically Endangered. In the steeper gullies, the Hawkesbury Soil Landscape dominates, and supports Hawkesbury Sandstone Gully Forest types with Ridgetop Woodlands on some of the upper slopes.

3.1.3. Greater Penrith to Eastern Creek Growth Area (GPECGA)

The GPECGA is a relatively large area that extends from Rooty Hill, Minchinbury and Hassell Grove in the east, across the Cumberland Plain to the Hawkesbury-Nepean River in the northwest, then south through Jamisontown, Glenmore Park, to the intersection between The Northern Road and the Warragamba Water Supply Pipelines in the far south-west.

The predominant geology is Wianamatta Shale on flat to gently undulating terrain that has been extensively cleared for agriculture, and later for housing and industrial use, with some remnant vegetation on current and former Defence holdings. The shale soils support(ed) Cumberland Plain Woodlands. Overlying the extensive shale deposits are small areas of weathered Paleogene-Neogene alluvium e.g. Shalvey and Willmot, that are much more common to the north. These support(ed) the Castlereagh Forests & Woodlands complex of vegetation types, which is strongly associated with several threatened plant species. More common are broadly linear deposits of Quaternary alluvium along watercourses such as South Creek and Eastern Creek, and on the flood terraces of the Hawkesbury-Nepean River. Other lithologies occur but are very rare and of very small extent.

Very little of the GPECGA is reserved in NPWS estate. Wianamatta Regional Park (which emphasises recreational uses) encloses small areas of former Defence land in the far north. Adjacent to the southwestern boundary is the small Mulgoa Nature Reserve (emphasises biodiversity values). Two Biobanking sites adjacent to the Nature Reserve have increased the area under conservation.

3.1.4. Western Sydney Aerotropolis Growth Area (WSAGA)

The WSAGA abuts the GPECGA's southernmost border near the locality of Sovereign (east of Mulgoa), then extends south past Greendale, northeast to the locality of Badgerys Creek, east to Kemps Creek, and northward to the vicinity of Mount Vernon, excluding Twin Creeks Golf Course and associated settlement.

The lithology and soils are broadly similar to that of the GPECGA, being effectively just an extension of that area to the south to incorporate the developing Badgerys Creek Airport and environs. The area is even more severely cleared of native vegetation, except along some streams and on rare occurrences of steeper terrain. It contains no NPWS reserves, with the nearest being the small Kemps Creek Nature Reserve, outside the Area to the southeast. Gulguer Nature Reserve and Bents Basin State Conservation Area occur to the southwest of Greendale.

3.2 Geology and remnant vegetation

All of the Growth Areas are within the Cumberland Subregion. The dominant lithology across all of the Growth Areas is Wianamatta Shale (Ashfield and Bringelly Shales), with much smaller areas of Paleogene-Neogene alluvium occurring largely outside these boundaries, and much larger areas of Quaternary alluvium associated with floodplains of the many watercourses.

The terrain varies from almost flat through to steeply hilly areas associated with minor volcanism and more often, in association with shale ranges. In the far south, the more elevated shale landscapes have been eroded down to the underlying Hawkesbury Sandstone in a series of gullies and gorges. A transition zone between the shale and the sandstone is discernible in some areas.

On the dominant shale geology, the associated Critically Endangered Cumberland Plain Woodlands are still present in all of the four Growth Areas but have been disproportionately cleared for rural and later urban and allied uses. Much of what remains of this ecological community occurs as paddock trees and areas of remnant native ground-layer vegetation in pastoral and other contexts, with the exception of some substantial, though fragmented and isolated remnants. Remnant vegetation in these relatively fertile and arable landscapes is often in poor condition. In the most heavily cleared areas, it can be restricted to strips along watercourses. Some forms are dominated by *Casuarina* species. Weeds are common and sometimes severe in the moister situations. Weeds often extend into higher and drier terrain, especially in the form of African Olive and African Love Grass, both of which can occur on a landscape scale.

Small areas of the biodiverse Castlereagh Forests & Woodlands persist in all but the Wilton Growth Area on often-laterised Paleogene-Neogene alluvium. These variable woodlands and open forests support a particularly high number of threatened plant species, and because their soils are less suitable for agriculture and grazing, are better conserved than the Cumberland Plain Woodlands. Nonetheless, they are all listed as threatened ecological communities.

In the two southern Growth Areas, vegetation of the shale sandstone transition zone is relatively common and tends to remain in less arable areas adjoining the largely cleared former Cumberland Plain Woodlands. It is often found fringing the largely uncleared sandstone-based terrain, and ranges from highly intact to significantly modified and degraded, largely due to grazing and weed invasion. The associated Shale Sandstone Transition Forest is recognised as Critically Endangered due to extensive clearing across its substantial range, and because of the severity of other threats. Very little is present in formal conservation areas.

In the two southern Growth Areas, diverse, sandstone-based vegetation persists in association with most of the many incised watercourses. This vegetation is broadly the same as what occurs in extensive conservation estate around urban Sydney, but some communities adjoining current or former Shale Sandstone Transition Forest are not well-conserved and are threatened by further clearing and degradation.

3.2.1 Plant Community Types

The following section lists the Plant Community Types mapped in each Growth Area with brief notes about their distribution in those Areas. The list is not restricted to PCTs associated with *A. bynoeana*.

3.2.1.1 Greater Macarthur Growth Area (GMGA)

The predominant ecological communities in the GMGA are or were Cumberland Plain Woodland (CPW), Shale Sandstone Transition Forest (SSTF) and River-flat Eucalypt Forest (RFEF), all of which are Threatened Ecological Communities. All have been extensively cleared and degraded, primarily by agriculture and weed invasion, but also by urban and allied uses. There are no NPWS reserves in this Growth Area. However, the very small Leacock, Edmondson and William Howe Regional Parks occur just outside the border and are managed primarily for recreation rather than conservation. Dharawal State Conservation Area and National Park border the southern portion of the Growth Area to the east.

A summary of the mapped ecological communities is found in Table 5. The maps are based on OEH products that have been updated by Biosis for DPE.

Table 5. Summary of all ecological communities within the Greater Macarthur Growth Area

PCT	PCT Name	Distribution & notes
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Small patch at Menangle Sugarloaf on SE slopes.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Along creek lines in shale areas in northern and central parts of GMGA.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Small patches on shale soils throughout GMGA but mostly in northern and central parts.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches on shale soils throughout GMGA, more common in southern parts on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	4 polygons, Macquarie Fields, most of which have long been historically mown (Milton Park Softball Complex). They are now subject to regeneration.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	One small occurrence mapped around the margins of bushland associated with Smiths Creek at Leumeah.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Nepean River north from Menangle Bridge.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Narrow zone along Nepean & Georges Rivers and tributary gullies and a small zone along Smiths Creek at Leumeah.
1292	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Restricted to parts of the riparian zones of the more incised and larger watercourses. Very restricted extent in this Area.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Relatively small remnants extend from Glenfield into the far south where it is extensive on transitional soils mostly south from Rosemeadow. Can intergrade with 849 and 1081.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Only mapped to a very minor extent as highly linear remnants between Glenfield and Macquarie Fields (along the railway) and at Ingleburn (adjoining roads).

3.2.1.2 Wilton Growth Area (WGA)

The predominant ecological communities in the WGA are or were Cumberland Plain Woodland (CPW) and Shale Sandstone Transition Forest (SSTF) both of which are Threatened Ecological Communities. Sandstone-based communities occur in and surrounding the more incised watercourses. There are no NPWS reserves in this Growth Area, though Upper Nepean State Conservation Area occurs immediately to the south. There is a Biobanking site on the northern side of the river near Douglas Park (within the WGA), and three more such properties to the immediate north (including St Marys Towers) and those associated with coal mines (Steenbeeke, pers. comm.).

Table 6. Summary of all ecological communities within the Wilton Growth Area

PCT	PCT Name	Distribution & notes
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	On shale soils of higher, gently undulating terrain of northern and central areas. Small patches with scattered trees (farming properties) adjoining more extensive exotic and native grasslands.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	One patch in a derived grassland (treeless) condition in the west, and a much larger portion in the far north.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Limited to a few patches in the north between 1395 on plateau edges and 1181 in sandstone gullies.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Common on slopes and plateau edges above and around incised sandstone-based watercourses that surround most of the Area.
1292	Water Gum – Coachwood riparian scrub along sandstone streams	Restricted to a very narrow riparian strip along the Nepean River.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	The most extensive community on shale sandstone transition soils between 849/850 and sandstone communities along gullies. Variable floristics.

3.2.1.3 Greater Penrith to Eastern Creek Growth Area (GPECGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Shale Gravel Transition Forest and Castlereagh Forests & Woodlands. River-flat Eucalypt Forest was previously much more extensive along the Hawkesbury-Nepean River and adjoining primary floodplain, and it remains to varying degrees along many watercourses such as Eastern Creek, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. There is one NPWS reserve in this Growth Area: Wianamatta Regional Park, however it is already significantly fragmented and may be required to potentially accommodate a large transport corridor. The small Mulgoa Nature Reserve and associated Biobanking sites occur near the south-western border of this Growth Area. Yarramundi SCA occurs on the western boundary but across the Nepean River, and Wianamatta NR occurs near the NW corner.

Table 7. Summary of all ecological communities within the GPECGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Scattered as small remnants and one larger remnant in the central portion, but with greater extent in the central north, mainly in the western ungazetted portion of Wianamatta Regional Park.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	A few very small remnants present south of the M4, with larger remnants within and near the gazetted and ungazetted portions of Wianamatta Regional Park.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northwest, with some small remnants in the southwest, often associated with watercourses.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Present to a very minor extent on the southwestern edge adjoining Mulgoa Nature Reserve
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains through the south and central areas.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Common in and near Orchard Hills in the south, and former ADI lands in the central north, with some areas in the ungazetted portion of Wianamatta Regional Park. Other scattered remnants, particularly in the east.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches in the south west, primarily in pastoral settings and on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Restricted to one linear polygon in the eastern portion of Wianamatta Regional Park.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Hawkesbury-Nepean River, primarily near Penrith Lakes.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Present as mostly-linear remnants along South Creek and Eastern Creek and tributaries, with some scattered occurrences, including along the M4.

3.2.1.4 Western Sydney Aerotropolis Growth Area (WSAGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Castlereagh Forests & Woodlands near the localities of Kemps and Badgerys Creeks, and potentially in the vicinity of the water pipeline crossing of Luddenham Road. Riverflat Eucalypt Forest remains to varying degrees along most watercourses, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. Swamp Oak Forest occurs mainly along South Creek and some tributaries. There are currently no NPWS reserves in this Growth Area. The small Kemps Creek Nature Reserve occurs just outside the south-eastern corner and Gulguer Nature Reserve and Bents Basin State Conservation Area are near the south-western corner.

Table 8. Summary of all ecological communities within the WSAGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Restricted to the Kemps and Badgerys Creek area as three patches of remnants.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	As above: two patches with smaller remnants nearby and on slightly higher ground than 724.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northeast, with one remnant in the centre.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains but very little remains, and most occurrences are linear.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	The most common PCT in this Area, with remnants throughout on the dominant shale terrain.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Only very small patches in the far south.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain and Hunter valley	Present as mainly very linear remnants along most watercourses but largely absent from the southernmost portion.

4. Assessment of species' presence and suitable habitat

4.1 Existing records and surveys

The principal source of threatened flora records in NSW is the OEH BioNet database, which includes most records held by the NSW Herbarium (specimen-based), as well as sightings, including those associated with vegetation sampling for the purposes of mapping. Other databases, such as Atlas of Living Australia, largely mirror BioNet data within NSW, but are not used in this Report due to their having lower data quality control, and because they do not allow even a registered user to access data that may not have been generalised to obscure the exact location of a record. Very few flora records that are in ALA but not in BioNet are original – most are simply replicate records based on specimens held in other herbaria.

The preliminary assessment of threatened species records undertaken for the preparation of this Expert Report reiterated the merit of reviewing BioNet data and resolving a range of errors, rather than simply using data 'as held'. *Acacia bynoeana* records within BioNet were reviewed, and numerous corrections were made, though the majority of these relate to the assigned spatial accuracy scores and to clarifying or correcting location placements and descriptions. Not all records were able to be checked in that stage, and a second review for records in or near the Growth Areas was conducted to further improve data quality. The reviews eliminated a range of errors and allowed many records that were otherwise too spatially vague, to be refined such that they were suitable for habitat modelling and for general reference. Not all records were reviewed, and inaccuracies remain in the dataset, but records within the Cumberland Subregion are now far more accurate in terms of their identification of the species, their location, and their spatial accuracy score.

BioNet data should only be treated as indicative, not least because there has not been comprehensive survey of all of the Growth Areas or environs, and surveys have been variously constrained. The absence of records from an area does not necessarily mean the species is absent, as it may not have been surveyed there, or survey conditions and methods may have been inadequate.

Field survey undertaken by consultancy firms engaged by DPE (Biosis and Ecoplanning) did not add any records of this species. Fellow botanist, Robert Miller and I undertook very limited survey in the Kemps Creek locality. No new records of the species were generated.

4.1.1 Existing records by Growth Area

Acacia bynoeana records in Greater Macarthur Growth Area

There are no records of the species from the GMGA, but numerous records just outside its boundaries to the northeast (Moorebank), east (Wedderburn and Appin), and south (between Appin and Cataract).

Prior to the BioNet data cleansing process, a record of the species from 2006 plotted in Appin township, however that record was investigated and seen to have been collected from 'East of Appin'. It has since been moved to co-ordinates consistent with that location, east of the river, just outside the GMGA. There are over 50 records of the species in that wider area within 8km north, east and south of Appin.

Acacia bynoeana records in Wilton Growth Area

The species has been recorded in 2015 within the WGA (20 records in one population detected as part of survey for the Bingara Gorge urban development northeast of Wilton village). The nearest record outside the WGA is ~5km ESE and is part of a group of records south of Appin within the Water NSW water catchment area. Two records occur ~14 km SSW and SW of the Bingara Gorge population. One is within Upper Nepean SCA, the other plots west of Bargo on what is likely vacant Crown land.

Acacia bynoeana records in Greater Penrith to Eastern Creek Growth Area

There are no records of the species in the GPECGA, and the nearest occur between 1 and 2 km north of the northern GA boundary. Of these, the only records that are considered spatially reliable are those in the northern section of Wianamatta Nature Reserve near Cranebrook Road. Those to the east of the Nature Reserve (e.g. Rodd, 1967, RBG Collection, 'Llandilo' – plots in two arbitrary locations in rural areas (second record is Atlas duplicate); and Chamberlain & de Lacey, 1999 'Cherrywood in Llandilo') lack sufficient detail to determine where they were collected. The 'Cherrywood' reference likely relates to Cherrywood Oval or Cherrywood Bicentennial Park (apparently now Wianamatta NR), however the vegetation mapped by OEH near the oval or in much of the NR doesn't match that described by the Collectors. The 'Cherrywood' record has been moved to the edge of the NR, which is close to the Oval. A collection in the area by Hind in 1987 gives a road intersection reference that allows for adequate spatial accuracy. When reviewed, it plotted incorrectly but was able to be moved to match the location description, placing it ~2.6 km north of the GPECGA northern boundary.

If the species were present in the GPECGA, it would likely be found in remnant Castlereagh Forest & Woodland communities. These occur mainly north of the Growth Area through Llandilo, Londonderry to Windsor Downs, with some present just inside this Area at Ropes Crossing, Wilmot and Lethbridge Park (mostly within Wianamatta Regional Park).

Acacia bynoeana records in Western Sydney Aerotropolis Growth Area

There are no records of the species in the WSAGA, nor within several kilometres of its boundaries. This is unsurprising given the very limited area of historic and current potential habitat in this Area. Additionally, much of the potential habitat is apparently long-unburnt, which likely disfavours the detection of this species.

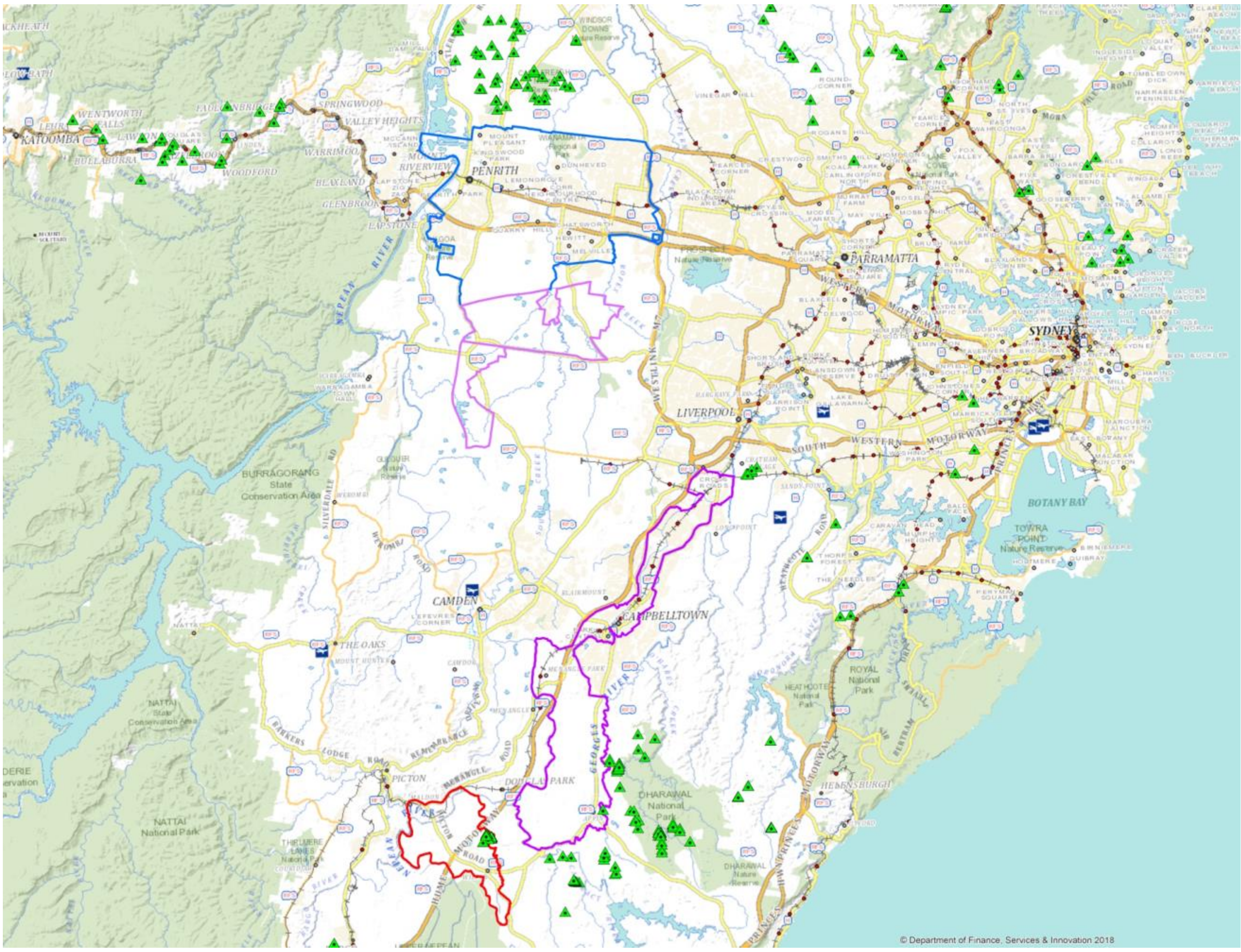
If the species is present in this Growth Area, it is likely to occur in remnant Castlereagh Forest & Woodland communities in the localities of Kemps Creek and Badgerys Creek. The only potential habitat in this Growth Area is ranked as having a Very Low association with *A. bynoeana*.

4.1.2 Prior surveys within each Growth Area

There is no central or local registry of surveys and survey effort for threatened biota, and a large proportion of survey reports are not made public or only made public when lodged with a planning consent authority. This makes it extremely difficult, if not impossible to compile a list of surveys, methods and findings across the study area.

The OEH Authorised Officer for *A. bynoeana* was contacted in this regard. He advised that he does not hold this information and he referred me to the manager of threatened biota matters in the Greater Sydney OEH office. No additional information was provided other than to note that a recent survey of State-owned land outside but near the GPECGA had contributed new threatened flora records to BioNet. No new records of *A. bynoeana* were apparent in that dataset.

I separately became aware of some earlier surveys of threatened flora that OEH had commissioned for areas of NPWS estate near the GPECGA. With approval from the NPWS, the lead ecologist who undertook those surveys provided information about his work, none of which entailed targeted searches for *A. bynoeana*, though incidental records were confirmed to have been lodged in BioNet.



Map 3. BioNet records (cleaned as of 26/11/18) relative to Growth Areas

NB each point may not designate a collection or observation at that location, as most very old records lacked any co-ordinates, or only supplied coarse co-ordinates, and may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

4.2 Summary of survey work undertaken for the biocertification assessment

4.2.1 Vegetation mapping

Vegetation mapping of the Cumberland Subregion was completed in stages by OEH in 2013 and 2016. These two vegetation layers have been used as the base to compile an updated vegetation community layer for each of the Growth Areas. This updated work has been completed by Biosis under contract to DPE. The mapping update includes checking plant community types and confirming the accuracy of boundaries to account for clearing or regrowth that may have occurred since the original mapping was completed. Field verification of the mapping was undertaken by Biosis and Ecoplanning, both of whom undertook vegetation surveys where access was permitted.

Vegetation in the Growth Areas was mapped and assessed based on five vegetation condition classes:

- Intact;
- Non-offsettable Grassland;
- Offsettable Grassland;
- Scattered Trees;
- Thinned.

4.2.2 Field survey effort

The information in section 4.2.2 has been provided by DPE but has been edited here to only deal with threatened flora where feasible. Further details are provided separately by DPE:

An initial 726 letters were sent to landholders within the Wilton and Greater Macarthur Growth Areas in late 2017 with a second letter following in March 2018. To increase the response rate, Biosis commenced targeted door-knocking in May 2018. From this, just under 20% of landholders within these Growth Areas allowed access to their property. However, this included access to large parcels of land owned by major developers, which allowed a reasonable amount of access, particularly for the Wilton Growth Area.

Floristic plot data collected:

- Wilton (86 plots across 6 PCTs)
- Greater Macarthur (82 plots across 9 PCTs)

Approximately 150 of the plots required to meet BAM requirements were obtained by supplementing Biometric plots from various recent assessments. This involved locating the previous plots and collecting additional data on stem classes, number of large trees, and litter cover to meet BAM requirements. The ecologists had no trouble locating the original survey sites and found that the additional data was quick and easy to collect (approximately 30 minutes per site).

The remaining plots in Wilton and Greater Macarthur, and all of the plots in Western Sydney Aerotropolis and Greater Penrith to Eastern Creek consisted of new plots surveyed for this project. All plots were sampled according to the methods prescribed by the BAM Manual (OEH 2017). This includes collecting information on species cover and abundance from 20 x 20 m or equivalent configuration plots within each vegetation zone.

A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Growth Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council.

Floristic plot data collected:

- Western Sydney Aerotropolis (53 plots across 6 PCTs)
- Greater Penrith to Eastern Creek (26 plots across 7 PCTs)

Targeted survey for threatened species

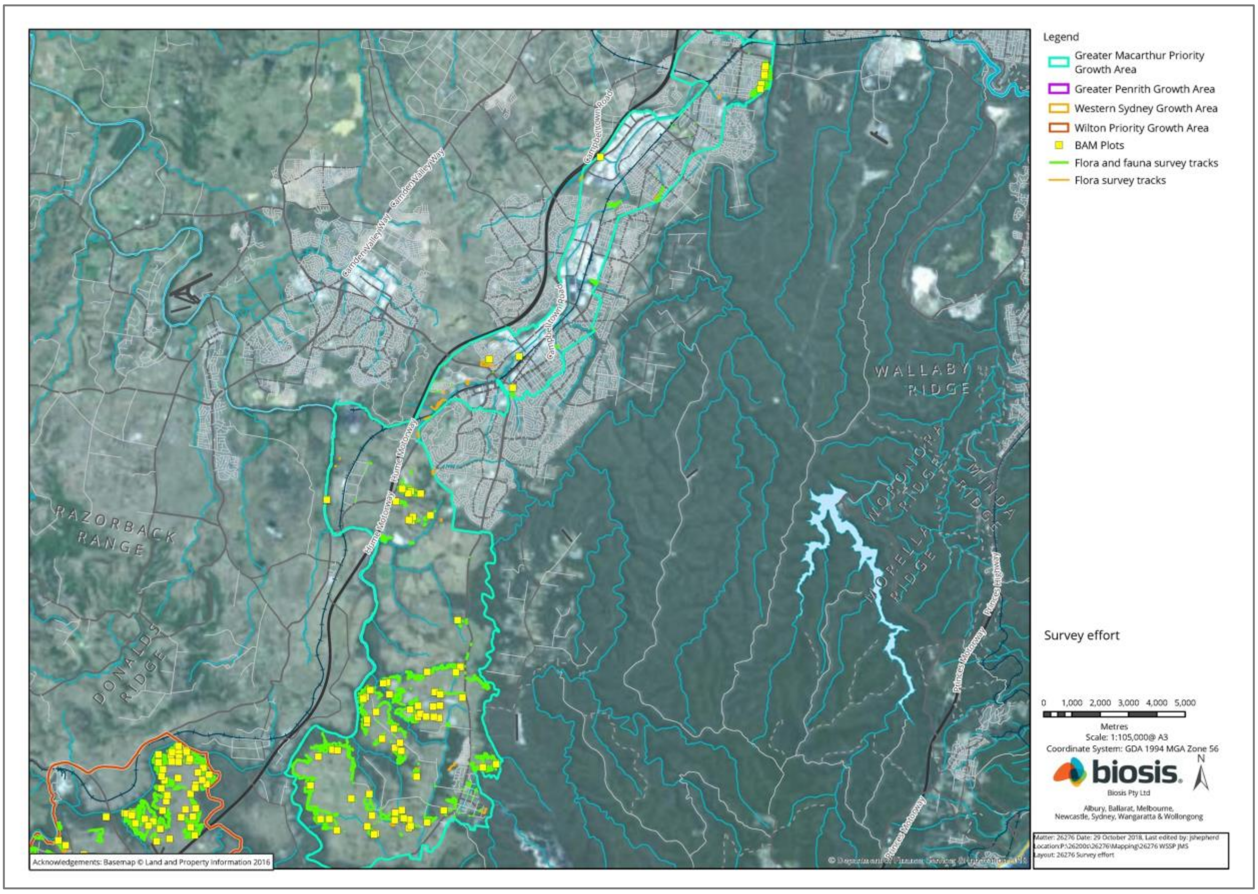
Targeted survey for threatened plant species has been conducted on lands where access has been granted. Vegetation transects and random meanders for threatened flora was conducted by Ecoplanning and Biosis in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey has included effort through each PCT and vegetation zone and has extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m).

Likely habitat for most threatened flora species comprised areas of lower disturbance. This includes areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora.

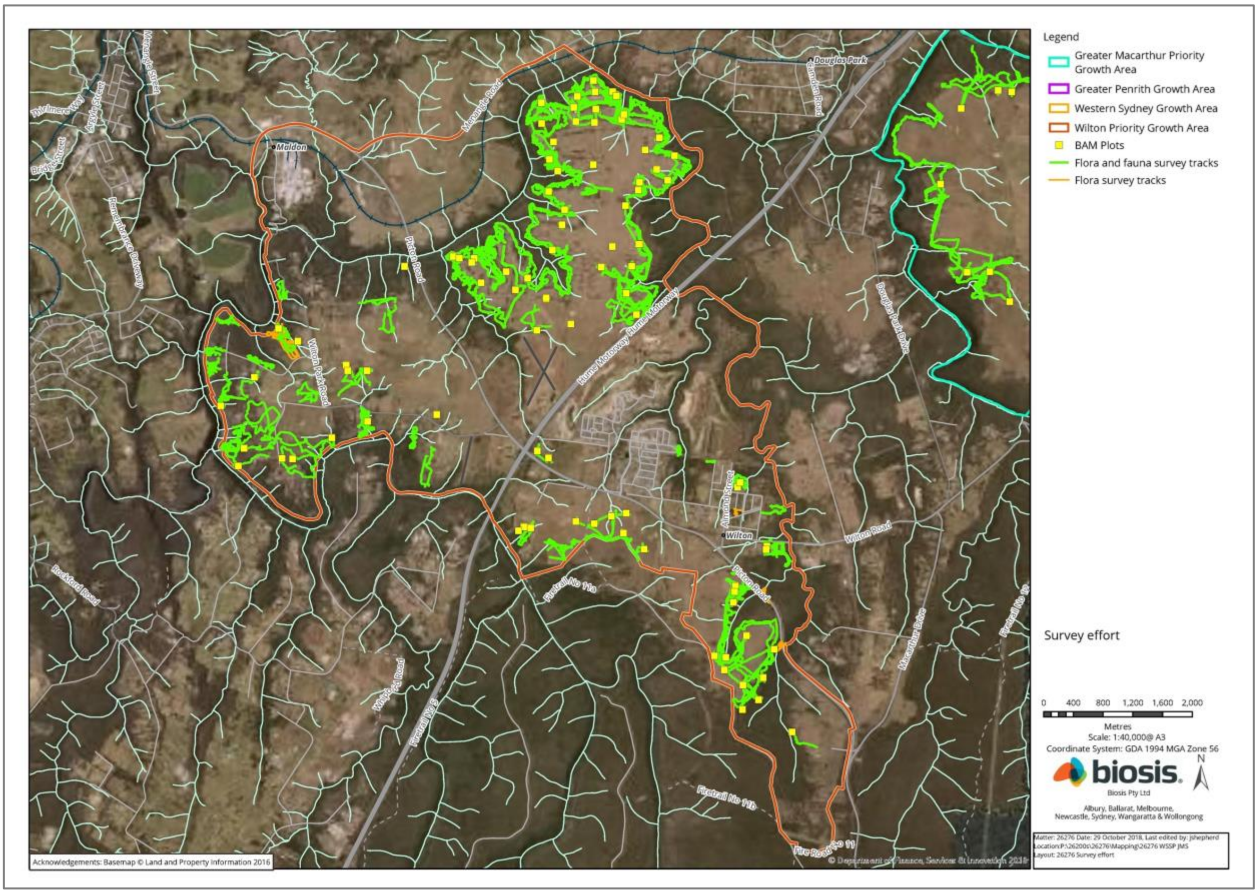
Table 9. Survey effort for threatened plant species *and* fauna habitat by PCT

PCT No.	Area of PCT in Growth Area (ha)	Area of PCT in urban zone (ha)	Field survey area (ha)	Percent of PCT surveyed within Growth Area (%)	Percent of PCT surveyed relative to urban zone (%)
724	191.3	57.0	12.1	6.3%	21.2%
725	167.4	51.4	6.9	4.1%	13.4%
781	68.9	5.6	0.9	1.4%	16.8%
830	21.6	0.8	1.7	7.8%	206.5%
835	1175.8	287.3	30.5	2.6%	10.6%
849	3078.3	637.6	125.0	4.1%	19.6%
850	522.9	294.3	36.1	6.9%	12.3%
883	7.4	0.0	0.5	6.8%	
1081	74.2	0.0	0.2	0.3%	
1105	138.6	0.0	0.0	0.0%	
1181	780.7	0.2	39.6	5.1%	19794.4%
1292	39.8	0.0	0.3	0.7%	
1395	3326.6	486.9	483.4	14.5%	99.3%
1800	232.6	20.2	7.3	3.1%	36.2%
TOTAL	**9826.1**	**1841.3**	**744.5**	**7.6%**	**40.4%**

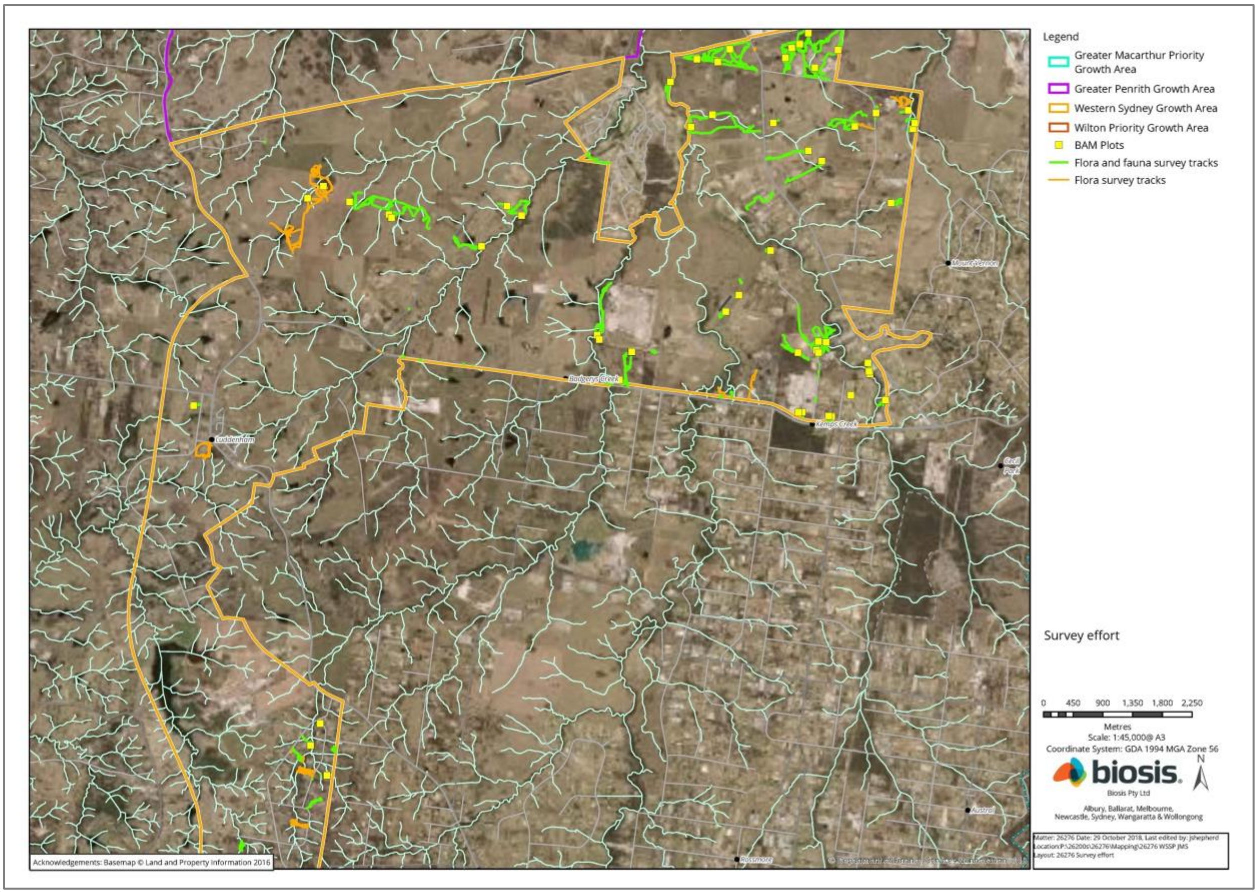
Field survey effort was not confined to the urban zone. Surveys occurred into nearby vegetation zoned for conservation. The urban zone has been revised over time and some areas where survey had already occurred were later removed. For these reasons, comparison of the survey area to the urban zone is indicative only. Survey effort has been calculated using a 20-metre buffer either side of GPS survey tracks. For the purposes of this analysis, the urban zone includes land zoned for future urban development plus transport corridors within the growth areas. It does not include any transport corridors outside the growth areas.



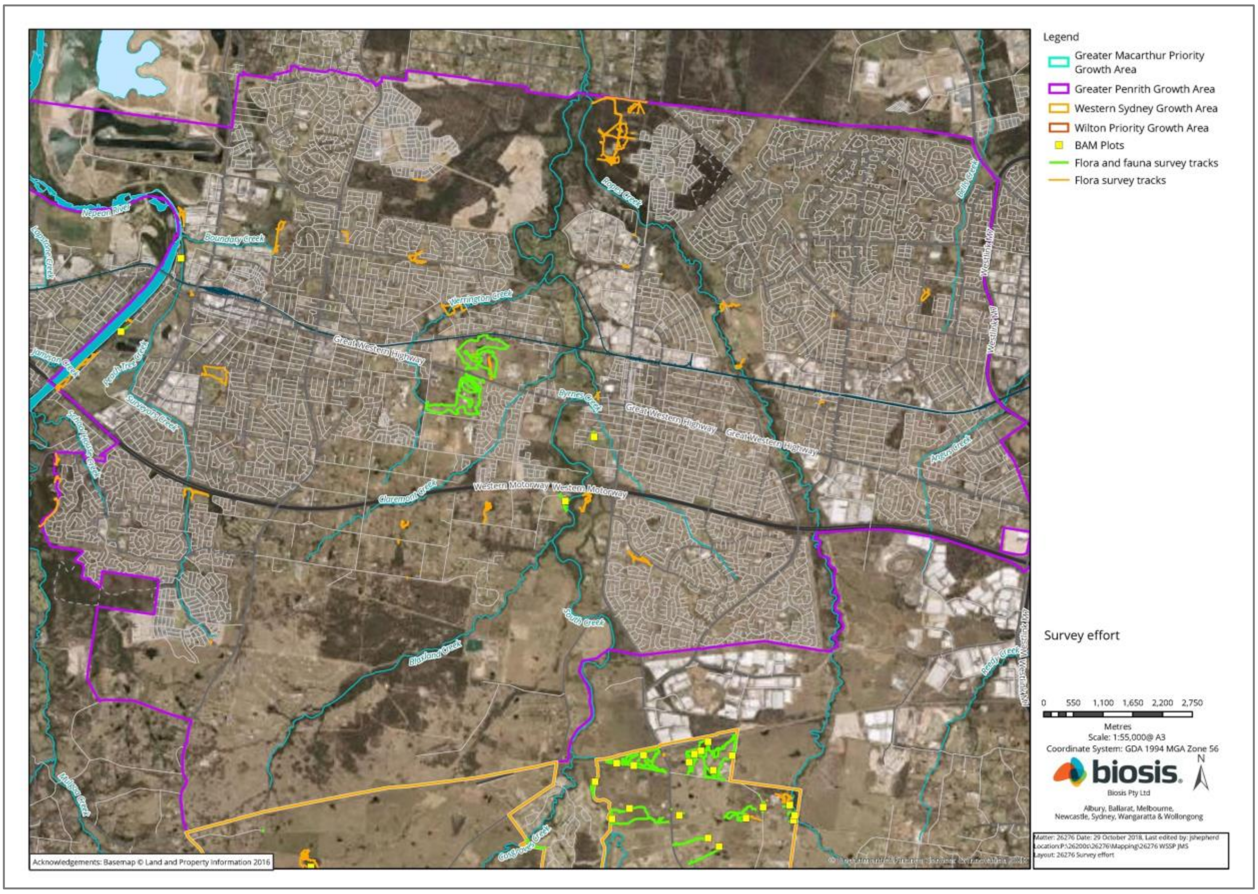
Map 4. GMGA survey effort (Biosis & Ecoplanning)



Map 5. WGA survey effort (Biosis and Ecoplanning)



Map 6. WSAGA survey effort (Biosis and Ecoplanning)



Map 7. GPECGA survey effort (Biosis and Ecoplanning)

4.2.3 Survey constraints –timing / site conditions

As noted earlier, severe drought affected all of the study areas for some or all of the survey period. The Wilton and Greater Macarthur GAs were only surveyed during drought, whereas the Greater Penrith & Eastern Creek and the Aerotropolis GAs were surveyed both during intense drought and the subsequently slightly wetter conditions that followed in the Spring of 2018. Whilst wetter, drought remained present, and fellow Expert, Robert Miller, reported that vegetation was evidently drought-affected across all of the Growth Areas into November.

Drought, combined with increased intensity and extent of total grazing pressure, meant that affected surveys are likely to have under-recorded the target species compared to normal conditions. Whilst drought alone is unlikely to cause *A. bynoeana* to die back to rootstock or die and only remain as seedbank, when combined with increased herbivory due to drought, this is a far more likely outcome.

Irrespective of drought, surveys for this species are constrained by consideration of fire ecology, in that this species can be suppressed and even rendered apparently extinct at a site if the area has not been burnt for many years. Prolonged absence of fire is a constraint in some of the surveyed areas. Conversely, the species could be undetectable or not readily distinguished and identified in areas burnt recently. Areas burnt too often may also see the species suppressed or even eliminated. This is a factor in some of the survey sites closer to urban areas where a mix of hazard reduction burning and arson occur.

4.2.4 Survey constraint – surveys undertaken by generalists / non-experts

A. bynoeana is regarded as a cryptic species (OEH, 2014) and even when adult, it can occur as a very small plant with dull-coloured leaves such that it is easily missed, even by expert observers. It is more likely to be present but not recorded when surveyed by personnel not very familiar with the species and its ecology, particularly in terms of micro-habitat features.

Even when the prescribed OEH survey methods are used, a combination of site-based constraints, the species' sometime-cryptic nature, and a lack of familiarity with this species creates a situation where the species may be present but was not recorded. This is supported in part by the observations of Driscoll (cited in OEH, 2014) who noted that irrespective of issues arising from clonality, the population size and local extent of this species is often under-estimated by observers for a range of explicable reasons. I am aware of a repeatedly surveyed site involving effort by different consultancy firms over at least 10 years, yet none managed to record all occurrences of this species.

4.3 Surveys completed specifically for this Report

I was provided with the opportunity to undertake limited surveys in the Wilton and Greater Macarthur Growth Areas but elected not to on the basis that severe drought undermined the value of any survey in determining if the species was absent from any area. This decision was later validated by feedback from fellow botanist, Robert Miller, in relation to his not being able to detect *A. bynoeana* under those conditions at a site where he had previously recorded it, even though the habitat was intact.

I undertook surveys of potential habitat for *A. bynoeana*, *A. pubescens* and *Persoonia nutans* in the localities of Kemps Creek and Badgerys Creek in early November 2018. There were no records of the species in those areas, and only relatively small and sometimes significantly altered areas of very low probability potential habitat remain within the Growth Area, and not all were accessible for a range of reasons. Some other threatened plant species with which *A. bynoeana* is sometimes known to occur are present in this area.

I was accompanied by Robert Miller during my brief survey, and whilst we detected other threatened plant species, we did not detect any new records of *A. bynoeana*. We concluded that potential habitat is present on the surveyed site and on adjoining, more heavily vegetated land to the south. Both areas are now excluded from the proposed urban footprint / biocertified land.

The map below shows the transects associated with a brief survey within the WSAGA (northern line largely within a s.88b conservation area) and outside the WSAGA (short southern line).

Map 8. GPS track logs (purple lines)

4.4 Assessment of species' presence

4.4.1 Greater Macarthur Growth Area

The species is not known to be present in this Growth Area but is considered likely to occur in the southern portion. It is unlikely to occur within the majority of the proposed urban footprint because that area was never suitable habitat or has been too heavily modified.

The northern half of the GMGA is not likely to support the species based on the extent of land clearing and/or the absence of suitable habitat parameters such as plant communities and soil types. Were the species found in the highly urbanised northern GMGA, it is likely that unless on public land able to be managed for conservation, any such occurrence may not be viable in terms of size, area of habitat, threats including fragmentation / isolation of habitat, and ability to maintain ecological processes.

In contrast, the southern half of the GMGA contains significant areas of potential habitat as determined by the presence of associated PCTs. This habitat mainly occurs around the upper slopes and ridges associated with gullies and valleys of incised watercourses, and some other remnants that appear to have escaped clearing and grazing due to their relative infertility or other constraints. Some potential habitat is present within and on some edges of the biocertification area (urban footprint). However, potential habitat within the proposed urban footprint is likely to be of lower condition and less viable due to historic and current land uses.

4.2.2 Wilton Growth Area

The species is known to be present in this Growth Area, though only on a site outside the proposed urban footprint, within a separately approved urban release area. A significant area of similar habitat occurs largely outside but occasionally on the margins of or adjoining the proposed urban footprint. However, surveys of some nearby sites supporting apparently suitable habitat by the same personnel who found the documented population did not detect any further occurrences. This may be a result of the areas having different disturbance histories, particularly in terms of grazing and fire. This situation does not preclude the species being present in those sites, as it may be restricted to the seed bank or to rootstock.

The species is unlikely to occur within the majority of the proposed urban footprint as it was never suitable habitat or has been too heavily modified. Potential habitat within the proposed urban footprint is likely to be of lower condition and less viable due to historic and current land uses.

4.2.3 Greater Penrith to Eastern Creek Growth Area

The species is not known to be present in this Growth Area, but a relatively small area of potential habitat is present within the proposed urban footprint, including within Wianamatta Regional Park, which appears to be proposed for further clearing and fragmentation to accommodate a large transport corridor. Areas of potential habitat are limited to the far central north of the Growth Area. On the Cumberland Plain, this species primarily occurs north of the GPECGA in the Castlereagh / Londonderry area.

4.2.4 Western Sydney Aerotropolis Growth Area

The species is not known to be present in this Growth Area, and most mappable areas of potential habitat are outside the proposed urban footprint. There is very little direct conflict between proposed urbanisation and potential habitat for the species in this area. The extent of potential habitat is limited to a few patches of remnant vegetation between the localities of Kemps Creek and Badgerys Creek. There are no nearby records. Most of the WSAGA was always unsuitable habitat for this species based on geology, soil and plant community associations.

4.5 Assessment of suitable habitat for *Acacia bynoeana*

4.5.1 Description and relative significance of potential habitat

As per the findings presented earlier in Table 4, combined with expert knowledge, the following vegetation communities are regarded as potential habitat for *A. bynoeana* where they occur across any of the Growth Areas. However, not all parts of these communities are likely to support the species. Wetter and sometimes more thickly vegetated areas associated with drainage lines are unlikely habitat, as this species prefers drier, more open conditions. This limitation is addressed later through the specification of riparian exclusion buffers.

Table 9. PCTs known or likely to be habitat for *A. bynoeana*

PCT	PCT Name	Relative significance
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	**Very Low**
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	High
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Very High
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney	Low
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate

The following sections describe the relative habitat value and local occurrences of each PCT mapped in each Growth Area.

<u>Greater Macarthur Growth Area</u>

The vegetation mapping provided for use in the project indicates that there is **1614.1 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs. However, significant portions of some components are of lesser habitat significance due to persistent disturbance, particularly intensive pastoralism (sewing of introduced pasture species, addition of fertiliser, commercial stocking rates), and are less likely to retain this species in any form. However, *Acacia* seeds can remain viable for ~100 years, so even in highly modified sites with persistent suppressive factors such as grazing, the species could regenerate from seed were those factors to cease or be adequately reduced in intensity and duration.

Table 10. Potential habitat in the GMGA

PCT	Distribution	Relative habitat value of local occurrences
883	Four very small polygons at Macquarie Fields	Very low at this site due to historical land use. The species may regenerate if issues of mowing, absence of fire, and intense weed invasion are remedied. Any resultant population would be isolated from core habitat and surrounded by unsympathetic land uses.
1081	Restricted to one remnant surrounding an incised watercourse in urban bushland.	Moderate to high but this community is of relatively limited extent in this GA
1181	Common only on the edges of and within sandstone gullies and gorges but very limited extent; from Gilead south, mainly on GA boundaries, with a small outlier at Leumeah	Low potentially extending to Moderate depending on sandstone influence – high sandstone and no shale influence is of lower habitat value. Not suitable habitat close to watercourses.
1395	Common in the far south from around Menangle Park through Gilead to Appin area; between cleared shale landscapes and the upper margins of sandstone gullies	Moderate to high depending on shale content – high shale content is of lower habitat value. Unlikely habitat when near watercourses

<u>Wilton Growth Area</u>

1380.8 ha of potential habitat is identified in the WGA, with several recent records within one population mapped as part of the Bingara Gorge housing project. Similar habitat extends along the upper slopes of many remnant vegetation areas associated with larger watercourses.

Table 11. Potential habitat in the WGA

PCT	Distribution	Relative habitat value of local occurrences
1081	Uncommon and restricted to three substantial patches above sandstone gorges, mainly on or near edges of WGA.	Moderate to high but this community is of relatively limited extent in this GA
1181	Common within sandstone gullies and gorges, mainly on or near WGA boundaries.	Low to moderate depending on sandstone influence – high sandstone and no shale influence is of lower habitat value. Not suitable habitat close to watercourses.
1395	Common in the far south from around Menangle Park through Gilead to Appin area; between cleared shale landscapes and the upper margins of sandstone gullies	Moderate to high depending on shale content – high shale content is of lower habitat value. Unlikely habitat when near watercourses

Greater Penrith to Eastern Creek Growth Area

There was always very limited scope for the species to occur in this Area, and much less so as a result of historic and on-going land clearing. However, **132.9 ha** of potential habitat is identified

Table 12. Potential habitat in the GPECGA

PCT	Distribution	Relative habitat value of local occurrences
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	This PCT occurs primarily in the far central north and is mostly within reserve. Very Low ranking but may be present depending on the disturbance history of the habitat.
883	Only in far north, and of very minor extent	High – strong association with this PCT but no records from this area at present, though proximate records are present to the north and northwest.

Western Sydney Aerotropolis Growth Area

Only a relatively small area of habitat existed in this Area, and even less remains due to historic and on-going land clearing. What little remains is known or likely to be associated with other threatened plant species. There are currently no records of *A. bynoeana* in this area. **39.8 h**a of potential habitat is identified.

Table 13. Potential habitat in the WSAGA

PCT	Distribution	Relative habitat value of local occurrences
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Very Low ranking but may be present depending on the disturbance history of the habitat. Restricted to Kemps Ck and Badgerys Ck localities as relatively small remnants – apparently long-unburnt.

4.5.2 Species habitat polygons

Species habitat polygons generated by this report relate to the extent of potential habitat and the area and percentage that is proposed to be cleared for urbanisation or transport corridors (Maps 9-11). These habitat polygons and associated calculations were generated to inform biodiversity offset requirements. The data presented in this section does not deal with species habitat outside proposed urban and allied zones as those areas are treated as conservation zones or are excluded from urban and associated transport zones for a range of reasons.

The species habitat polygons include all relevant condition classes of relevant PCTs as identified in this Report. In this case, all condition classes are included.

As part of the formulation of the species habitat polygons, graded riparian exclusion buffers were used in recognition that *A. bynoeana* does not occur in riparian vegetation. Buffers are relatively large for this species as it does not occur in riverflat/creekflat situations. The buffer distances increase with the mapped Strahler stream order as shown in Table 14. The accuracy of the buffers is limited by available data, including the mapped location of streams. The buffer is applied either side of the mapped stream centreline. Note that these riparian buffer distances are a different concept and serve a different purpose to those applied by DPE for the purposes of protecting streamside vegetation and watercourses in its planning within the Growth Areas.

Table 14. Buffer distance applied to stream orders

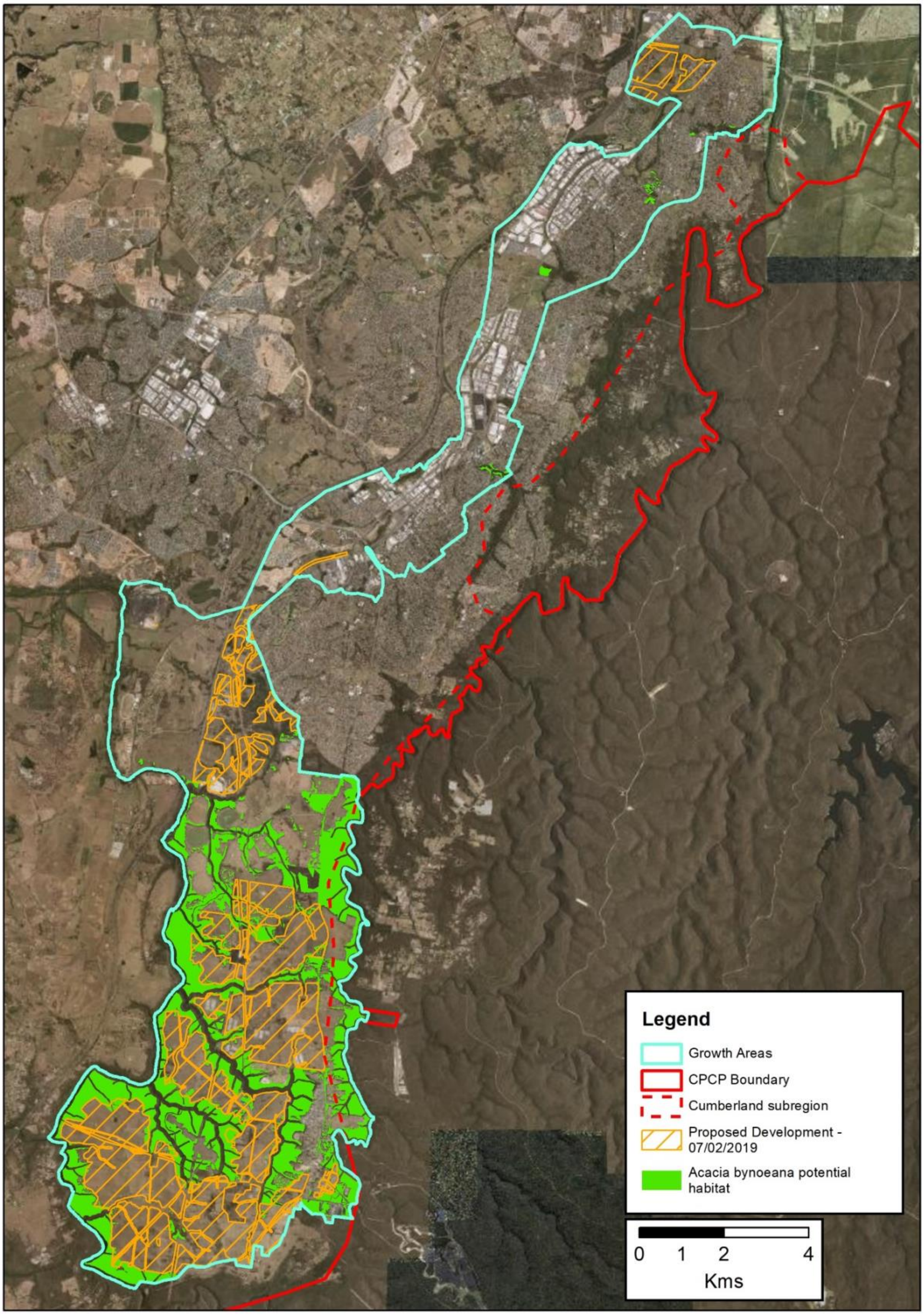
Stream order	Buffer distance (m)
1	20
2	30
3	40
4	60
5	70
6	80
7	90

Table 15. Potential habitat and proposed removal of potential habitat by Growth Area

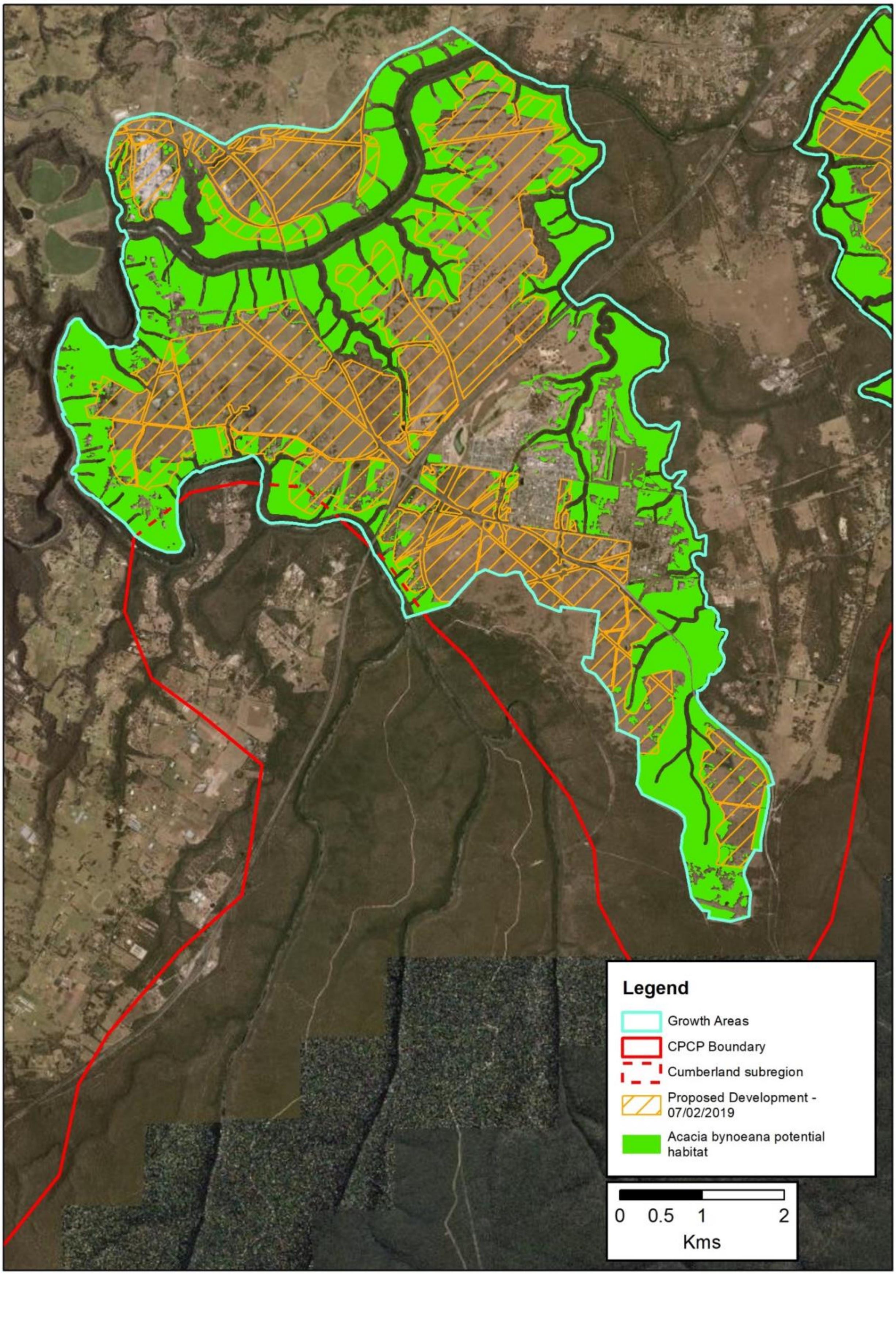
Growth Area	Area of potential habitat (ha)	Area of potential habitat removal (ha)	% area of potential habitat removal by GA
Greater Penrith to Eastern Creek	132.9	3.8	2.9
Western Sydney Aerotropolis	39.8	11.8	29.6
Greater Macarthur	1614.1	126.5	7.8
Wilton	1380.8	300.8	21.8
Transport corridors **(all GAs)**	-	20.7	0.7
TOTAL	**3167.6**	**463.7**	**14.6**

These figures are based on precautionarily modelled *potential* habitat, and do not necessarily equate with *actual* habitat, nor do they provide any information of potential population sizes or population viability. It is unlikely that a large percentage of the potential habitat identified in this Report would actually support *A. bynoeana* because this species is naturally rare and patchily distributed, even though it can sometimes be locally abundant in favourable conditions.

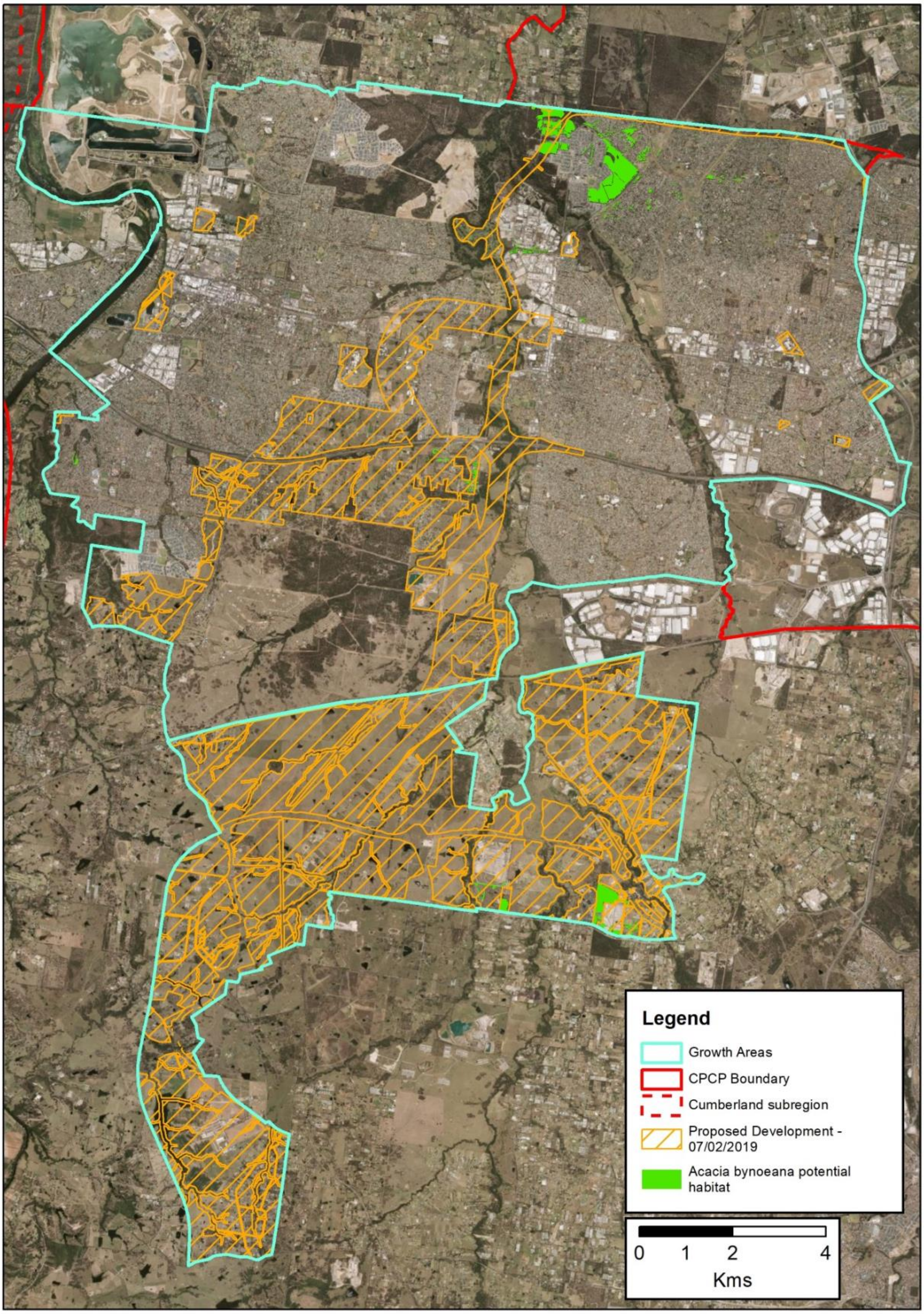
Map 9 Greater Macarthur - Potential habitat and proposed urban/transport habitat removal



Map 10 Wilton - Potential habitat and proposed urban/transport habitat removal



Map 11 Greater Penrith & Eastern Creek plus Western Sydney Aerotropolis
– potential habitat and proposed urban/transport habitat removal



5. Summary and conclusion

Within the four Growth Areas, *Acacia bynoeana* is currently only known from the Wilton GA. However, potential habitat for this species exists in all four Growth Areas, based on the species' known association with specified Plant Community Types, with other threatened plant species, and with abiotic factors. In the southern Growth Areas, it is most likely to occur in habitat associated with the shale sandstone transition, the Mittagong Formation, and upper Hawkesbury Group on plateaux margins and upper slopes. In the northern Growth Areas, it is likely to occur only in relatively small remnants of a particular subset of Paleogene-Neogene alluvium associated with the Castlereagh Forests & Woodlands.

Based on current information, the proposed urban footprint and associated transport corridors of all four Growth Areas would destroy 463.7 hectares of potential habitat for *A. bynoeana*. This equates to 14.6% of the area of potential habitat identified in those Growth Areas. Not all of the area proposed for removal is of equal value as potential habitat, and different PCTs and condition classes have different probabilities of supporting *A. bynoeana*. The actual extent of conflict between habitat for the species and proposed clearing for urbanisation is likely to be much smaller as the species is naturally rare and patchily distributed.

In the Greater Penrith to Eastern Creek Growth Area, the greatest direct conflict between proposed urbanisation and potential habitat for this species is a proposed transport corridor through the western (apparently ungazetted) portion of Wianamatta Regional Park. Most of this Growth Area is and always was unsuitable habitat for this species for geological reasons, and only relatively small areas remain in the central far north in and near the Regional Park.

In the Greater Macarthur, Western Sydney Aerotropolis, and Wilton Growth Areas, the majority of potential habitat for this species is outside the proposed urban footprint. However, because this species is relatively tolerant of some quite intense types of disturbance, and that it can persist for many decades in the soil seedbank, as well as surviving for some time as rootstock, it may occur in habitat that might otherwise be disregarded and even not mapped as native vegetation. It is likely that highly modified sites that might support the species in some form are of relatively low significance for it in the context of the much larger areas of more intact potential habitat that are excluded from proposed urbanisation. It is also feasible that disturbance associated with urbanisation, particularly the creation of bushfire Asset Protection Zones between bushland conservation areas and housing, could advantage this species, especially where the habitat has not burnt for many years. Thinning of the shrub layer by fire or mechanical means could favour the species, as may soil disturbance associated with fire trail construction. More frequent, moderate intensity burning of bushland that represents known or likely habitat for this species, may, within limits, also advantage it compared to low frequency and/or very cool burning.

The positioning of the bushland/urban interface and associated infrastructure such as APZs should have regard to this species' habitat and ecology, and appropriate buffers and other strategies are required to prevent direct and indirect harm to this species as a result of the urbanisation of adjoining lands. For example, potential habitat should not be compromised by the placement of housing nearby as this might prevent that habitat being managed for conservation, especially in terms of bushfire risk management. DPE has informed me that APZs would be accommodated within the proposed urban footprint, not in the adjoining non-biocertified bushland.

The absence of records from areas of potential habitat does not mean it could not be present because:

- not all areas have been surveyed historically or recently;
- all surveys have a range of limitations, and recent efforts were particularly constrained by drought;
- not all discoveries of threatened species are disclosed;
- large areas of potential habitat are highly likely to have fire regimes that do not favour this species, meaning it may currently occur in very low numbers or as seedbank, yet could appear in substantial numbers after an appropriate fire or equivalent disturbance; and
- this species can persist in cryptic forms such that even thorough coverage of a site cannot rule out its presence if otherwise suitable habitat is present.

These factors have been considered in the preparation of the species habitat polygons that will inform DPE in relation to biodiversity offset obligations.

6. Information used in the assessment

6.1 DPE or OEH resources

- BioNet data (internal access provided under license for use in this Expert Report and associated dataset cleaning for the purposes of species habitat modelling to meet EPBC Act requirements)
- Atlas of Living Australia on-line (partial use to check for records not in BioNet)
- EMU data (NSW Herbarium specimen database, provided by OEH)
- OEH on-line threatened species profile
- OEH Threatened Species Data Collection on-line
- OEH BioNet Vegetation Classification Database (previously known as VIS)
- EPBC Act Listing/Conservation Advice
- OEH PCT (vegetation) maps for Sydney Metropolitan and Cumberland Plain
- Field data from Biosis and Ecoplanning consultancies engaged by DPE
- GIS layers and maps provided by DPE and its contractors

6.2 References

Bell, S.A.J. 2008. 'Rare or threatened vascular plant species of Wollemi National Park, central eastern New South Wales'. *Cunninghamia* 10(3): 331–371. https://www.rbgsyd.nsw.gov.au/getattachment/Science/Scientific-publications/Cunninghamia/Cunninghamia-10-3-331-Bell-331.pdf.aspx?lang=en-AU

Bell, S.A.J. and Driscoll, C. 2002. *Population size and habitat of the endangered Acacia bynoeana Benth (Fabaceae: Mimosoideae) in Lake Macquarie SRA*. Unpublished report to NSW NPWS, Hunter Coast Region. EastCoast Flora Survey, Kotara Fair.

Benson, D. & McDougall, L. 1996. 'Ecology of Sydney plant species Part 4: Dicotyledon family *Fabaceae'*. *Cunninghamia*. 4(4):553-756. Royal Botanic Gardens, Sydney.

Bernhardt, P., 1987. 'A comparison of the diversity, density and foraging behaviour of bees and wasps on Australian Acacia'. *Annals of the Missouri Botanical Gardens* 74: 42–50.

Cowan, R.S. 2018. Acacia bynoeana. In: A.E. Orchard (February 2018), P.G. Kodela (February 2018) (ed.) Flora of Australia. Australian Biological Resources Study, Department of the Environment and Energy, Canberra. https://profiles.ala.org.au/opus/foa/profile/Acacia%20bynoeana [Date Accessed: 01 November 2018]

Cumberland Ecology, 2011. *Heathcote Ridge, West Menai – State Significant Site: Ecological assessment*. Cumberland Ecology, Carlingford Court. https://majorprojects.affinitylive.com/public/fac9361572a52306e5e4fcbcc438f799/Appendix%209%20-%20Ecological%20Asst%208059RP2.pdf [Date Accessed: 01 November 2018]

Department of Environment & Energy (Commonwealth), 2008 (August 22). *Species Profile and Threats Database: Acacia bynoeana – Bynoe's Wattle, Tiny Wattle*. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=8575 [Date Accessed: 01 November 2018]

Department of Environment & Energy (Commonwealth), 2013. *Approved Conservation Advice for Acacia bynoeana (Bynoe's Wattle)*. http://www.environment.gov.au/biodiversity/threatened/species/pubs/8575-conservation-advice.pdf [Date Accessed: 01 November 2018]

Driscoll, C., 2006. *Acacia bynoeana: a review of species information*. Unpublished Report prepared for the Department of Environment and Conservation, Newcastle. EcoBiological. June 2006.

Fairley, A., 2004. *Seldom Seen. Rare Plants of Greater Sydney*. New Holland, Sydney.

Kodela, P.G., 2012 (May). Acacia bynoeana Benth. *PlantNET* (New South Wales Flora Online). http://plantnet.rbgsyd.nsw.gov.au/cgi-bin/NSWfl.pl?page=nswfl&lvl=sp&name=Acacia~bynoeana [Date Accessed: 01 November 2018]

Martyn, J. 2018. *Rocks and Trees: a photographic journey through the rich and varied geology, scenery and flora of the Sydney region*. STEP Inc., Turramurra.

NSW National Parks and Wildlife Service, 2002. *NSW NPWS Fire Response database v1.3a*. NSW National Parks and Wildlife Service, December 2002.

NSW Scientific Committee, 1999. *Final Determination to list* Acacia bynoeana *Benth. (a shrub) as an Endangered species*. The Committee, Hurstville. https://www.environment.nsw.gov.au/determinations/AcaciaBynoeanaEndSpListing.htm [Date Accessed: 01 November 2018]

Office of Environment & Heritage (OEH), 2014 (April). *Draft Recovery Plan: Bynoe's Wattle,* Acacia bynoeana. Unpublished manuscript provided to SOS project panel, OEH, Newcastle.

Office of Environment & Heritage (OEH), 2017 (December). Acacia bynoeana *Benth. threatened species profile*. https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10006 [Date Accessed: 01 November 2018]

SEWPaC, 2012. *Interim Biogeographic Regionalisation for Australia, Version 7*. Department of Sustainability, Environment, Water, Population and Communities. http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html

Whitney K.D. 2002. 'Dispersal for distance? *Acacia ligulata* seeds and meat ants *Iridomyrmex viridiaeneus'*. *Austral Ecology* 27: 589–595

7. Acknowledgements

I acknowledge the contributions of DPE staff, particularly Dayle Green, Greg Steenbeeke and Christian Marando (GIS), and DPE contractor Darren James (GIS) in the preparation and refinement of this document and associated maps. My contractor, Rhys Grogan, also assisted with GIS output in the form of drafts of the 'species polygons'.

Consultant botanist, Robert Miller assisted with fieldwork at Kemps Creek, and provided information about field observations associated with searches for his target species and with opportunistic sitings of my target species.

OEH staff assisted with some aspects of data availability and with the processing of many amendments to BioNet records.

8. Statement of professional independence

Whilst I was engaged and funded by DPE to prepare this Expert Report, and draft reports and maps were reviewed by DPE staff, I was not coerced by DPE to amend my work in any manner that I did not otherwise agree with. I believe that I had appropriate professional independence in the preparation of this document and associated maps.

I also declare that I do not have any personal or commercial conflict of interest in the preparation of this Report. I do not own real estate or businesses with property in the Growth Areas, nor do I have other active clients with real estate or associated commercial interests in the Growth Areas.

9. Appendix 1. Author's *Curriculum Vitae*

Dr Steven Douglas (BSc., MEnv. Plan., PhD.)

I have over twenty years of experience as an ecologist and environmental planner, primarily in New South Wales, with some experience in the ACT, Victoria and South Australia. I have worked for all levels of government, for environmentalist non-government organisations (NGOs), and for a large number of private clients ranging from individuals to multinational firms, directly and as a subcontractor. I have often worked as a sole consultant but have also collaborated with other specialists and have sometimes been part of large teams involved in large-scale, even interstate projects.

I specialise in the detection, management and conservation of rare and threatened flora species and communities, and in associated ecological impact assessment and mitigation.

I have qualifications and experience in a range of general and specific ecological, social, organisational and 'sustainability' fields.

I have served on environment-related ministerial committees and have held other ministerial appointments in NSW, including those dealing with bushfire management.

I have published in journals dealing with plant conservation, environmental law and policy, social science, and ecological ethics. Aspects of my work have been published by government, prominent NGOs, and in the popular press and other media.

This CV only contains content directly related to my botanical expertise.

Employment summary

1996 to present:

Self-employed, trading as *Ecological Surveys & Planning* (www.ecologicalsurveys.net)

Through this enterprise, I have undertaken a large number of consultancies for public and private sector clients including environmental impact assessment and mitigation; threatened biota research, profiling and management; vegetation mapping; preparing management plans for conservation estate; providing environmental planning and catchment management advice; advising on bushfire risk management; acting as an expert witness in Land & Environment Court proceedings; and developing organisational sustainability policies and practices.

July 2017 to July 2018:

Senior Ecologist, NSW Office of Environment & Heritage (NVIS, Science Division)

My work on the project below led to OEH retaining my services to research and document problems with the description, interpretation and mapping of Threatened Ecological Communities (TECs) statewide. This project provides advice to OEH, the NSW Threatened Species Scientific Committee, and through those agencies, to the Commonwealth Threatened Species Scientific Committee. It identifies technical issues with the description of TECs and their mapping, as well as wider problems of how TECs are defined. It draws on a major project undertaken by OEH for the NSW EPA and Forestry Corporation, in which TECs of the east coast and ranges were assessed and mapped for regulatory purposes on forestry estate. However, my work includes many more TECs and recent information emerging from Save Our Species project panels.

November 2015 to July 2017:

Team Leader, NSW Office of Environment & Heritage (NVIS, Science Division)

This project in Wingecarribee Shire is the first in which OEH's vegetation mapping team has worked at a very fine scale for a single local government area. The project entails auto-segmentation of digital aerial photography; supervising contract vegetation sampling; conducting strategic sampling; modelling of most vegetation communities; describing new communities; and extensive remote and on-ground map validation. I was hired partly because of my extensive familiarity with much of the vegetation of this geodiverse and biodiverse region. The role included supervision of two staff; liaison with consultants; and substantial networking with OEH and Wingecarribee Council staff. An update of vegetation classification will occur from mid 2019 onwards, and I have drafted a peer-reviewed journal article about the project that will be submitted for publication.

1995/6:

Project consultant, then Project Manager, Urban Bushland Biodiversity Survey (NPWS)

The Urban Bushland Biodiversity Survey was undertaken by the NPWS to compile comprehensive data on indigenous flora and fauna in twelve local government areas in Western Sydney. Contracted initially as a consultant to design and scope the project, I was later employed as Project Manager. Responsibilities involved an extensive literature review, preparation of a project plan and a background paper for the Survey and the overall management of the project including up to twelve staff and several consultants. The major focus was on coordinating research work, fauna and flora field surveys, and a community liaison and media campaign. Extensive flora survey work and scientific data analysis was undertaken. I provided a tour of important vegetation sites for the South Creek Catchment Management Committee. I also wrote media releases and conducted various media events including a live-to-air interview on ABC Radio National, and filming of a story in the field for the Totally Wild program.

1994:

Catchment Environment Officer (*Hawkesbury City Council*).

The project was funded by a grant from the former Hawkesbury-Nepean Catchment Management Trust and had the objective of identifying land uses on riverside properties to assess their potential to generate water pollution. The information on land use and riparian vegetation was primarily gained from aerial photo interpretation, limited land-based inspections and several water-based inspections, and was recorded in a GIS. Work site inspections, pollution control on agricultural lands, community meetings, site visits with landowners, and facilitating the formation of a Landcare group in the Sackville area.

1993/4:

Technical Officer (*Hawkesbury-Nepean Catchment Management Trust*).

Work included assisting with the preparation of a vegetation management strategy for the Trust and the outline of a revegetation strategy for South Creek. Other responsibilities involved providing scientific advice for development assessments, the preparation of hard copy and computer-based catchment maps, and advising on the implementation of revegetation projects in the catchment.

Ministerial appointments

- Appointed a member of the **National Parks & Wildlife Service Regional Advisory Committee** (South Coast) (2010-mid 2018). I opted not to reapply for this role after serving two terms. The restructure of the NPWS meant that the Committee would operate from Wollongong to the Victoria border and inland to the Tablelands. This was logistically fraught, and the role of RACs was evidently being diminished, with larger areas to manage but less meetings held.
- Appointed a member of the **NSW Sustainability Network** (2001), part of the Sustainability Advisory Council reporting to the Minister for Planning. I did not take up this position due to my relocating to Victoria.
- Nature Conservation Council representative on the former NSW **Native Vegetation Advisory Council** (1999-2001) reporting to the Minister for Land & Water Conservation under the Native Vegetation Conservation Act. I served as a member of the Regional Vegetation Planning Subcommittee, which amongst other matters, reviewed draft Regional Vegetation Management Plans and Codes of Practice for activities such as native forestry and timber plantations. I was particularly involved in reviewing and recommending amendments to the Code of Practice for plantation forestry. I resigned due to my relocating to Victoria.
- Nature Conservation Council representative on the former **Southern Catchment Management Board** (June 2000 - March 2001). I resigned due to relocating to Victoria. I expressed my dissatisfaction with the design of the catchment boards and recommended to the Minister that they be replaced with the Catchment Management Authority model used in Victoria. The Boards were later replaced with such Authorities.
- Nature Conservation Council representative on Baulkham Hills and Hornsby-Ku-ring-gai **District Bushfire Management Committees** (1995-2001).
- Australian Conservation Foundation representative on the former **Environmental Works Community Audit Committee** reporting to the Minister for Environment in relation to the Special Environment Levy imposed by the then Water Board (1993-5). I completed my term when the Committee concluded its business and dissolved upon acceptance of its final report by the Minister.

Tertiary qualifications & titles

Adjunct Research Fellow

School of Philosophical, Historical & International Studies, Monash University, 2014-16

Doctor of Philosophy

Fenner School of Environment & Society, The Australian National University, 2004-7

The research was undertaken in the transdisciplinary Human Ecology Program and covered fields such as ecological philosophy, ecotheology, environmental policy-making, policy evaluation, organisational change, and critical systemic analysis. My thesis was passed unanimously and unamended by one Australian and two USA-based professors. I was awarded a $10,000 Publication Fellowship by the Fenner School and have since published aspects of my research.

Master of Environmental Planning

Macquarie University Grad. Sch. Env., 1994-96

This course included environmental law and politics, community involvement in planning, environmental education, development approval processes, urban planning, EIA, environmental science/fieldwork and heritage management. The dissertation component involved a pioneering report on the significant flora of the Greater Cattai Region (Cattai subcatchment) in north-western Sydney and led to my being offered employment with the NSW NPWS to design and manage a biodiversity survey of western Sydney.

Bachelor of Science

Macquarie University, 1990-93

My degree majors are Resource and Environmental Management, Land Management, and Plant Biology/Ecology.

Graduate Certificate of Research Information Literacy

The Australian National University, 2004-7

This course included advanced word processing, citation management, literature gathering (including on-line literary databases and other Internet sources), on-line publishing, presentation software, and thesis production.

Professional memberships

- Founding member of the Ecological Consultants Association of New South Wales (did not renew due to my relocating to Victoria and later to the ACT).
- Member of the NSW Environmental Defenders Office (EDO) Scientific Advisory Service (continuing).

Threatened biota experience

The following threatened plant species and populations and threatened ecological communities (TECs) have been engaged with in the various forms and processes listed below. The list is not complete, and some processes are on-going. I also successfully nominated three Key Threatening Processes under the TSC Act: Bushrock Removal; Clearing of Native Vegetation; Competition from European Honey Bee.

Species / population	Work conducted
Acacia bynoeana	Fieldwork, research, successful nomination, monitoring, advice to authorities, expert witness, rediscovered lost population, documented new population near range limit, PAS2 review, SOS review panel, review and amendment of BioNet dataset. Recognised by OEH as a species expert (Nov 2018).
A. gordonii	Fieldwork, successful nomination, advice to NPWS, PAS2 review, SOS research and monitoring program (fire ecology, BMtns NP), review and amendment of BioNet dataset.
A. prominens	Successful nomination of Endangered Population
A. pubescens	Fieldwork, contribution to Recovery Plan, confirmed disjunct southern populations, nominated population, PAS2 review, review and amendment of BioNet dataset. Recognised by OEH as a species expert (Nov 2018).
Ancistrachne maidenii	Fieldwork, research, successful nomination, advice to NPWS, CAM review
Asterolasia elegans	Fieldwork, species profile, advice to Council and NPWS
Baloskion longipes	Research linked to *Carex klaphakei*, review of BioNet records, advice to OEH
Boronia deanei	Research, SOS review, CAM review, advice to OEH
Bossiaea oligosperma	SOS fieldwork, review of records (NW population), report to OEH, establishment of monitoring plots in Yerranderie SCA
Callistemon linearifolius	Fieldwork, research, successful nomination, advice to RMS and NPWS, PAS2 review
Callistemon megalongensis	Co-described new species, successful nominations (listing then upgrade), fieldwork, advice to Council and OEH, PAS2 review, SOS monitoring program (OEH, BMCC, on-going)
Callistemon purpurascens	Described new species, fieldwork, successful nominations, advice to Council and OEH, SOS monitoring project (2018 on-going)
Calotis glandulosa	Fieldwork (new and extended populations, Kosci NP), CAM review
Calotis pubescens	Fieldwork (new population, Kosci NP), CAM review
Carex klaphakei	SOS research project and recommendation for monitoring; resolved errors in BioNet records

Species / population	Work conducted
Commersonia prostrata	PAS2 / PKF research, fieldwork, advice to NPWS and OEH, documentation and monitoring of new and known populations for Forestry Corp, designed recovery actions for populations in Wingello and Penrose SFs
Cullen parvum	Fieldwork, located new NE population, report to NPWS
Dampiera fusca	Research, fieldwork, successful nominations, monitoring program for ACT Parks & Conservation, advice to NPWS and OEH, CAM review
Darwinia biflora	Fieldwork, research, contributor to Recovery Plan, PAS2 review, review and amendment of BioNet dataset.
Darwinia glaucophylla	Fieldwork, research, successful nomination, advice to NPWS, PAS2 review
Darwinia fascicularis ssp. *oligantha*	Fieldwork, research, successful nomination of population
Darwinia peduncularis	Research, successful nomination, CAM review
Dillwynia tenuifolia	Fieldwork, research, successful population nominations, advice to OEH
Epacris purpurascens var. *purpurascens*	Fieldwork, research, nomination, new SW range limit (Nattai NP), advice to NPWS/OEH
Eucalyptus aggregata	Research, successful nomination of species and population, fieldwork (Wingecarribee Shire) and advice to Council and OEH, CAM reviews
E. aquatica	Fieldwork, advice to Council and Forestry Corporation
E. sp. *Cattai*	Successfully argued for recognition of this entity as a new species, successful nomination, fieldwork, PAS2 review, advice to OEH, SOS project panel
E. kartzoffiana	Fieldwork, research, expert witness
E. macarthurii	Fieldwork, research, successful nominations, advice to Council and OEH
E. parvula	Fieldwork (Wadbilliga NP), CAM review
E. pulverulenta	Fieldwork (Bredbo Hills), CAM review
Galium australe	PAS2 research, recommended taxonomic review of most records in NSW based on Herbarium assessment, advice to OEH, CAM review
Grevillea juniperina ssp. *juniperina*	Fieldwork, research, advice to OEH (Colebee NR offset site)
Grevillea molyneuxii	Fieldwork, advice to OEH for CAM review
Grevillea parviflora ssp. *parviflora*	Fieldwork, research, expert witness, review and amendment of BioNet dataset.
Grevillea parviflora ssp. *supplicans*	Fieldwork, research, nomination, advice to NPWS
Grevillea raybrownii	Fieldwork, research, nomination and advice to NSWSC – listing pending
Gyrostemon thesioides	Successful nomination
Helichrysum calvertianum	Fieldwork, research, nomination, advice to NSWSC – listing pending
Hibbertia fumana	Research, minor fieldwork, expert witness
H. incana (syn. *superans)*	Successful nomination of population then species
H. praemorsa	ROTAP, researched, fieldwork (informal)
H. puberula ssp. *furcatula*	Fieldwork (incidental) documenting new occurrence, advice to OEH/NPWS
H. puberula ssp. *puberula*	Research, minor fieldwork with R. Miller, expert witness
Homoranthus binghiensis	CAM review (recommended changing to CE)
Keraudrenia corrolata var. *denticulata*	Successful nomination of population
Lasiopetalum joyceae	Fieldwork, research, successful nomination, species profiling for Council and NPWS, PAS2 review

Species / population	Work conducted
Leptospermum deanei	Fieldwork, research into hybridization with *L. trinervium*, advice to RBG, Council, OEH
Leucopogon fletcheri ssp. *fletcheri*	Fieldwork, research, successful nomination, advice to OEH and NPWS
Melaleuca deanei	Research, fieldwork, successful nominations, advice to NPWS/OEH and species profile for Council, review and amendment of BioNet dataset. Recognised by OEH as a species expert under BC Act (Nov 2018).
Olearia cordata	Fieldwork and report to NPWS, PAS2 review
Persoonia acerosa	Fieldwork, PAS2 review, SOS monitoring plots, advice to Council and OEH
Persoonia bargoensis	Fieldwork, research, successful nomination, PAS2 review, CAM review, review and amendment of BioNet dataset.
Persoonia hirsuta	Fieldwork, research, nominations of species and population, PAS2 review, review and amendment of BioNet dataset.
Persoonia glaucescens	Fieldwork, nomination, report to NPWS, PAS 2 review, CAM review, review and amendment of BioNet dataset.
Persoonia marginata	Fieldwork and report to OEH, CAM review
Persoonia mollis ssp. *revoluta*	Fieldwork, research, advice to OEH and Forestry Corp., nomination as Vulnerable - listing pending
Persoonia nutans	Fieldwork, nomination, advice to OEH, review and amendment of BioNet dataset. Recognised by OEH as a species expert under BC Act (Nov 2018).
Phyllota humifusa	PAS2 fieldwork and research; advice to NPWS, OEH, Council, Forestry Corp (monitoring plots, reduced APZ width), review of BioNet dataset.
Pimelea curviflora var. *curviflora*	Fieldwork, research, successful nomination, advice to OEH
Pomaderris brunnea	Incidental fieldwork and documentation of new populations and range extension; review and amendment of BioNet dataset.
P. cotoneaster	Fieldwork, research, advice to Council, NPWS, OEH, liaise with ANBG seed collectors, CAM review
P. sericea	PAS2 research (review of records and habitat), recommended consideration of Presumed Extinct or at least CE
Pultenaea elusa	PAS2 research (review of records and habitat), recommended Presumed Extinct
P. glabra	SOS fieldwork and monitoring plots. Review of Mts Wilson/Irvine records resulted in these being reallocated to an undescribed species given the interim name, *P. monticola*.
P. parviflora	SOS fieldwork and report to OEH (Colebee NR offset site); review and amendment of BioNet dataset.
P. pedunculata	Fieldwork, research, expert witness, CAM review
Solanum armourense	PAS2 fieldwork, research, report, advice to OEH, CAM review
S. celatum	Fieldwork, research, new populations (new range limit and habitat), advice to OEH, CAM review
Tetratheca glandulosa	Fieldwork, PAS2 review, advice to OEH and Cwlth DEE re conservation status
Triplarina nowraensis	SOS fieldwork, review of BioNet records, advice to OEH/NPWS, establishment of monitoring plots
Zieria involucrata	Fieldwork, input to Recovery Plan, CAM review
Zieria murphyi	Liaise with ANBG, fieldwork, advice to OEH

Threatened Ecological Communities (TECs)

My work for OEH in reviewing all NSW and EPBC Act TECs in the State has given me at least some familiarity with most of these entities and builds on already-strong knowledge of some. I have also been an expert witness in cases involving some of these communities – some entailing basic reviews and advice, and others involving in-depth considerations. All of the EPBC Act parallel listings are not included here unless I was involved in a particular nomination:

Ecological community	Nature of engagement
Blue Gum High Forest	Successful nomination, expert witness
Blue Mountains Basalt Cap Forest	SOS panel
Blue Mountains Shale Cap Forest	Successful nomination, SOS panel
Blue Mountains Swamps	Fieldwork, mapping, advice to BMtns Council, modelling
Castlereagh Scribbly Gum Woodland	Successful nomination, advice to DEE re Cwlth listing, expert witness
Cooks River / Castlereagh Ironbark Forest	Advice to DEE for EPBC Act listing
Cumberland Plain Woodland	Correction of OEH mapping, fieldwork, assessments, advice to Councils and NPWS
Eastern Suburbs Banksia Scrub	Major review for DEE Recovery Plan update, advice to OEH
Elderslie Banksia Scrub Forest	Major review for DEE Recovery Plan, SOS panel
Illawarra Lowlands Grassy Woodland	DEE review panel for EPBC Act listing
Lowland Grassy Woodland & Forest of SE Corner Bioregion	Successful nomination
Maroota Sands Swamp Forest	Successful nomination, SOS panel
Melaleuca armillaris Tall Shrubland	fieldwork, mapping, advice to OEH
Montane Peatlands & Swamps	Fieldwork, modelling and mapping, advice to OEH
Mount Gibraltar Forest	Detailed review for modelling and mapping, and advice about revised listing, advice to DEE re Upland Basalt Eucalypt Forest inclusion of NSW TECs
O'Hares Creek Shale Forest	Research and review for modelling and mapping
Pittwater & Wagstaffe Spotted Gum Forest	Successful nomination
Riverflat Eucalypts Forest on Coastal Floodplains	Successful nomination (component), research, modelling and mapping (limited extent)
Robertson Basalt Tall Open-forest	Modelling and mapping, advice to NSW SC
Robertson Rainforest	Modelling and mapping
Shale/Gravel Transition Forest	Mapping, TEC review
Shale/Sandstone Transition Forest	First to describe this concept c. 1996 based on Masters research. Formally published as a concept in NPWS (1997, UBBS). Successful nomination, research, major review and advice to DEE for EPBC Act listing, modelling and mapping
Southern Highlands Shale (Forest &) Woodland	Major contributor to DEE listing, drafting of Listing and Conservation Advices, advice to OEH about revision of NSW listing, modelling and mapping. Contracted to prepare listing for upgrade to CE.
Subtropical & Temperate Coastal Saltmarsh (EPBC Act)	Funded to prepare successful nomination
Sun Valley Cabbage Gum Forest	Successful nomination, mapping, advice to Council, SOS project panel

Ecological community	Nature of engagement
Swamp Sclerophyll Forest on Coastal Floodplains	Allied major research project cited in the Final Determination, TEC review (gap analysis)
Sydney Turpentine Ironbark Forest	Successful nomination, mapping, advice to Councils and to OEH/SC about revision
Tablelands Basalt Forest	Research, expert witness, advice to OEH about revision, modelling and mapping
Tablelands Snow Gum…Grassy Woodland	Fieldwork documenting new occurrences, modelling and mapping, advice to OEH
Upland Basalt Eucalypt Forest (EPBC Act)	Major contributor to DEE listing of this composite community that includes several NSW TECs. Draft Listing and Conservation Advices
Western Sydney Dry Rainforest and Moist Shale Woodland	SOS panel, TEC review

Publications / presentations / media

Ecology / conservation / environmental law & policy / ecological ethics

Refereed journal articles

Douglas, S.M. and Wilson, P.G. 2015. "Callistemon purpurascens (Myrtaceae): a new and threatened species from the Blue Mountains region of New South Wales, Australia". *Telopea* 18: 265-272

Douglas, S.M. 2000. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link". *Australasian Journal of Natural Resources Law & Policy,* 6(2)

Conference proceedings

Douglas, S.M. 2003. "Ecological offsets – what's the idea?" in Morrison, C. (Ed.) *Urban bushland and remnant vegetation: toolkits for a sustainable future – conference proceedings*. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 2001. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link"; in Newton, S. (Ed.) *Bushland or buildings? The dilemma for biodiversity conservation in urban areas* – conference proceedings. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 1998. "The Threatened Species Conservation Act; a consultant's perspective" in *On the brink; your bush, their habitat, our Act.* Threatened Species Network, Nature Conservation Council of NSW, and Environmental Defenders Office, Sydney

Book chapters

Douglas, S.M. 1999. "Development & Sydney's threatened biota" in *Greenprint for Sydney: an environmental strategy for the 21st Century*. Total Environment Centre, Sydney, NSW

Professional reports

Douglas, S.M. & Anderson, J.R.B. 2002. Eucalyptus robusta *(Swamp Mahogany) communities and their conservation status in New South Wales*. Swamp Mahogany Project, Central Coast Community Environment Centre, Newcastle University Campus, Ourimbah

Douglas, S.M. 1997. "Local Government Area Reports: Baulkham Hills Shire", in James, T. (Ed.) *Urban Bushland Biodiversity Survey* (Stage 1, Western Sydney) Flora Appendices Vol. 2. NSW National Parks & Wildlife Service, Hurstville

Edited but not refereed publications

Douglas, S.M. 2014. "When biosecurity is threatened from within: the case of the native environmental weed, Pittosporum undulatum". *Australasian Plant Conservation*, 23(2)

Douglas, S.M. 2009. "Black Gum: a threatened tree of upland New South Wales and Victoria." *Australasian Plant Conservation*, 17(4)

Douglas, S.M. 2009. "Species profile and monitoring of Dampiera fusca". *Australasian Plant Conservation*, 17(3)

Douglas, S.M. 2006. "Endangered plant discovered" (St. Clements Retreat, Galong). *Biodiversity Research Newsletter,* 20, p.4, July, NSW Department of Environment & Conservation, Hurstville.

Douglas, S.M. 2006. "Endangered plant discovered (*Cullen parvum*) at St. Clements Retreat, Galong". News of Friends of Grasslands, November-December, p7

Douglas, S.M. 2005. "Phoenix flora: a post-fire discovery in the ACT". *Australasian Plant Conservation*, 13(3)

Douglas, S.M. 2004. "Phoenix flora" (re Dampiera fusca). *Journal of the Australian Native Plant Society Canberra Region*, 14(2), December

Douglas, S.M. 2003. "Mysteries of the Megalong Valley: another rare plant for the Blue Mountains." *Australasian Plant Conservation*, 12(1)

Douglas, S.M. 2001. "Land of the living dead – tree decline in urban areas". *Environment NSW* (newsletter of the Nature Conservation Council of NSW), September

Douglas, S.M. & Newton, S. 2000. "Bushland weeds – more on native weeds". *Environment NSW*, December

Douglas, S.M. 2000. "Regional Parks". *National Parks Journal* Vol. 44 (5 & 6) (journal of the National Parks Association of NSW)

Douglas, S.M. 1996. "Community biodiversity surveys". *National Parks Journal*, 40(3)

Douglas, S.M. 1996. "Mapping our urban bushland". *The Gardens*, Spring (journal of the Royal Botanic Gardens, Sydney)

Douglas, S.M., Bolesic, T. and Ware, K. 1994. "Healing the Hawkesbury: start with bushland protection". *National Parks Journal*. 38(4)

Public media coverage

2004, November 6. "Bright flowering spot after fire" - discovery of Dampiera fusca – a new genus and nationally significant species for the ACT and a new northern limit for the species. *Canberra Times*

2004. Live-to-air interview re discovery of *Dampiera fusca* in Namadgi NP, *ABC 666* AM Radio, Canberra

1996. Live to air interview re NPWS Urban Bushland Biodiversity Survey, *ABC 2BL* AM Radio, Sydney

1996. Pre-recorded TV segment re discovery of several nationally threatened plants in the one location during surveys for NPWS UBBS. *Totally Wild* program, Channel 10, Sydney

Consultancy projects

Short descriptions of the many larger projects that I have been involved in are available at http://ecologicalsurveys.net/?page_id=10, and a list of smaller projects is at http://ecologicalsurveys.net/?page_id=14

Voluntary and other works

- Assist **International Union for the Conservation of Nature (IUCN)** with a review of the conservation status of *Proteaceae* in eastern Australia (Melbourne, 2019).
- Assist **NSW Environmental Defenders Office** with a review of NPWS monitoring proposals to assess the effects of permitting horse riding in declared Wilderness areas (Kosciusko National Park) (2014).
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Noxious Weeds Act 1993 (in 2011)
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Threatened Species Conservation Act 1995 (in 2010)
- Assist discoverers (**Blue Mountains Bushcare**) of a previously undescribed *Epacris* species (*E. apungens* Coleby & Brown) in south Leura to prepare an article for the journal, *Telopea*, describing this species and its ecology
- Assist **NPWS** with a search for the ultra-endemic and rare rainforest plant, *Thismia clavarioides*, in Morton National Park (2010)
- Expert panel member assisting **Hawkesbury-Nepean CMA** with its Draft Climate Change Vulnerability Assessment for selected threatened ecological communities of the NSW Southern Highlands (2010)
- Assist PhD student, David Field (**University of Wollongong and CSIRO**) with information about the ecology, distribution, and conservation status of *Eucalyptus aggregata* (Black Gum) (2007)
- Fieldwork assisting with group preparation of vascular plant species lists in numerous NPWS and ACT Parks reserves in the Southern Tablelands area. **Australian Native Plants Society** (2003-2007)
- Searches for *Euphrasia scabra* (critically endangered) in Packers Swamp and Nunnock Swamp. Discovered new population (3rd in NSW) in unnamed swamp, SE Forests National Park. **Friends of Grasslands** (2004)
- Assistant part-time editor of "*Danthonia*" (now *Australasian Plant Conservation*), the journal of the **Australian Network for Plant Conservation** Inc., Canberra (2002-2003)
- Assist PhD student, David Clunas (**University of Wollongong**) with review of his research in the ecology of the nationally Rare, *Pultenaea villifera* var. *villifera* (2002)
- Provide technical assistance to four final year undergraduate Environmental Science students (**Australian Catholic University**) working in Marramarra National Park, (c. 2000)
- Discovery of and subsequent surveys for *Persoonia hirsuta* ssp. nov. 'Yengo NP'. **NPWS/RBG**
- Vascular flora and fauna (microchiropteran bats) surveys within Pilliga Nature Reserve. **NPWS** Coonabarabran
- Supervisor for undergraduate dissertation, "Environmental rehabilitation of Peats Crater and Peats Bight in Muogamarra Nature Reserve" (D. Maestri), **Southern Cross University** (1997)
- Co-supervisor for undergraduate dissertation "Riparian Vegetation of upper Cattai Creek" (D. Buckle). **Southern Cross University** (1997)
- Preliminary flora assessment for proposed subdivision and development; Red Gum Avenue, Pennant Hills. The bushland area was subsequently added to Berowra Valley Regional Park. **Friends of Berowra Valley Bushland**

- **NSW National Parks Association** (NPA) Biodiversity Audit, proposed Bargo River National Park. Team Leader, Vegetation - threatened flora
- Guided interpretive walk of Fred Caterson Reserve. **Cattai Catchment Management Committee**
- **NSW NPA** audit of Greater Sydney proposed conservation reserves and additions - assistant and author of NW Sydney reserve proposals
- **NSW NPA** Biodiversity Audit of the proposed Dyarrabin Nature Reserve (~2000 ha) - Project Co-ordinator
- **NSW NPA** Proposal for the creation of Dyarrabin Nature Reserve; revised submission and report of the second NPA Biodiversity Audit
- Preliminary flora study of Crown lands (Functional Area 1), Cattai Ridge Road, Halcrows Road, Hillside/Glenorie; submission to Director NPWS and to Baulkham Hills Council. **NSW NPA**
- Flora survey of Morans Rock Crown lands for proposed addition to Wollemi National Park. **NSW NPA**
- Proposed Welcome Reef Dam (Shoalhaven River north of Braidwood) - assist with flora and fauna surveys. **NSW NPA**. Much of the area is now within Nadgigomar Nature Reserve
- Flora survey of surplus Department of Education lands at Ellerman Park, Round Corner. The local community proposed that the area become a reserve to protect a critically endangered plant community present on the site. **Friends of Ellerman Park**
- Flora survey of Crown lands at South Maroota for proposed Crescent Reach Nature Reserve (later declared as the Maroota Ridge State Conservation Area), **NSW NPA**
- Calangara Nature Reserve Proposal in Kenthurst. Survey and report to **NSW NPA**
- Preliminary Survey of bushland in Holland Reserve, Glenhaven
- Survey of Crown Reserve (now part Scheyville NP), Pitt Town; report to **NSW NPA**

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Expert report – *Acacia pubescens*

Expert report for *Acacia pubescens* (Downy Wattle), Dr Steven Douglas, February 2019

ECOLOGICAL
SURVEYS & PLANNING

Expert Report For

Acacia pubescens

(Downy Wattle)

Strategic Assessment for the
Cumberland Plain Conservation Plan

Greater Macarthur, Greater Penrith to Eastern Creek,
Wilton, and Western Sydney Aerotropolis Growth Areas

Prepared for NSW Department of Planning & Environment, February 2019

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Table of Contents

1. Introduction

1.1 Purpose of the Expert Report

An Expert Report may be prepared under s.6.5 of the Biodiversity Assessment Method (BAM) in place of undertaking a threatened species survey of sufficient extent, intensity and duration as would otherwise be necessary to comply with the BAM. Use of an Expert Report may be beneficial where it is highly unlikely that a species may occur within a study area; where survey cannot meet BAM specifications; and/or the reliability of detecting the species is low. In respect of *Acacia pubescens*, insufficient survey extent; constraints on the effectiveness of survey; and unreliability of detection due to aspects of the species' ecology are the primary reasons for preparing an Expert Report.

The purpose of this Report is to provide an assessment of the current status and conservation requirements of *Acacia pubescens* within the four priority growth areas of Greater Macarthur (GMGA); Wilton (WGA); Penrith to Eastern Creek (PECGA); and Western Sydney Aerotropolis (WSAGA)to determine whether:

a) The species is unlikely to be present and would thus require no further assessment; or
b) The species is known or likely to be present, and the Expert Report must provide estimates of potential habitat within growth areas and development footprints as part of the biocertification process.

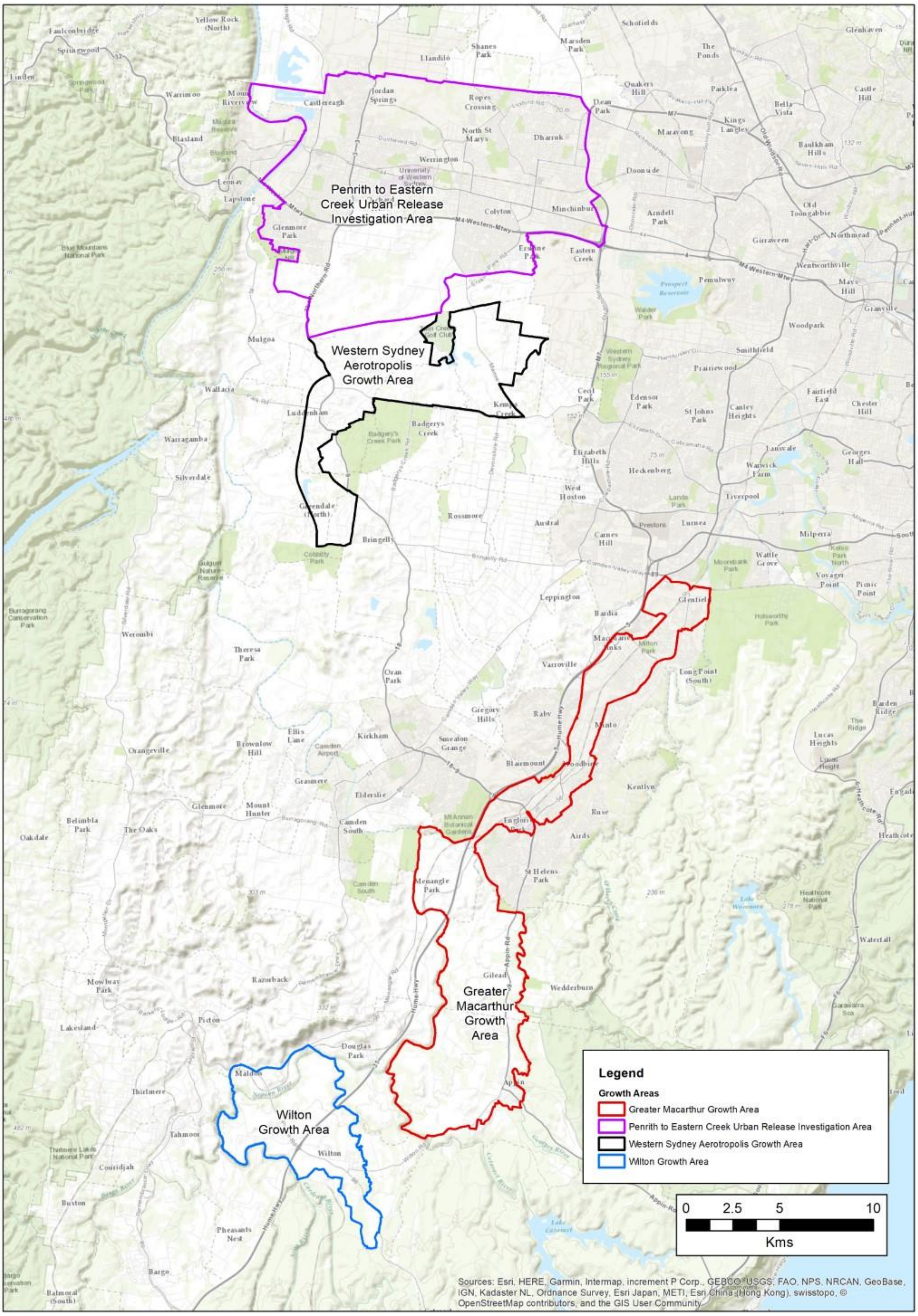
1.2 Project context

The NSW Government is identifying areas for future urban land use and associated infrastructure in western Sydney. The four priority growth areas are all located in the Cumberland Subregion under the Interim Biogeographic Regionalisation for Australia (IBRA) (SEWPaC, 2012).

As part of the planning for these areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify land use outcomes. A strategic assessment of this Plan is underway, and this Expert Report will assist in determining the extent and quantum of impacts of the proposed urban growth on *Acacia pubescens*.

Acacia pubescens, Aylmerton © S. Douglas

1.3 Study area



Map 1. Growth Areas subject to this Expert Report

Greater Penrith & Eastern Creek Growth Area (GPECGA)

A large portion of this Growth Area is already urbanised, with several areas of industrial land use. Significant rural and peri-urban areas remain in the central north, the centre, and the southwest. Large areas of remnant vegetation are present in the far north (former Australian Defence Industries site, now in part Wianamatta Regional Park), and the Orchard Hills Defence facility. Mining of alluvium for sand and soil continues in the far northwest of the area in the Penrith Lakes locality.

The area has been extensively cleared because of its relatively arable terrain, based mainly on shale and alluvium. Some of the remaining vegetation is associated with the much less arable to infertile Castlereagh Woodlands and its older, leached and mineralised alluvium and shale-derived soils. Strips of remnant vegetation are present along some of the larger watercourses such as Eastern and South Creeks. Significant parts of the study area are or were flood-prone, and this has influenced the retention of vegetation in some affected areas.

Western Sydney Aerotropolis Growth Area (WSAGA)

This Growth Area adjoins the Greater Penrith to Eastern Creek area, extending south to the locality of Greendale, west of Bringelly. It is currently largely rural, with villages at Luddenham and Kemps Creek. Most rural areas are pastoral, but there are significant areas of more intensive rural use, including poultry and egg production, a large dairy and associated fodder cropping, and some market gardens and enclosed fruit and vegetable production. Quarrying occurs at the localities of Badgerys Creek and Kemps Creek.

This Growth Area is extensively cleared but retains native vegetation in areas where rural uses were constrained by steeper terrain, flooding along streams, or unsuitable soils.

Greater Macarthur Growth Area (GMGA)

The GMGA occurs in southwestern Sydney on predominantly shale soils that have been heavily cleared for agriculture and urban or industrial use. The northernmost section has long-established urban and commercial / industrial land use, while the southern section is largely rural (pastoral, minor cropping), with some villages and primarily subsurface mining (e.g. coal and coal seam gas). It extends from urban Glenfield in the north, to the rural village of Appin in the south.

In the southernmost section, geological uplift and erosion have exposed infertile sandstone terrain along gullies and valleys. Much of that terrain remains naturally vegetated because it is unsuited to agriculture, however it occupies only a small percentage of the total area of this heavily-cleared region. Between the infertile sandstone valleys and the relatively arable shale plateau and hills is a geological and ecological transition zone. Whilst much of the vegetation of the shale terrain has been cleared, a greater area of vegetation remains on the transition zone, primarily in the south. Both the shale and transition zones support Critically Endangered ecological communities that are potential habitat for some threatened plant and animal species.

Wilton Growth Area (WGA)

The Wilton Growth Area is the most southerly of the four Western Sydney Growth Areas dealt with in this Report. It extends from the village of Douglas Park in the north, to the village of Wilton in the south. It is primarily rural (pastoral) area with some more intensive agriculture, significant but mostly underground mining (primarily coal), and some long-established villages. The Hume Motorway dissects this Growth Area.

The pattern of clearing and vegetation retention is broadly similar to that of Greater Macarthur, with the majority of remnant vegetation associated with infertile but biodiverse sandstone gullies and the Nepean River gorge, and with associated transition into the heavily cleared shale landscapes.

1.4 Justification for the use of an Expert Report

An Expert Report for *Acacia pubescens* is required as part of the threatened biota assessment for the Cumberland Plain Conservation Plan because:

1) Survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH, 2016) for field traverses due to limitations on land access, particularly in the GMGA;
2) Survey quality was constrained by drought conditions. Whilst this species is perennial, under sufficiently severe drought and associated total grazing pressure (livestock, if relevant; native species; feral species), it can be suppressed such that it only remains apparent (but likely undetectable) as rootstock and as seed bank. Drought was a major limitation on survey effectiveness in this instance. A known location of the threatened species, *Acacia bynoeana* was visited by fellow botanist, Robert Miller, but could not be detected, even though the habitat was still in place. This is believed to be a result of drought;
3) Survey effectiveness was further constrained by parts of the study area having been long-unburnt. This can create an unnaturally dense shrub layer that limits access.

Surveys associated with biocertification of the study areas and earlier projects in those areas have been insufficient to reliably determine the presence and extent of the species. An Expert Report is required to provide an assessment of the likely presence, location, and significance of occurrences of the species in those areas.

1.5 Credentials of expert

I have worked as an ecologist since the mid-1990s, primarily in the Greater Sydney region, but also in the ACT, Central Coast, southern NSW (coast, tablelands and slopes), throughout Victoria and eastern South Australia. I have primarily been self-employed with a mix of government, private, and corporate clients, and have also worked as a subconsultant to larger firms, including two university-based consultancies. I have also worked directly for the NSW NPWS, and more recently for OEH (Native Vegetation Information Science). A summary of my credentials as required under the BAM is provided below as Table 1. I was approved by OEH as a species expert for *Acacia pubescens* under s.6.5 of the BAM in November 2018.

Table 1. Credentials of Dr Steven Douglas as Expert in relation to *Acacia pubescens*

BAM section	BAM requirement	Details
s.6.5.2.8 (g)	Name of expert	Dr Steven Douglas
s.6.5.2.3 (a)	Expert's qualifications	Bachelor of Science (Plant Ecology, Land Management, Resource & Environmental Management), Macquarie University, 1993. Master of Environmental Planning, Graduate School of Environment, Macquarie University, 1996. Doctor of Philosophy, Australian National University, 2008. Graduate Certificate of Information Literacy, ANU, 2006. BAM Accredited Ecologist, 2018.
s.6.5.2.3 (b)	History of experience in ecological research and survey method for the relevant entity	Review of BioNet and incorporated NSW Herbarium database records of *A. pubescens* (DPE, 2018). Included reclassification of suspect outlying records, known plantings, hybrids, and significant refinement of data about the outlying Mountain Lagoon population (a single collection site, not several). Provision of expert witness evidence in relation to *Acacia pubescens* (QUBE proposal, Moorebank; included assessment of adequacy of biobanking arrangements) L&EC 2017/81889 (2017-18). Rediscovery, documentation and validation of disjunct Southern Highlands record of *Acacia pubescens* (2016-17). Advice to OEH and Wingecarribee Shire Council. Successfully nominated Wingecarribee Shire population of *A. pubescens* as Endangered under *Threatened Species Conservation Act* – later omitted due to changes caused by Biodiversity Conservation Act. Rediscovery and validation of disjunct southernmost population (South Nowra) (2016-17). Acknowledged by NPWS for contributions to and review of the Recovery Plan for *A. pubescens* (2003). Consulted by OEH in relation to illegal clearing of a known population, and appropriate remedial actions (2017). Consulted by NPWS in relation to proposed horse riding in known and likely habitat for this species (2018). Numerous historic surveys in northwest and western Sydney including Hills Shire, Hawkesbury Shire, Fairfield City, and Penrith LGAs (1994-2000) as evidenced by BioNet and NSW Herbarium records.
s.6.5.2.3 (c)	Resumé detailing projects pertaining to the survey of the relevant entity	See Appendix 1. Relevant surveys and works listed above. Minor incidental survey of potential habitat at locality of Kemps Creek for DPE Expert Report. Meandering transect used.
s. 6.5.2.3 (d)	Employer's name and period of employment (if relevant)	Self-employed ecological consultant, 1996 to present (continuous other than for periods of study). Employed by OEH as contracted staff from November 2015 to July 2018 (Wingecarribee Shire vegetation map, South Coast Regional vegetation map, Review of mapping issues for TECs).

s.6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant entity	Consulted by OEH in PAS2 reviews of this species. Engaged by DPE to review and refine/correct BioNet data for this species. Consulted by DECCW on this and other threatened flora species of the region as part of a data review for the purposes of the BioBanking Tool (2006). Requested by OEH to nominate as a contributor to forthcoming CAM / BAM Calculator review of this (and numerous other threatened flora) (2018/19). Approved as a BAM species expert for *Acacia pubescens* by OEH in November 2018.

2. Species information

2.1 Description

Acacia pubescens is "A spreading (to slightly weeping) shrub, 1 - 5 m high with brilliant yellow flowers, bipinnate leaves (divided twice pinnately) and conspicuously hairy branchlets" (OEH, 2017; Kodela, 2016; NPWS, 2003a; Benson & McDougall, 1996).

It "May be confused with *A. cardiophylla*, which has cordate pinnules. Hybridises with *A. baileyana*, *A. cardiophylla* and other species" (Kodela, 2016) including the nationally rare *A. jonesii* (NPWS, 2003a). All such hybrids are unnatural occurrences as the other species have been introduced into *A. pubescens'* range. This is a threat to the species' genetic integrity (NPWS, 2003a, b), though the extent of such occurrences are unknown. Natural hybrids with *A. irrorata*, *A. mearnsii* and other local species are feasible where they co-occur.

2.2 Ecology

A. pubescens "Flowers from August to October. Pollination of *Acacia* flowers is usually by insects and birds. The pods mature in October to December." (OEH, 2017). *Acacia* species are generally self-incompatible, and the pollinators are likely to be small native bees and wasps (Bernhardt, 1987).

Seed dispersal is most likely by ants seeking to collect the aril. Seeds are taken into the ant nest, and later discarded in a wide area around the nest (Whitney, 2002). Seeds are likely to remain viable over many years in the absence of germination cues, with the species likely to develop a persistent, soil-stored seed bank, as is typical for most *Acacias* (NPWS, 2003a, b).

A. pubescens can occur as copses or thickets due to its suckering habit, especially in areas where there has been disturbance such as slashing, attempted / earlier clearing or 'underscrubbing', roadworks, excavations or fire. Many remnant occurrences are linear and restricted to roadsides and fence lines.

"Recruitment is more commonly from vegetative reproduction than from seedlings. The percentage of pod production and seed fall for this species appears to be low. *Acacia* species generally have high seed dormancy... It is thought that the species needs a minimum fire free period of 5 - 7 years to allow an adequate seedbank to develop. Longevity is unknown, but clonal species [such as *A. pubescens*] have been known to survive for many decades" (OEH, 2017). Preliminary generic work by Moore *et al*. (1999) has shown that in most cases, the often-dense patches in which the species can occur, often with hundreds of stems, are one individual (NPWS, 2003). One clonal individual was seen to cover 1.2 ha (Moore *et al*., 1999).

Experiments that involved providing *A. pubescens* seed to captive emus provided preliminary evidence that seeds that survived digestion germinated earlier than those not ingested, but the experiment was truncated and did not produce a result in relation to germination frequency differences (P. Ridgeway, pers. comm., 2018).

Acacia pubescens © S. Douglas

2.3 Distribution and abundance

NPWS (2003a) describes the species as being restricted to clayey soils in the Sydney region, with most occurrences on the Cumberland Plain. Kodela (2016) lists the species' distribution as "Bilpin to Georges River and in the Oakdale area (Central Coast botanical division); southern limit outlier populations at Aylmerton (Central Tablelands) and Nowra area (South Coast); dubiously recorded at Woodford where it is possibly cultivated." OEH (2017) states the species' distribution is "Concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with outliers occurring at Barden Ridge, Oakdale and Mountain Lagoon."

As the species has been in cultivation for some decades, care is required to ensure that database records are not plantings or associated naturalisations. Three records of the species (all are apparent replicates) at Woodford in the Blue Mountains are regarded by NPWS (2003a) as plantings. They occur in a former garden, not in bushland, and on geology not known to support the species. These were recoded as 'planted' during the BioNet data cleansing project that forms part of the DPE biocertification assessment.

A publicly available BioNet map of the species' distribution will generally be accurate at a coarse scale, but can include records that are unsound e.g. misidentified, data entry error, incorrectly located, and in this case, potentially planted. "Some organisations have planted *A. pubescens* on land under their control… Bankstown Council planted *A. pubescens* in at least five reserves (Mirambeena Reserve, Salt Pan Creek Reserve, Deepwater Park, Roberts Park and at The Crest of Bankstown). It is also believed that the RTA planted some plants along the M5 Motorway, which were taken from plants lost during its construction... There are also *ex situ* plantings of the species in Mount Annan Botanic Garden, the Australian National Botanic Gardens and the Burrendong Arboretum. The species is sold in some commercial and Council nurseries…" (NPWS, 2003a). Known plantings may be appear in general BioNet search results but should be clearly coded as such and will be shown with the annotation 'cv' (cultivated) in Herbarium records.

Two north-eastern outlying records of the species in the Central Coast region were also assessed. The northernmost has been corrected as it was apparently a data entry error. The other, east of Gosford is regarded as a planting or naturalisation from a planting (the identification is supported by a vouchered specimen, but the habitat is considered illegitimate – Narrabeen Sandstone in or at least near wet sclerophyll forest). NPWS (2003a) sensibly dismisses a reference to the species at the junction of Yalwal and Ettrema Creeks in Morton National Park as a likely misidentification of *A. irrorata*. That record no longer appears in BioNet.

The northern-western limit of the species at Mountain Lagoon (referred to by some as Bilpin) remains the same as described in NPWS (2003a, b). However, a review of BioNet data, particularly that from the Royal Botanic Gardens Sydney Database, revealed that there were numerous records spread across that area and beyond, yet there is only one actual location where the species occurs at that locality. Explanations for the spread of those records, most of them in unsuitable habitat for the species, include generalisation of records due to the use of coarse resolution co-ordinates, plus what appear to be data entry errors when co-ordinates were entered into one of the databases. A record from nearby ‘Bilpin’ is likely to also be from Mountain Lagoon, and a record from Scheyville that plotted incorrectly south of Bilpin has been corrected. The Mountain Lagoon population was confirmed by me in early December 2018.

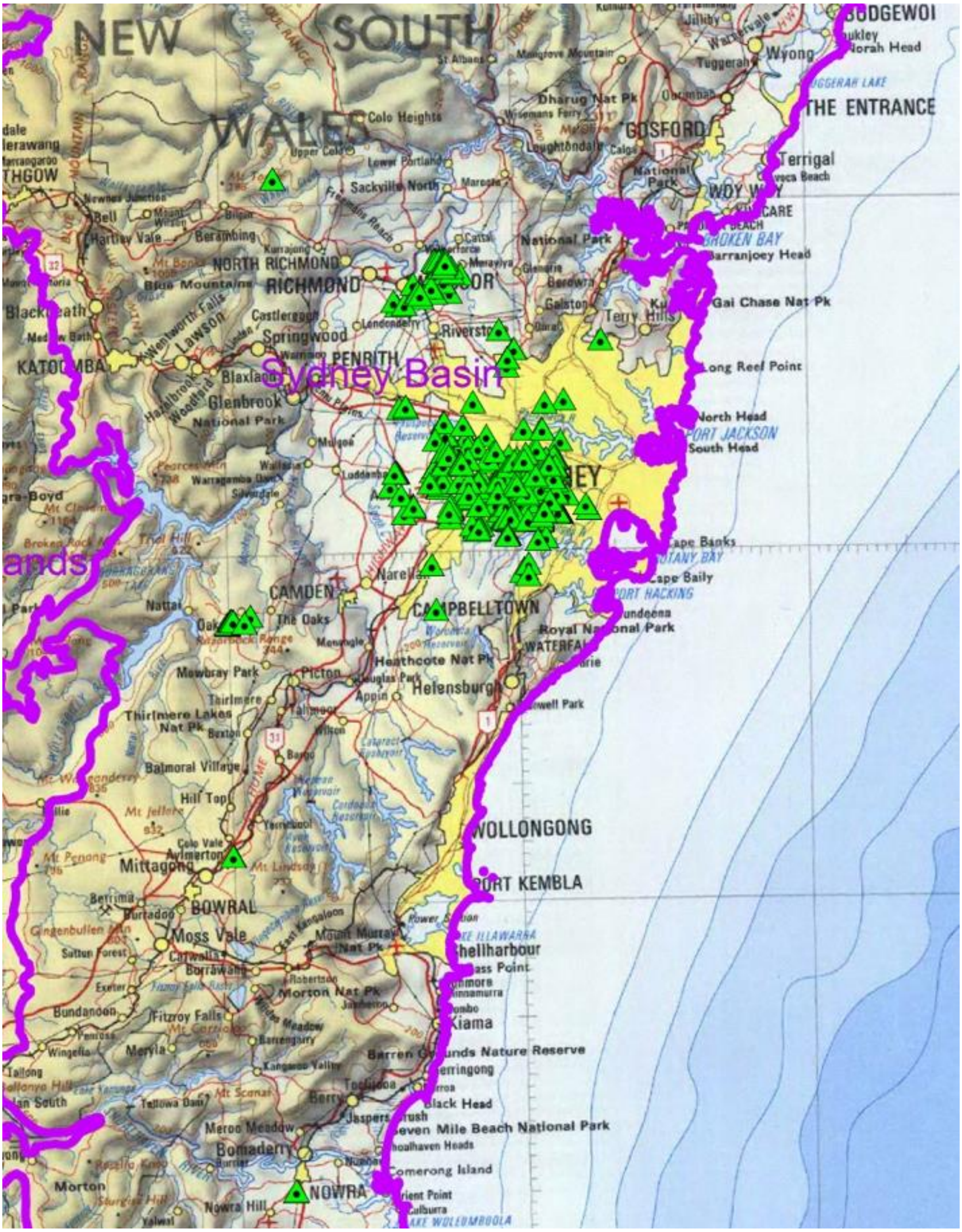
The south-western limit of the species is still the Macarthur district (The Oaks) in the form of several records within one scattered population. The easternmost record is at Bardwell Creek (1999). It was rediscovered, and its location was more accurately recorded in 2012. A ‘1770’ collection from ‘Port Jackson’ plots on South Head but will likely be from much further inland, probably close to the Parramatta River where other collections have been made. South Head is not a legitimate eastern limit for the species and is inappropriate habitat. That record has since been moved to the nearest known population as part of the data cleansing process. A new north-eastern extant limit was documented in 2009 from North Turramurra and is accepted to be valid.

The now quite dated Recovery Plan for this species (NPWS, 2003a) reports, “*Acacia pubescens* has been recorded from 195 sites and is currently known from 151 of these. Although the species is known from a large number of sites, a high percentage of these (51%) consist of populations of fewer than 20 ramets (or ‘clones’). Most of these populations are subject to numerous threats.”

The range of Downy Wattle prior to European settlement is likely to have been similar to the current extent, however considerable losses from within this range have occurred. This is particularly evident within the Sydney region. It is likely that many more populations or subpopulations have been destroyed by the clearing of habitat, prior to their discovery. “Habitat loss is a major issue in Western Sydney. Over 90% of the original distribution of vegetation in the region has been cleared (NPWS, 1997). Eleven of the sites recorded on the Atlas for NSW Wildlife (as of 1998) no longer contain *A. pubescens*. Most of these sites have been lost to residential development. Many old records indicate that the species occurred in locations that have now been developed, such as Georges Hall, Belmore, Cabramatta, Chester Hill and Warwick Farm” (NPWS, 2003a). It is likely that approval has been granted by authorities to the destruction of some of the known populations since 2003, though previously undocumented populations are also likely to have been found, primarily towards the edges of its range where pressure for habitat removal and thus survey effort is likely to have been historically lesser.

Some translocation projects are known to have occurred. In the absence of an updated Recovery Plan or component information, it is not known how many populations are extant, and what the estimated total population size is. It is important to note that because the species is clonal, most population ‘counts’ are estimates because it is often very difficult to determine the number of individuals without genetic testing or potentially destructive sampling. NPWS (2003a) uses a separation distance of 300 m to arbitrarily define individuals.

Most of the Plant Community Types (PCTs) that are significantly associated with this species in the Growth Areas are Threatened Ecological Communities ranging from Critically Endangered to Vulnerable, with some having different status under NSW and Federal law. Some of the other PCTs that are known habitat for this species are also threatened by historic and on-going clearing and degradation, and by inadequate reservation.



Map 2. Cleaned BioNet data (extracted 26/11/18)

NB, each point may not designate a collection or observation at that location, as most very old records lacked any co-ordinates, or only supplied coarse co-ordinates, and may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

2.3.1 Reservation status

NPWS (2003a, b) state that "Only five of the 151 known sites (of the species) occur within conservation reserves (Scheyville National Park and Windsor Downs Nature Reserve)." As of 2018, there are currently only two records of the species in Windsor Downs Nature Reserve, and both are on the northern edge of the reserve, adjoining an established urban area. There are many more records from Scheyville National Park and on an adjoining Crown road reserve. Since 2003, Prospect Nature Reserve has been declared and incorporates three records of the *A. pubescens*. The species is also now known from Western Sydney Regional Park (4 records in the reserve, several just outside).

NPWS (2003a) note that some NSW Herbarium specimen records of the outlying population at Mountain Lagoon say that they were obtained in Wollemi National Park, but NPWS could only locate the species at one site on land then owned by the Department of Land and Water Conservation (DLWC) i.e. not in the National Park. Part of the problem in this instance is that historically, there have been numerous records of the species incorrectly plotted around the Mountain Lagoon locality and beyond. When reviewed as part of the BioNet data cleansing project funded by DPE, the large number of records from this locality were interpreted to have all been collected at the one readily detected roadside site – the one verified by NPWS in 2003 as part of the Recovery Plan. All BioNet records of the species (and NSW Herbarium records) have since been moved to that location which was checked by me and confirmed to be in what is now NPWS estate. The former DLWC portion appears to have been added to the National Park since 2003. Searches for this species at the locality of Mountain Lagoon on and near trails in NPWS estate resulted in no new occurrences being detected (Goosen, N. and Monahan, D. [NPWS] pers. comm. 2018).

A. pubescens also occurs in numerous Council reserves, though some of these are known to entail outright plantings (NPWS, 2003a) or augmentation plantings. BioNet data suggests that the greatest number of apparent plants on public land occur within Council reserves, though this may be at least in part a result of increased survey effort in those areas. NPWS (2003) also notes that a population at Rookwood Cemetery and another at Liverpool Showground are subject to protective management.

The species is present in a Biobanking offset site on former Defence Department land at Moorebank, and may be present in other such areas, but this information was not provided by OEH. Information about other reserved populations in Biobanking offset / stewardship sites was requested from the Biodiversity Conservation Trust that now administers such areas. DPE has since advised that it has been provided with that information but is unable to provide it to me due to confidentiality constraints.

2.4 Habitat

2.4.1 Geology and soil

Acacia pubescens occurs on Paleogene-Neogene and Quaternary alluviums; on Wianamatta Shale; at the interface between it and Hawkesbury Sandstone (including the Mittagong Formation); and in one atypical instance, on a clayey variant of Permian Nowra Sandstone. Occurrences associated with the Wianamatta Shale / Hawkesbury Sandstone interface tend to represent the limits of the species' distribution where the once-more extensive shale soils are eroding. The majority of occurrences are associated with Paleogene-Neogene alluvium (including Londonderry Clay, Rickabys Creek Gravels) and its interface with Wianamatta Shale. Associated soils can be gravelly, often with ironstone i.e. laterite (*sensu* Martyn, 2018). Soil Landscapes include but are not limited to Berkshire Park; Blacktown, Luddenham, Glenorie; Faulconbridge; Lucas Heights; South Creek, Birrong, Richmond; and Nowra.

"The topography of the habitat of the species is flat to gently undulating: a characteristic of the Cumberland Plain region. The sites of *A. pubescens* range in altitude from 0 to 650 metres a.s.l." (NPWS, 1998 cited in NPWS, 2003a). This information remains broadly correct. It appears that in 1998, NPWS already regarded the Southern Highlands outlier as legitimate (the specimen was collected by a NPWS staff member), as it is the only population to occur anywhere near as high as 650 m elevation (the altitude is ~550 m).

2.4.2 Associated vegetation communities and NSW TECs

The species “occurs in open woodland and forest, in a variety of plant communities including Cooks River/Castlereagh Ironbark Forest, Shale/Gravel Transition Forest and Cumberland Plain Woodland” (OEH, 2017). All of these are Threatened Ecological Communities (TECs). According to the OEH Threatened Species Database, NPWS (2003a), and analysis undertaken for this Report, additional TECs that should be mentioned in the OEH profile include Shale/Sandstone Transition Forest, and Castlereagh Scribbly Gum Woodland. The strong correlation between this species and TECs is an indication of how threatened its habitat is. The species is also known from plant communities that are not currently TECs, but those associations are relatively weak. These are discussed later in this Report.

“Stands of *A. pubescens* have been recorded in open, disturbed areas, surrounded by exotic species. Although these areas are clearly not the natural habitat of *A. pubescens*, the species may survive in these situations for many years, due to its suckering nature and ability to tolerate some levels of disturbance. These areas are important as they provide information as to the original extent of the species and they may contain examples of genetic variability that have been lost elsewhere” (NPWS, 2003a). In a particularly acute example of the species’ resilience, in 1999, the species was found surviving in tiny pockets of remnant habitat within a formal carpark at Fairfield Showground. Many such small and/or significantly modified habitats are not mapped as native vegetation.

The OEH Threatened Biodiversity Data Collection (July 2018) listed the following Keith vegetation classes as being associated with *A. pubescens*:

- Coastal Valley Grassy Woodlands;
- Cumberland Dry Sclerophyll Forests;
- Northern Hinterland Wet Sclerophyll Forests;
- Sydney Coastal Dry Sclerophyll Forests;
- Sydney Hinterland Dry Sclerophyll Forests;
- Sydney Sand Flats Dry Sclerophyll Forests; and
- ‘Highly disturbed areas with no or limited native vegetation’.

Associations between a species and Vegetation Classes and Plant Community Types (PCTs) in the Threatened Species Data Collection were determined by the species’ Accountable Officer within OEH some years ago, and staff were required to take a relatively inclusive approach in accordance with the precautionary principle (Steenbeeke, pers. comm.). This may mean that for some species, Vegetation Classes and PCTs have been associated with them even though there is little or no empirical evidence to support that, but where the officer believed that these attributes credibly represent *potential* habitat. Given the limitations of vegetation mapping and that in most cases, survey effort for threatened species is incomplete across their range, such an approach is understandable.

It appears that in some cases, the associations with Vegetation Class and PCTs in the Threatened Biodiversity Data Collection may have been amended after the assignments described above, and that some more recent associations may be influenced by spatial errors in species’ records and/or errors in or limitations of vegetation maps. In this case, the link to Northern Hinterland WSF is unsound and most likely produced by an invalid northern outlying record of the species. OEH was advised of this and related issues in mid-July 2018. Some such errors have since been rectified through the BioNet data cleansing process undertaken as part of DPE’s assessment of the effects of biocertification on threatened species.

An assessment of the association between *A. pubescens* and PCTs was undertaken to better understand the potential habitat for this species in terms of plant communities. The assessment is constrained by limitations of BioNet data and available vegetation maps. The assessment of the species' relationship with PCTs in and near the Cumberland Subregion used OEH vegetation maps that were publicly available at the time and did not use the updated vegetation maps produced within the Growth Areas by the biocertification process. The information is used to generate 'species polygons' (maps of potential habitat) as required under the BAM. Whilst DPE required habitat associations to be graded i.e. strong to weak association with particular PCTs, only ungraded PCT association data was used to generate the species polygons.

Some records of the species were seen to not be spatially associated with a PCT. This may be because:

- the record occurs in a site now cleared of native vegetation or too degraded to be captured by mapping;
- because the record is too spatially uncertain, so has been assigned generic co-ordinates, usually in a named town or suburb, and such settled areas often lack remnant native vegetation; and/or
- the record plots just outside an area of mapped vegetation because it is on a road verge, and even most GPS records are only accurate to 5m, meaning it could plot on the road, not on the vegetated verge.

To overcome this latter problem, those records were assigned a 10 m buffer so that they would associate with the nearest mapped vegetation polygon up to 10 m from the plotted location.

A further consideration is that survey effort for the species is not evenly distributed across the area subject to analysis. Some sites of potential habitat have had very little or no effort, often due to tenure constraints, yet others have had every apparent plant recorded (mostly in reserves or as part of ecological impact assessments). This creates very substantial biases in the data, which can create misleading weightings of association between the species and particular PCTs.

Most records do not include population data, meaning that a record might relate to one apparent plant or to many: a situation significantly compounded by the clonal nature of this species such that many apparent plants may be one individual. Furthermore, not all occurrences have been subject to intensive surveys that record all apparent individuals. This can cause a bias in the apparent strength of association between a PCT and the species. In short, this analysis is best used only for presence/absence i.e. whether the species has been recorded at a point that is mapped as a particular PCT, or not. Analysis beyond that is very constrained by deficiencies and biases in the datasets, especially in BioNet data.

The analysis of association with PCT in Table 2 deals only with records in the Cumberland Subregion plus a 10 km buffer. Records that associate with a PCT when a 10 m buffer is used are included in the counts of sightings below and are not shown separately. Two analyses were undertaken: All records in the target area without regard to spatial Accuracy score; and only records in that area with Accuracy score of 100 m or better. The latter analysis is considered more reliable, but both sets of figures are provided. Sightings with Accuracy <=100 m are shown in square brackets **[ ]** and in bold text. Where available, the combined count of individuals associated with the records is provided in parentheses { }. Those counts relate only to records with Accuracy <=100 m. Where a record doesn't contain population data, it is assumed to relate to a single plant.

Only PCTs mapped in the Growth Areas are dealt with in Table 2. This can mask associations between the species and PCTs that occur elsewhere. Because of the concentration of occurrences on the Cumberland Plain, this effect is largely limited to outlying and atypical populations beyond the Cumberland Subregion.

In the raw data, some PCTs can appear to have a greater or lesser association than is actually the case. PCTs 850 and 1181 have been excluded from Table 2 and are not regarded as potential habitat for the species on the basis of there being too few records mapped in those PCTs, and on known habitat parameters. The very few records that the raw data showed to be associated with those PCTs are likely a result of spatial errors in the records or spatial or other limitations of the vegetation maps. Additionally, there are 68 records of the species in Mangrove Forest, 4 in Coastal Lagoons, and 2 in Saltmarsh, yet the species does not occur in any of those communities. Consequently, all such occurrences are excluded from the analysis in Table 2, though some regard has been given to the PCTs in which those records most likely occur, and this has been used in the weightings afford to PCTs in the column 'Adjusted relative association'.

TABLE 2 – BioNet records of *A. pubescens* and counts of individuals relative to mapped PCTs

PCT	PCT Name	Associated TECs (NSW BC Act)	% Cleared (VIS)	Sightings & Population	Relative association	Adjusted relative association#
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Shale Gravel Transition Forest (E)	75	1887 **[1780]** {10278}	Very High	Very High
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Cooks River/Castlereagh Ironbark Forest (E)	95	2240 **[2405]** {2930}	Very High	Very High
808	Derived shrubland on Tertiary Gravels of the Cumberland Plain	Shale Gravel Transition Forest (E) Cooks River/Castlereagh Ironbark Forest (E)	75-95 inferred from 724/725	Not mapped	Very High (inferred)	Very High (inferred)
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	River-flat Eucalypt Forest of Coastal Floodplains (E)	93	93 **[78]** {77}	Low	Low
849	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CE)	93	579 **[521]** {10262}	High	Moderate
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Castlereagh Scribbly Gum Woodland (V) Castlereagh Swamp Woodland (E)	50	33 **[33]** {2955}	Very Low	Very Low
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Not a TEC but some areas may be within Shale Sandstone Transition Forest (CE)	40	164 **[164]** {285}	Moderate	Low
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (CE)	80	5 **[3]** {155}	Very Low	Very Low

2.4.2 Associated Commonwealth TECs

The Commonwealth Department of Environment & Energy (DEE) Species Profile and Threats Database for *Acacia pubescens* (DEE, 2003) shows that an Approved Conservation Advice for this species was released in 2016 (TSSC, 2016). However, like the species' SPRAT webpage, this only reiterates content from the Recovery Plan and other NSW Government sources. The now quite dated (2003) Recovery Plan is relied upon to list the associated TECs, but only NSW-listed TECs are mentioned – not Commonwealth TECs. For this species, the NSW TECs with which the species is accepted to be associated are largely equivalent to or components of Commonwealth TECs. An exception is River-flat Eucalypt Forest of Coastal Floodplains, which does not have a Commonwealth equivalent.

2.4.3 Habitat condition

Degraded and significantly modified areas of the PCTs that are known or likely habitat for *A. pubescens* can still support it due to its ability to persist in the soil seed bank and as root suckers. Modified sites may have reduced or no canopy and/or midstorey, and/or reduced understorey and some weed invasion. Some may be dominated by shrubs in areas of regrowth after earlier clearing or 'under-scrubbing'.

This species is known to occur in highly modified sites such as slashed bushfire Asset Protection Zones, and road / trail and railway verges and corridors, and in former small-scale quarries or spoil dumps (NPWS, 2003a, 2003b; Kodela, 2016; Douglas, pers. obs.). Some forms of disturbance, even relatively severe forms that would be considered clearing of vegetation, appear to be beneficial to this species, within limits. This situation is recognised for numerous threatened plant species in and beyond the Sydney Basin Bioregion. It may be related to the fact that modern fire regimes are likely to be significantly different to those prior to 1788, and that some native animal species that had a role in seed dispersal and understorey modification are now extinct or regionally extinct.

The condition of potential habitat for this species is not a reliable indicator of the species' presence, and accordingly, **all vegetation condition states are considered in determining potential habitat,** i.e. intact, thinned, scattered, derived shrubland, and derived grassland. However, sites with long and intensive grazing history will be unlikely to retain the species.

3. Description of the study area

3.1 Landscape context and land use history

All of the Growth Areas have been significantly cleared for earlier activities, primarily timber production associated with opening areas for agriculture and pastoralism, minor areas of surface resource mining, and to varying degrees, for urban and commercial/industrial use. They are proposed to accommodate phased increases in urban land use, primarily within existing cleared or highly modified lands. Increased urban use is planned as a response to population growth.

3.1.1. Greater Macarthur Growth Area (GMGA)

The GMGA extends from Glenfield in the north to Appin in the south. It is largely within the Campbelltown LGA with the southernmost section within the Wollondilly LGA. The northern half comprises an urban renewal corridor centred on the Sydney to Southern Highlands railway line. It encompasses the existing industrial and residential suburbs of Glenfield, Macquarie Fields, Minto, Leumeah and Campbelltown. The GMGA is associated with extensively cleared, gently undulating shale terrain typical of the Cumberland Plain, and contrasts the sandstone gorges of the Woronora Plateau across the Georges River to the east. The northern portion of the GMGA is already substantially urbanised, with remnant vegetation largely restricted to creek-lines or small patches associated with designated open space. Vegetated creek-lines include Bunbury Curran Creek, Bow Bowing Creek, Leumeah Creek, Fishers Ghost Creek and Spring Creek.

The more extensive southern half of the GMGA, south of Rosemeadow, comprises proposed urban land releases at Menangle Park, Mount Gilead and Appin. Menangle Park and Mount Gilead are subject to separate planning processes, so are not within the scope of this biocertification. In the north-west, Mount Sugarloaf (213 m AHD) forms the southern end of a hilly ridge on the Luddenham Soil Landscape above the Menangle floodplain that extends north to Denham Court, then to Cecil Hills and Prospect Hill. Some native vegetation persists, although it is often invaded by African Olive. The floodplain is dissected by Menangle Creek and its tributaries, including Nepean Creek, Woodhouse Creek and Leafs Gully.

The southern GMGA is primarily semi-rural and agricultural land, with creek corridors and some larger patches of remnant vegetation located between the Nepean and Georges Rivers. Geologically, the area comprises gently undulating hills on Wianamatta Shale intergrading via a shale sandstone transitional zone (can include the Mittagong Formation) with steeper and infertile terrain on Hawkesbury Sandstone along the rivers. Transitional and sandstone geologies are sometimes exposed along the smaller creek lines.

3.1.2. Wilton Growth Area (WGA)

The WGA is a relatively smaller area that occurs to the south of the GMGA, extending from the vicinity of Douglas Park in the north, Maldon in the north-west, and beyond Wilton in the southeast. The boundaries closely follow the Nepean River in the north and west, a tributary Allens Creek in the east, and the Cordeaux River in the south. Away from the Nepean River and gullies, a higher, gently undulating zone has been largely cleared for agriculture. The Woronora Plateau forms the southern boundary and includes the northernmost section of the large Upper Nepean State Conservation Area, with unreserved but closed areas of the Water NSW Special Area (Sydney water supply catchment) extending to the east and southeast. The Hume Motorway dissects the WGA roughly north to south, and Picton Road traverses it roughly northwest to southeast.

The WGA includes both shale, shale sandstone transition and sandstone environments. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The flatter shale terrain has soils of the Blacktown Soil Landscape, which is derived from Ashfield Shale (a member of the Wianamatta Group), and typically supported the now Critically Endangered Cumberland Plain Woodlands. Much of this area is cleared or modified for agriculture and hobby farms. It comprises native/exotic grassland with smaller areas of Derived Native Grasslands in relatively better condition. Areas above the gullies feature soils of the Lucas Heights Soil Landscape derived from the Mittagong Formation (a transitional bed between the Wianamatta and Hawkesbury Groups). These support variable shale sandstone transition woodlands and forest, some of which are also Critically Endangered. In the steeper gullies, the Hawkesbury Soil Landscape dominates, and supports Hawkesbury Sandstone Gully Forest types with Ridgetop Woodlands on some of the upper slopes.

3.1.3. Greater Penrith to Eastern Creek Growth Area (GPECGA)

The GPECGA is a relatively large area that extends from Rooty Hill, Minchinbury and Hassell Grove in the east, across the Cumberland Plain to the Hawkesbury-Nepean River in the northwest, then south through Jamisontown, Glenmore Park, to the intersection between The Northern Road and the Warragamba Water Supply Pipelines in the far south-west.

The predominant geology is Wianamatta Shale on flat to gently undulating terrain that has been extensively cleared for agriculture, and later for housing and industrial use, with some remnant vegetation on current and former Defence holdings. The shale soils support(ed) Cumberland Plain Woodlands. Overlying the extensive shale deposits are small areas of weathered Paleogene-Neogene alluvium e.g. Shalvey and Willmot, that are much more common to the north. These support(ed) the Castlereagh Forests & Woodlands complex of vegetation types, which is strongly associated with several threatened plant species. More common are broadly linear deposits of Quaternary alluvium along watercourses such as South Creek and Eastern Creek, and on the flood terraces of the Hawkesbury-Nepean River. Other lithologies occur but are very rare and of very small extent.

Very little of the GPECGA is reserved in NPWS estate. Wianamatta Regional Park (which emphasises recreational uses) encloses small areas of former Defence land in the far north. Adjacent to the southwestern boundary is the small Mulgoa Nature Reserve (emphasises biodiversity values). Two Biobanking sites adjacent to the Nature Reserve have increased the area under conservation.

3.1.4. Western Sydney Aerotropolis Growth Area (WSAGA)

The WSAGA abuts the GPECGA's southernmost border near the locality of Sovereign (east of Mulgoa), then extends south past Greendale, northeast to the locality of Badgerys Creek, east to Kemps Creek, and northward to the vicinity of Mount Vernon, excluding Twin Creeks Golf Course and associated settlement.

The lithology and soils are broadly similar to that of the GPECGA, being effectively just an extension of that area to the south to incorporate the developing Badgerys Creek Airport and environs. The area is even more severely cleared of native vegetation, except along some streams and on rare occurrences of steeper terrain. It contains no NPWS reserves, with the nearest being the small Kemps Creek Nature Reserve, outside the Area to the southeast. Gulguer Nature Reserve and Bents Basin State Conservation Area occur to the southwest of Greendale.

3.2 Geology and remnant vegetation

All of the Growth Areas are within the Cumberland Subregion. The dominant lithology across all of the Growth Areas is Wianamatta Shale (Ashfield and Bringelly Shales), with much smaller areas of Paleogene-Neogene alluvium occurring largely outside these boundaries, and much larger areas of Quaternary alluvium associated with floodplains of the many watercourses (*sensu* Martyn, 2018).

The terrain varies from almost flat through to steeply hilly areas associated with minor volcanism and more often, in association with shale ranges. In the far south, the more elevated shale landscapes have been eroded down to the underlying Hawkesbury Sandstone in a series of gullies and gorges. A transition zone between the shale and the sandstone is discernible in some areas.

On the dominant shale geology, the associated Critically Endangered Cumberland Plain Woodlands are still present in all of the four Growth Areas but have been disproportionately cleared for rural and later urban and allied uses. Much of what remains of this ecological community occurs as paddock trees and areas of remnant native ground-layer vegetation in pastoral and other contexts, with the exception of some substantial, though fragmented and isolated remnants. Remnant vegetation in these relatively fertile and arable landscapes is often in poor condition. In the most heavily cleared areas, it can be restricted to strips along watercourses. Some forms are dominated by *Casuarina* species. Weeds are common and sometimes severe in the moister situations. Weeds often extend into higher and drier terrain, especially in the form of African Olive and African Love Grass, both of which can occur on a landscape scale.

Small areas of the biodiverse Castlereagh Forests & Woodlands persist in all but the Wilton Growth Area on often-laterised Paleogene-Neogene alluvium. These variable woodlands and open forests support a particularly high number of threatened plant species, and because their soils are less suitable for agriculture and grazing, are better conserved than the Cumberland Plain Woodlands. Nonetheless, they are all listed as threatened ecological communities.

In the two southern Growth Areas, vegetation of the shale sandstone transition zone is relatively common and tends to remain in less arable areas adjoining the largely cleared former Cumberland Plain Woodlands. It is often found fringing the largely uncleared sandstone-based terrain, and ranges from highly intact to significantly modified and degraded, largely due to grazing and weed invasion. The associated Shale Sandstone Transition Forest is recognised as Critically Endangered due to extensive clearing across its substantial range, and because of the severity of other threats. Very little is present in formal conservation areas.

In the two southern Growth Areas, diverse, sandstone-based vegetation persists in association with most of the many incised watercourses. This vegetation is broadly the same as what occurs in extensive conservation estate around urban Sydney, but some communities adjoining current or former Shale Sandstone Transition Forest are not well-conserved and are threatened by further clearing and degradation.

3.2.1 Plant Community Types

The following section lists the Plant Community Types mapped in each Growth Area with brief notes about their distribution in those Areas. The list is not restricted to PCTs associated with *A. pubescens*.

3.2.1.1 Greater Macarthur Growth Area (GMGA)

The predominant ecological communities in the GMGA are or were Cumberland Plain Woodland (CPW), Shale Sandstone Transition Forest (SSTF) and River-flat Eucalypt Forest (RFEF), all of which are Threatened Ecological Communities. All have been extensively cleared and degraded, primarily by agriculture and weed invasion, but also by urban and allied uses. There are no NPWS reserves in this Growth Area. However, the very small Leacock, Edmondson and William Howe Regional Parks occur just outside the border and are managed primarily for recreation rather than conservation. Dharawal State Conservation Area and National Park border the southern portion of the Growth Area to the east. A summary of the mapped ecological communities is found in Table 3. The maps used here are based on OEH products that have been updated by Biosis for DPE.

Table 3. Summary of all ecological communities within the Greater Macarthur Growth Area

PCT	PCT Name	Distribution & notes
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Small patch at Menangle Sugarloaf on SE slopes.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Along creek lines in shale areas in northern and central parts of GMGA.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Small patches on shale soils throughout GMGA but mostly in northern and central parts.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches on shale soils throughout GMGA, more common in southern parts on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	4 polygons, Macquarie Fields, most of which have long been historically mown (Milton Park Softball Complex). They are now subject to regeneration.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	One small occurrence mapped around the margins of bushland associated with Smiths Creek at Leumeah.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Nepean River north from Menangle Bridge.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Narrow zone along Nepean & Georges Rivers and tributary gullies and a small zone along Smiths Creek at Leumeah.
1292	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Restricted to parts of the riparian zones of the more incised and larger watercourses. Very restricted extent in this Area.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Relatively small remnants extend south from Glenfield; extensive on transitional soils mostly south from Rosemeadow. Can intergrade with 849 and 1081.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Only mapped to a very minor extent as highly linear remnants between Glenfield and Macquarie Fields (along the railway) and at Ingleburn (adjoining roads).

3.2.1.2 Wilton Growth Area (WGA)

The predominant ecological communities in the WGA are or were Cumberland Plain Woodland (CPW) and Shale Sandstone Transition Forest (SSTF) both of which are Threatened Ecological Communities. Sandstone-based communities occur in and surrounding the more incised watercourses. There are no NPWS reserves in this Growth Area, though Upper Nepean State Conservation Area occurs immediately to the south. There is a Biobanking site on the northern side of the river near Douglas Park (within the WGA), and three more such properties to the immediate north (including St Marys Towers) and those associated with coal mines (Steenbeeke, pers. comm.).

Table 4. Summary of all ecological communities within the Wilton Growth Area

PCT	PCT Name	Distribution & notes
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	On shale soils of higher, gently undulating terrain of northern and central areas. Small patches with scattered trees (farming properties) adjoining more extensive exotic and native grasslands.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	One patch in a derived grassland (treeless) condition in the west, and a much larger portion in the far north.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Limited to a few patches in the north between 1395 on plateau edges and 1181 in sandstone gullies.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Common on slopes and plateau edges above and around incised sandstone-based watercourses that surround most of the Area.
1292	Water Gum – Coachwood riparian scrub along sandstone streams	Restricted to a very narrow riparian strip along the Nepean River.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	The most extensive community on shale sandstone transition soils between 849/850 and sandstone communities along gullies. Variable floristics.

3.2.1.3 Greater Penrith to Eastern Creek Growth Area (GPECGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Shale Gravel Transition Forest and Castlereagh Forests & Woodlands. River-flat Eucalypt Forest was previously much more extensive along the Hawkesbury-Nepean River and adjoining primary floodplain, and it remains to varying degrees along many watercourses such as Eastern Creek, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. There is one NPWS reserve in this Growth Area: Wianamatta Regional Park, however it is already significantly fragmented and may be required to potentially accommodate a large transport corridor. The small Mulgoa Nature Reserve and associated Biobanking sites occur near the south-western border of this Growth Area. Yarramundi SCA occurs on the western boundary but across the Nepean River, and Wianamatta NR occurs near the NW corner.

Table 5. Summary of all ecological communities within the GPECGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Scattered as small remnants and one larger remnant in the central portion, but with greater extent in the central north, mainly in the western ungazetted portion of Wianamatta Regional Park.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	A few very small remnants present south of the M4, with larger remnants within and near the gazetted and ungazetted portions of Wianamatta Regional Park.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northwest, with some small remnants in the southwest, often associated with watercourses.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Present to a very minor extent on the southwestern edge adjoining Mulgoa Nature Reserve
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains through the south and central areas.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Common in and near Orchard Hills in the south, and former ADI lands in the central north, with some areas in the ungazetted portion of Wianamatta Regional Park. Other scattered remnants, particularly in the east.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches in the south west, primarily in pastoral settings and on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Restricted to one linear polygon in the eastern portion of Wianamatta Regional Park.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Hawkesbury-Nepean River, primarily near Penrith Lakes.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Present as mostly-linear remnants along South Creek and Eastern Creek and tributaries, with some scattered occurrences, including along the M4.

3.2.1.4 Western Sydney Aerotropolis Growth Area (WSAGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Castlereagh Forests & Woodlands near the localities of Kemps and Badgerys Creeks, and potentially in the vicinity of the water pipeline crossing of Luddenham Road. Riverflat Eucalypt Forest remains to varying degrees along most watercourses, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. Swamp Oak Forest occurs mainly along South Creek and some tributaries. There are currently no NPWS reserves in this Growth Area. The small Kemps Creek Nature Reserve occurs just outside the south-eastern corner and Gulguer Nature Reserve and Bents Basin State Conservation Area are near the south-western corner.

Table 6. Summary of all ecological communities within the WSAGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Restricted to the Kemps and Badgerys Creek area as three patches of remnants.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	As above: two patches with smaller remnants nearby and on slightly higher ground than 724.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northeast, with one remnant in the centre.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains but very little remains, and most occurrences are linear.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	The most common PCT in this Area, with remnants throughout on the dominant shale terrain.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Only very small patches in the far south.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain and Hunter valley	Present as mainly very linear remnants along most watercourses but largely absent from the southernmost portion.

4. Assessment of species' presence and suitable habitat

4.1 Existing records and surveys

The principal source of threatened flora records in NSW is the OEH BioNet database, which includes most records held by the NSW Herbarium (specimen-based), as well as sightings, including those associated with vegetation sampling for the purposes of mapping. Other databases, such as Atlas of Living Australia, largely mirror BioNet data within NSW, but are not used in this Report due to their having lower data quality control, and because they do not allow even a registered user to access data that may not have been generalised to obscure the exact location of a record. Very few flora records that are in ALA but not in BioNet are original – most are simply replicate records based on specimens held in other herbaria.

The preliminary assessment of threatened species records undertaken for the preparation of this Expert Report reiterated the merit of reviewing BioNet data and resolving a range of errors, rather than simply using data 'as held'. *Acacia pubescens* records within BioNet were reviewed, and numerous corrections were made, though the majority of these relate to the assigned spatial accuracy scores and to clarifying or correcting location placements and descriptions. Not all records were able to be checked in that stage, and a second review for records in or near the Growth Areas was conducted to further improve data quality. The reviews eliminated a range of errors and allowed many records that were otherwise too spatially vague, to be refined such that they were suitable for habitat modelling and for general reference. Not all records were reviewed, and inaccuracies remain in the dataset, but records are now far more accurate in terms of their identification of the species, their location, and their spatial accuracy score.

BioNet data should only be treated as indicative, not least because there has not been comprehensive survey of all of the Growth Areas or environs, and surveys have been variously constrained. The absence of records from an area does not necessarily mean the species is absent, as it may not have been surveyed there, or survey conditions and methods may have been inadequate.

Field survey undertaken by consultancy firms engaged by DPE (Biosis and Ecoplanning) did not add any records of this species. Fellow botanists engaged by DPE to prepare Expert Reports also reported that no new records of this species were found by them.

4.1.1 Existing records by Growth Area

Acacia pubescens records in Greater Macarthur Growth Area

There is one duplicated record (NSW Herbarium and Wildlife Atlas) in this Growth Area. It is a 1960 collection that only gives the location as 'Minto'. This record was reviewed and given a 5000 m spatial accuracy to reflect the potential spatial variability within this suburb. There are no modern or spatially accurate records from this Growth Area, but there are several just beyond the northeast corner within current and former Defence Department land at Moorebank / Holsworthy. Part of this population is now within a Biobank reserve. There are also several records from an industrial area in Prestons, just north of the northern end of the Growth Area. There is one record near the central eastern boundary of the Growth Area at Kentlyn.

Acacia pubescens records in Wilton Growth Area

The species has been never been recorded within or near the WGA. The nearest records are approximately 14, 19 and 24 km from the WGA boundary to the northwest, northeast, and southeast. There is no apparent reason that the species could not occur here, as there are PCTs that the species is known to occur in. However, outside its core range on the Cumberland Plain, the species appears to be very sparsely distributed, with substantial distances between what are now quite disjunct remnant populations. This Growth Area may be naturally devoid of this species, or it could be present in unsurveyed habitat or in seedbank.

Acacia pubescens records in Greater Penrith to Eastern Creek Growth Area

There are seven records of the species in the southeast of this Growth Area. Some are duplicates or capture separate apparent plants at a scale finer than the resolution of GPS units used to record the sightings. All occur in the vicinity of the M4, Roper Road and Eastern Creek. There is only one location on the M4 in a small, thin section of remnant vegetation that has likely been subject to some supplemental planting. The other locations are associated with a very thin strip of apparently remnant vegetation bordering a large industrial site east of Eastern Creek off Sargents Road, Minchinbury. Some of the plants may be within Daraga Badu Reserve, but most of that land lacks tree cover, appears highly modified / degraded, and seems to be primarily associated with high voltage electricity easements and a floodway.

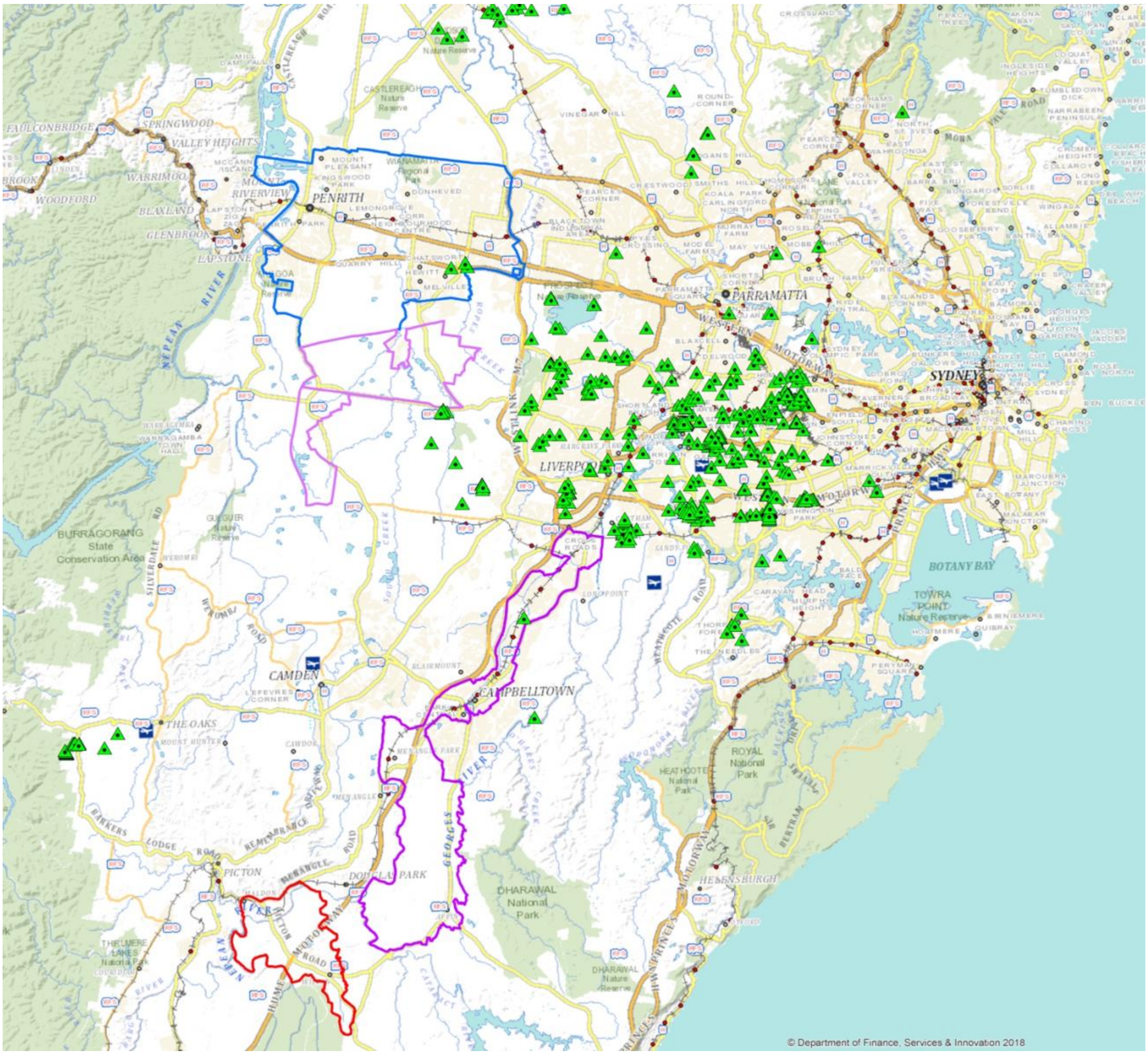
Acacia pubescens records in Western Sydney Aerotropolis Growth Area

The species is not currently known from this Growth Area but there are a small number of credible records immediately south of the Area's southeastern corner near Elizabeth Drive and Cross Street. All are associated with an isolated remnant of Paleogene-Neogene alluvium. Equivalent habitats occur north of Elizabeth Drive within the Growth Area but have been excluded from biocertification.

4.1.2 Prior surveys within each Growth Area

There is no central or local registry of surveys and survey effort for threatened biota, and a large proportion of survey reports are not made public or only made public when lodged with a planning consent authority. This makes it extremely difficult, if not impossible to compile a list of surveys, methods and findings across the study area.

The OEH Authorised Officer for *A. pubescens* was contacted in this regard. He advised that he does not hold a record of this information, so I contacted the manager of threatened biota matters in the Greater Sydney OEH office for further assistance. She committed to providing the relevant information by consulting key staff. I was included in the associated emails. No additional information about this species was provided.



Map 3. BioNet records (cleaned as of 26/11/18) relative to the Growth Areas

NB each point may not designate a collection or observation at that location, as most very old records lacked any co-ordinates or only supply coarse co-ordinates, and they may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

A BioNet map of the species' distribution gives a generally accurate indication of its known range, but not the extent of potential habitat. Large areas of private or corporate tenure have not been subject to the same level of survey effort as more accessible areas. An absence of records of the species where potential habitat remains should not be taken to indicate that the species does not occur there.

4.1.2 Prior surveys within each Growth Area

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4.2 Summary of survey work undertaken for the biocertification assessment

4.2.1 Vegetation mapping

Vegetation mapping of the Cumberland Subregion was completed in stages by OEH in 2013 and 2016. These two vegetation layers have been used as the base to compile an updated vegetation community layer for each of the Growth Areas. This updated work has been completed by Biosis under contract to DPE. The mapping update includes checking plant community types and confirming the accuracy of boundaries to account for clearing or regrowth that may have occurred since the original mapping was completed. Field verification of the mapping was undertaken by Biosis and Ecoplanning, both of whom undertook vegetation surveys where access was permitted.

Vegetation in the Growth Areas was mapped and assessed based on five vegetation condition classes:

- Intact;
- Non-offsettable Grassland;
- Offsettable Grassland;
- Scattered Trees;
- Thinned.

4.2.2 Field survey effort

The information in section 4.2.2 has been provided by DPE but has been edited here to only deal with threatened flora where feasible. Further details are provided separately by DPE:

An initial 726 letters were sent to landholders within the Wilton and Greater Macarthur Growth Areas in late 2017 with a second letter following in March 2018. To increase the response rate, Biosis commenced targeted door-knocking in May 2018. From this, just under 20% of landholders within these Growth Areas allowed access to their property. However, this included access to large parcels of land owned by major developers, which allowed a reasonable amount of access, particularly for the Wilton Growth Area.

Floristic plot data collected:

- Wilton (86 plots across 6 PCTs)
- Greater Macarthur (82 plots across 9 PCTs)

Approximately 150 of the plots required to meet BAM requirements were obtained by supplementing Biometric plots from various recent assessments. This involved locating the previous plots and collecting additional data on stem classes, number of large trees, and litter cover to meet BAM requirements. The ecologists had no trouble locating the original survey sites and found that the additional data was quick and easy to collect (approximately 30 minutes per site). The remaining plots in Wilton and Greater Macarthur, and all of the plots in Western Sydney Aerotropolis and Greater Penrith to Eastern Creek consisted of new plots surveyed for this project. All plots were sampled according to the methods prescribed by the BAM Manual (OEH 2017). This includes collecting information on species cover and abundance from 20 x 20 m or equivalent configuration plots within each vegetation zone.

A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Growth Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council.

Floristic plot data collected:

- Western Sydney Aerotropolis (53 plots across 6 PCTs)
- Greater Penrith to Eastern Creek (26 plots across 7 PCTs)

Targeted survey for threatened species

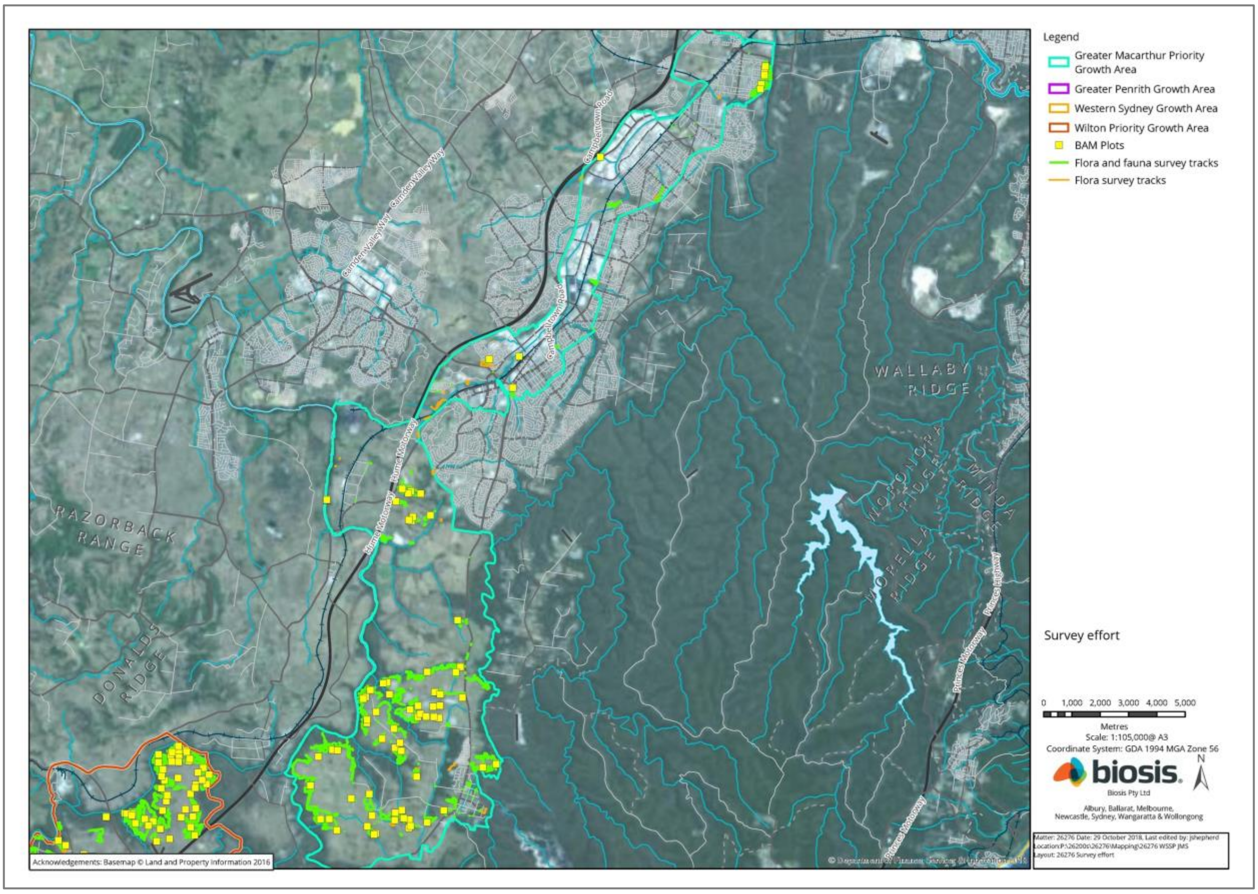
Targeted survey for threatened plant species has been conducted on lands where access has been granted. Vegetation transects and random meanders for threatened flora was conducted by Ecoplanning and Biosis in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey has included effort through each PCT and vegetation zone and has extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m).

Likely habitat for most threatened flora species comprised areas of lower disturbance. This includes areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora.

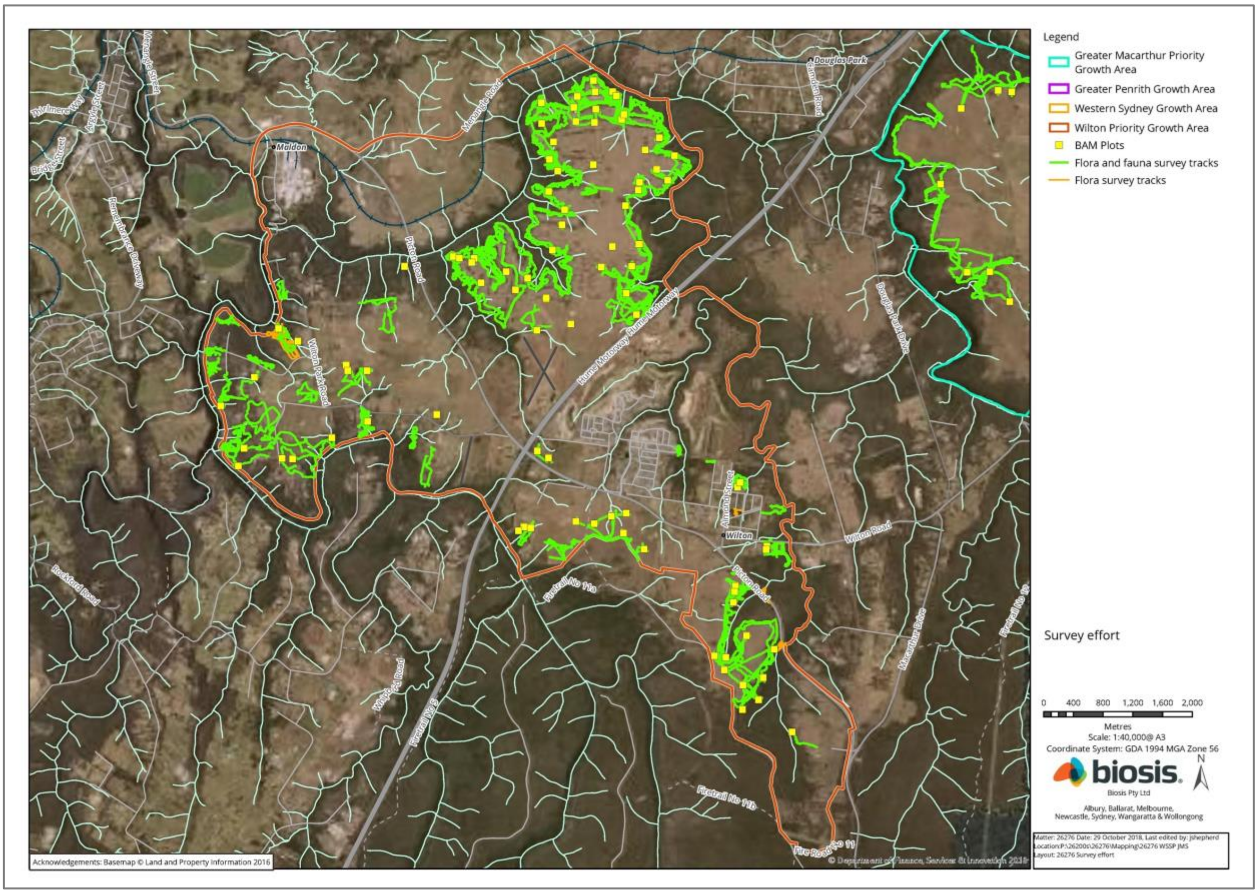
Table 7. Survey effort for threatened plant species *and* fauna habitat by PCT

PCT No.	Area of PCT in Growth Area (ha)	Area of PCT in urban zone (ha)	Field survey area (ha)	Percent of PCT surveyed within Growth Area (%)	Percent of PCT surveyed relative to urban zone (%)
724	191.3	57.0	12.1	6.3%	21.2%
725	167.4	51.4	6.9	4.1%	13.4%
781	68.9	5.6	0.9	1.4%	16.8%
830	21.6	0.8	1.7	7.8%	206.5%
835	1175.8	287.3	30.5	2.6%	10.6%
849	3078.3	637.6	125.0	4.1%	19.6%
850	522.9	294.3	36.1	6.9%	12.3%
883	7.4	0.0	0.5	6.8%	
1081	74.2	0.0	0.2	0.3%	
1105	138.6	0.0	0.0	0.0%	
1181	780.7	0.2	39.6	5.1%	19794.4%
1292	39.8	0.0	0.3	0.7%	
1395	3326.6	486.9	483.4	14.5%	99.3%
1800	232.6	20.2	7.3	3.1%	36.2%
TOTAL	**9826.1**	**1841.3**	**744.5**	**7.6%**	**40.4%**

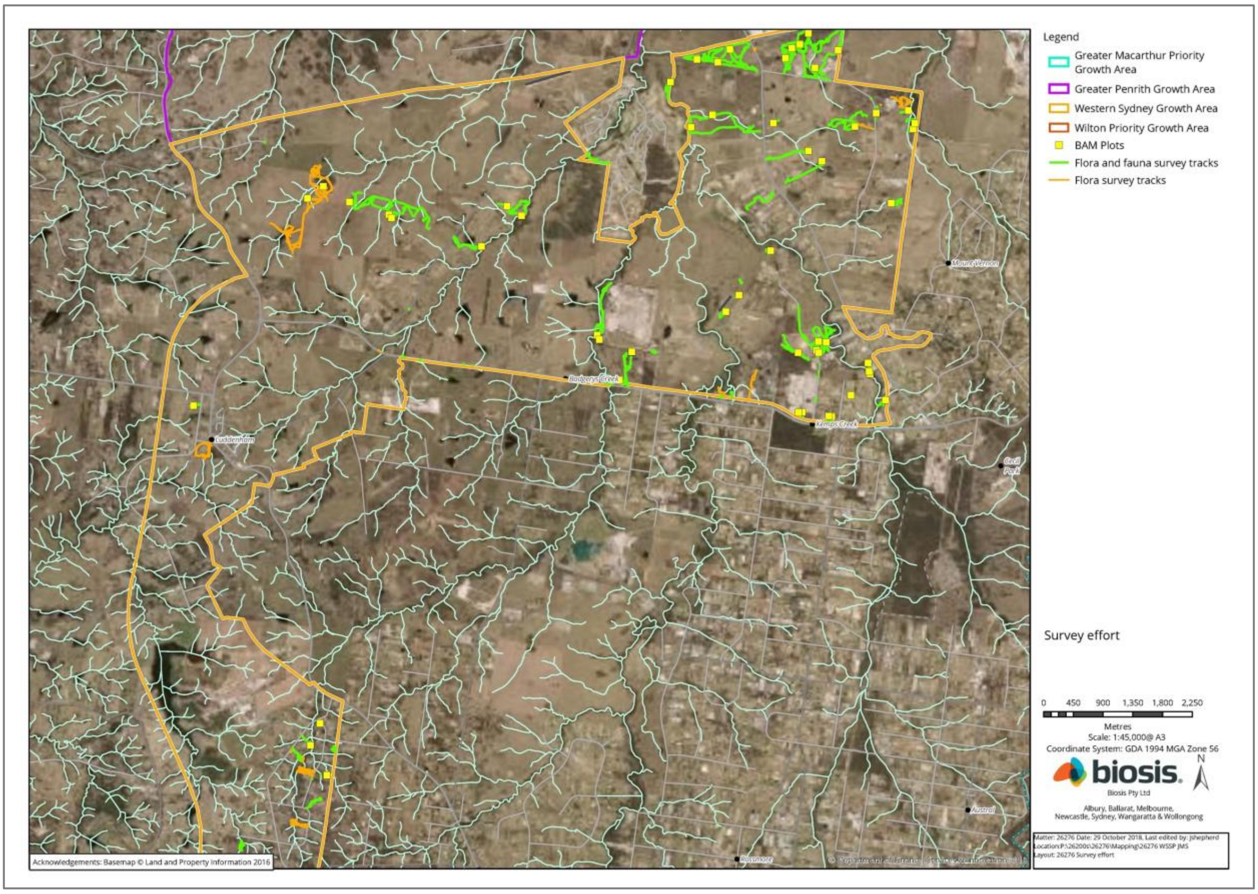
Field survey effort was not confined to the urban zone. Surveys occurred into nearby vegetation zoned for conservation. The urban zone has been revised over time and some areas where survey had already occurred were later removed. For these reasons, comparison of the survey area to the urban zone is indicative only. Survey effort has been calculated using a 20-metre buffer either side of GPS survey tracks. For the purposes of this analysis, the urban zone includes land zoned for future urban development plus transport corridors within the growth areas. It does not include any transport corridors outside the growth areas.



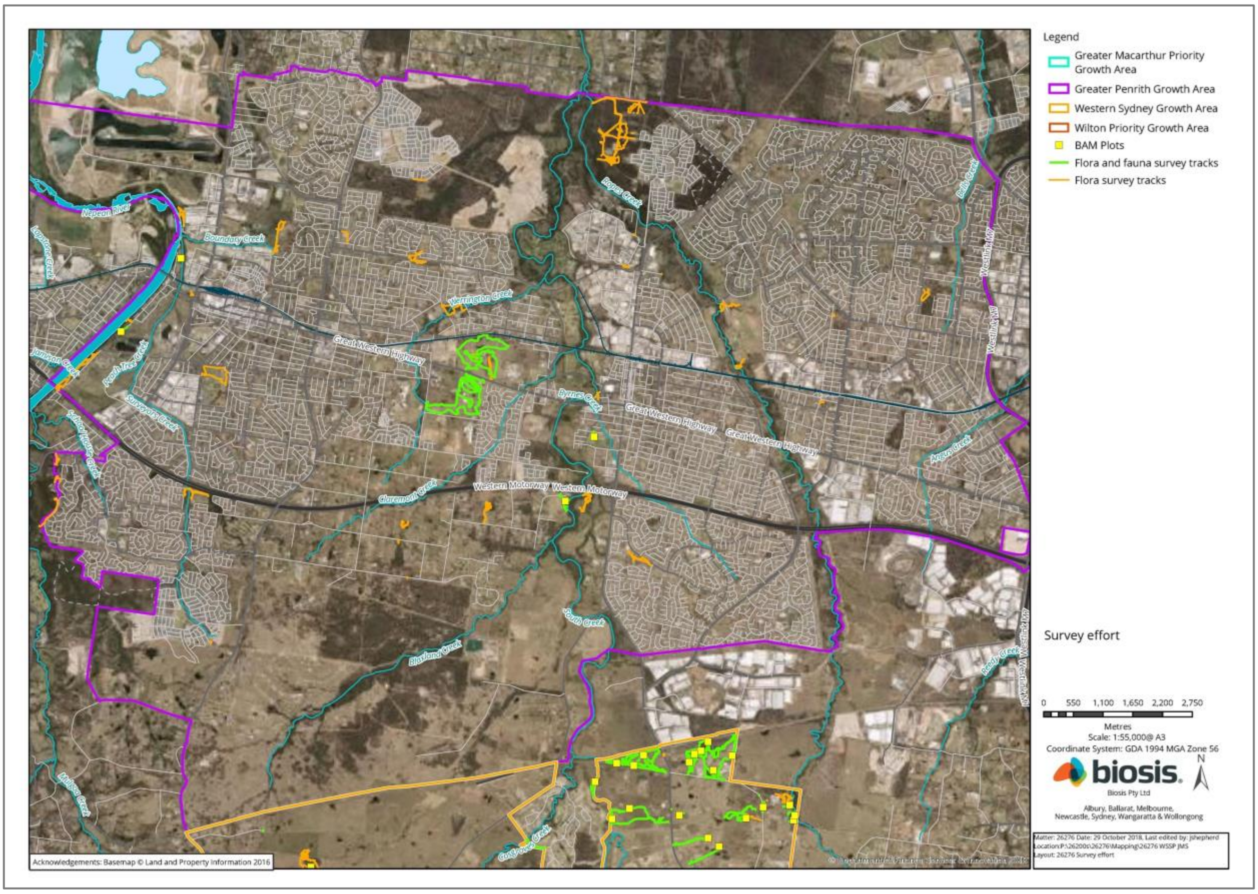
Map 4. GMGA survey effort (Biosis & Ecoplanning)



Map 5. WGA survey effort (Biosis and Ecoplanning)



Map 6. WSAGA ('Western Sydney') survey effort (Biosis and Ecoplanning)



Map 7. GPECGA survey effort (Biosis and Ecoplanning)

4.2.3 Survey constraints –timing / site conditions

As noted earlier, severe drought affected all of the study areas for some or all of the survey period. The Wilton and Greater Macarthur GAs were only surveyed during drought, whereas the Greater Penrith & Eastern Creek and the Aerotropolis GAs were surveyed both during intense drought and the subsequently slightly wetter conditions that followed in the Spring of 2018. Whilst wetter, drought remained present, and fellow botanist, Robert Miller, reported that vegetation was evidently drought-affected across all of the Growth Areas into November.

Drought, combined with increased intensity and extent of total grazing pressure, meant that affected surveys are likely to have under-recorded the target species compared to normal conditions. Whilst drought alone is unlikely to cause *A. pubescens* to die back to rootstock or die and only remain as seedbank, when combined with increased herbivory due to drought, this is a far more likely outcome.

4.2.4 Survey constraint – surveys undertaken by generalists / non-experts

Even when the prescribed OEH survey methods are used, a combination of site-based constraints, a species' ecology and a lack of familiarity with the species creates a situation where it is likely that it can be present in plant form, but not recorded, or present only as seedbank.

Acacia pubescens, like *P. nutans* and *A. bynoeana* is one of several threatened plant species that should not be treated as absent simply because it was not observed in plant form. If suitable habitat occurs, the species should be considered present unless there are clear reasons to rule otherwise. That approach is taken in this Report in relation to the designation of 'species polygons' (i.e. maps of where the plant is known or likely to occur).

4.3 Surveys completed for this Report

I undertook a very brief survey of potential habitat for *P. nutans*, *A. bynoeana* and *A. pubescens* in the locality of Kemps Creek in mid-November 2018. Robert Miller was also present to survey for his target species. He examined some sites that I did not. He is very familiar with these species and did not report any new sightings of *A. pubescens*.

The main remnant habitat in this locality is just to the south of the WSAGA but was checked by Miller for reference purposes. That remnant was seen to be largely unmanaged and degrading due to several threats, and it is feasible that the species is now restricted to seed bank at that location, though it could be present on disturbance margins that were not traversed.

Relatively little potential habitat remains for this species in the WSAGA, and whilst little of this was available to be surveyed by me or by consultants engaged by DPE, all such habitat has been excluded from the proposed urban footprint. The map below shows the transects associated with a brief survey within the WSAGA (northern line largely within a s.88b conservation area) and outside the WSAGA (short southern line).

Map 8. GPS track logs (purple lines)

I did not survey for any of my target species in the GPECGA because most of the potential habitat is either reserved, or proposed for reservation by OEH, and because of logistical constraints (time, property access). DPE offered access to a large area of remnant bushland in this Growth Area, but it was already excluded from the proposed urban footprint, so I did not take up that offer.

I did not survey the WGA, as the species is not known from or likely to occur there. Logical constraints were also a consideration.

I did not survey the GMGA due to a mix of logistical constraints and knowledge that most areas of potential habitat had already been excluded from the proposed urban footprint.

4.4 Assessment of species' presence

4.4.1 Greater Macarthur Growth Area

There are no modern or spatially accurate records of this species in this Growth Area, but suitable habitat is present. The extent of earlier habitat removal in the two thirds of the Growth Area has greatly limited where the species might remain amongst the now urban and industrial areas. Most of the potential habitat is present in the southern third of the Growth Area in what is largely rural land. Much of that area is fragmented by clearing of the higher and more arable shale-based vegetation, primarily leaving the shale/sandstone transitional vegetation and the sandstone vegetation associated with gullies.

4.2.2 Wilton Growth Area

The species is not known from this Growth Area but could be present in most of the remaining native vegetation, with the exception of the sandstone-based terrain around the gullies and larger watercourses. Most of the potential remnant habitat occurs around the edges of the Growth Area, primarily associated with the shale/sandstone transition. Much of that environment is or has been grazed but remains potentially viable habitat.

4.2.3 Greater Penrith to Eastern Creek Growth Area

The species is present in this Growth Area, and most of the native vegetation that remains in this heavily cleared Area is potential habitat for this species. The largest areas of potential habitat are within the former Australian Defence Industries land in the far north, some of which is within or proposed to become part of Wianamatta Regional Park; and the Orchard Hills Defence site in the southwest.

4.2.4 Western Sydney Aerotropolis Growth Area

Extensive clearing has meant that relatively little native vegetation remains in this Growth Area, however, the species could be present in most of the associated remnants. The most likely potential habitat is limited to a few patches of remnant vegetation in the localities of Kemps Creek and Badgerys Creek. Other areas occur throughout the Growth Area.

4.5 Assessment of suitable habitat for *Acacia pubescens*

4.5.1 Description and relative significance of potential habitat

As per the findings presented earlier in Table 2, combined with expert knowledge, the following PCTs are regarded as potential habitat for *A. pubescens*. Not all of these PCTS are present in all of the Growth Areas, and not all occurrences or parts of these communities are likely to support the species in plant or seedbank forms. Wetter and sometimes more thickly vegetated areas associated with drainage lines are less likely habitat. Riparian buffer exclusions will be used as a component of the 'species polygons' discussed later. All vegetation condition classes are included:

Table 10. PCTs known or likely to be habitat for *A. pubescens*

PCT	PCT Name	Relative significance
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Very High
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Very High
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Low
849	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain	Moderate
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Very Low
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Low
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Very Low

The following sections describe the relative habitat value and local occurrences of each PCT mapped in each Growth Area.

<u>Greater Macarthur Growth Area</u>

The vegetation mapping provided for use in the project indicates that there is **2364.2 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs.

Table 11. Potential habitat in the GMGA

PCT	Distribution	Relative habitat value
835	Scattered remnants in the northern two-thirds.	Low on the basis of PCT association.
849	Scattered remnant throughout.	Moderate on the basis of PCT association
883	Four very small polygons at Macquarie Fields	Low on the basis of PCT association but also because of a long history of mowing and weed invasion.
1081	A small remnant at Leumeah (Smiths Creek) is the only occurrence in this Growth Area.	Low on the basis of PCT association and being restricted to a single urban remnant that is likely to be significantly compromised.
1395	Common in the far south from around Menangle Park through Gilead to Appin area; between cleared shale landscapes and sandstone gullies	Moderate to high depending on shale content – high shale content is of lower habitat value. Unlikely habitat when near watercourses

Wilton Growth Area

The vegetation mapping provided for use in the project indicates that there is **1742.7 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs.

Table 12. Potential habitat in the WGA

PCT	Distribution	Relative habitat value
849	A few medium to large remnants, mainly in the northern half, and some are in 'derived grassland' condition.	Moderate on the basis of PCT association. Likely reduced value in derived grassland remnants.
1081	Uncommon and restricted to three patches above sandstone gorges, mainly on or near northern edges.	Low on the basis of PCT association but habitat quality appears good.
1395	Common around and near margins between cleared shale landscapes and sandstone gullies.	Very Low based on PCT association over the four Growth Areas, but probably Moderate in this Growth Area. Unlikely habitat when near watercourses.

Greater Penrith to Eastern Creek Growth Area

The vegetation mapping provided for use in the project indicates that there is **2640.4 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs.

Table 13. Potential habitat in the PECGA

PCT	Distribution	Relative habitat value
724	Uncommon, mostly in the central north, but also the centre, with smaller remnants further east. Very little combined extent.	Very high based on PCT association
725	Largely restricted to a few relatively large remnants in the central north, primarily in Wianamatta Regional Park (east) and nearby. Smaller remnants to the east in largely urban areas.	Very high based on PCT association
835	Relatively common along drainage lines, so most remnants are linear.	Low on the basis of PCT association. Many remnants are likely to be significantly degraded by weeds, though this species can survive in such situations.
849	The most extensive PCT in this Growth Area but largest remnants are Orchard Hills (SW) and former ADI lands (central north).	Moderate on the basis of PCT association. Not so likely to be found in the north due to prior survey efforts over some years.
883	Only one polygon in eastern Wianamatta Regional Park (in Biosis map)	Very low on the basis of PCT association plus the very small area involved.

Western Sydney Aerotropolis Growth Area

The vegetation mapping provided for use in the project indicates that there is **721.4 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs.

Table 14. Potential habitat in the WSAGA

PCT	Distribution	Relative habitat value
724	Uncommon, restricted to localities of Kemps Ck and Badgerys Ck. Very little combined extent.	Very high based on PCT association plus proximate records.
725	Uncommon, restricted to localities of Kemps Ck and Badgerys Ck. Very little combined extent.	Very high based on PCT association plus proximate records.
835	Relatively common along drainage lines, so most remnants are linear.	Low on the basis of PCT association. Many remnants are likely to be significantly degraded by weeds, though this species can survive in such situations.
849	The most extensive PCT in this Growth Area but many remnants are grazed.	Moderate on the basis of PCT association and proximate records, though these are associated with other PCTs

4.5.2 Species habitat polygons

Species habitat polygons generated by this report relate to the extent of potential habitat that is proposed to be cleared for urbanisation or transport corridors (Maps 9-11). These habitat polygons and associated calculations were generated to inform biodiversity offset requirements. The data presented in this section does not deal with species habitat outside proposed urban and allied zones as those areas are treated as conservation zones or are excluded from urban and associated transport zones for a range of reasons.

The habitat polygons include all relevant condition classes of relevant PCTs as identified in this Report. In this case, all condition classes are included.

As part of the formulation of the species habitat polygons, graded riparian exclusion buffers were used in recognition that *A. pubescens* does not occur in riparian vegetation. Buffers are relatively small for this species as *A. pubescens* can occur in riverflat/creekflat situations. The buffer distances increase with the mapped Strahler stream order as shown in Table 15. The accuracy of the buffers is limited by available data, including the mapped location of streams. The buffer is applied either side of the mapped stream centreline. Note that these riparian buffer distances are a different concept and serve a different purpose to those applied by DPE for the purposes of protecting streamside vegetation and watercourses in its planning within the Growth Areas.

Table 15. Stream exclusion buffers

Stream order	Buffer distance (m)
1	5
2	10
3	15
4	20
5	25
6	30
7	40

As *A. pubescens* can occur in quite modified sites, all condition classes are included for the relevant PCTs identified as potential habitat.

Furthermore, as this species can occur in sites that are so modified that they would not be mapped as native vegetation, this report may under-estimate the extent of potential habitat. This should be considered an inherent methodological constraint. The only alternative to the PCT-based approach taken here would seem to be mapping all areas with suitable soil/geology as potential habitat, and not excluding what would otherwise be viewed as 'cleared' land. I do not consider that practical in this context. I consider that land not mapped as native vegetation is less likely to support this species, and that if the species were present there, such populations may be less viable because of the extent of habitat modification. I suggest that if feasible within the scope of biocertification, there remain a provision that if a threatened plant species is detected in any surveys or works, OEH be advised and assessments undertaken by that agency with a view to conserving or translocating the material if feasible.

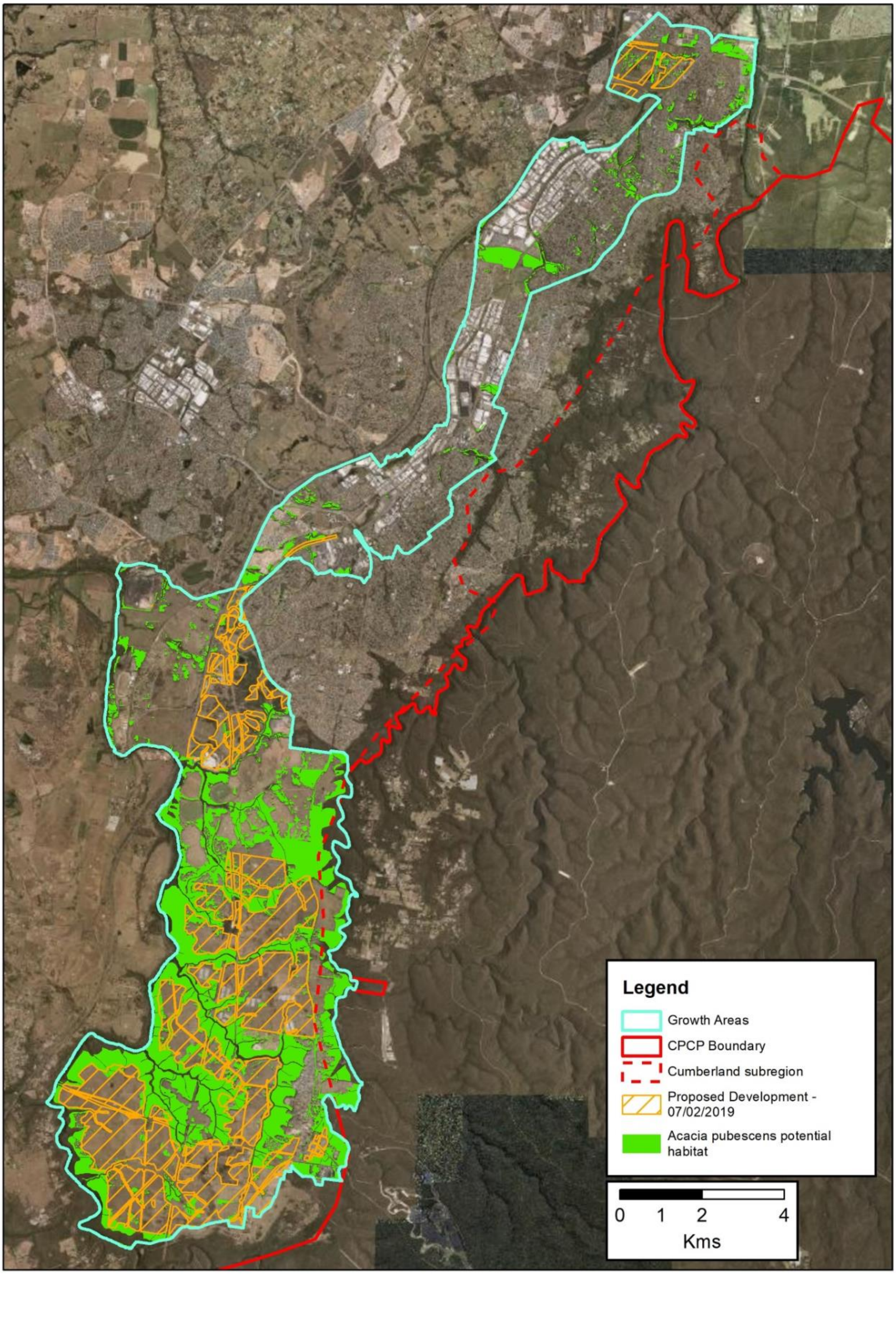
Species polygons in the form of GIS shape files were provided to the Biodiversity and Sustainability Branch of DPE in November 2018. Analysis of the area of potential habitat that is subject to development/removal in each of the four growth areas is shown in Table 16. A summary of the potential habitat that may be removed as a percentage of total potential habitat present in the growth areas is presented in Table 16.

These figures are based on precautionarily modelled *potential* habitat, and do not necessarily equate with *actual* habitat, nor do they provide any information of potential population sizes or population viability. It is unlikely that a large percentage of the potential habitat identified in this Report would actually support *A. pubescens* because this species is naturally rare and patchily distributed, even though it can be locally abundant in favourable conditions.

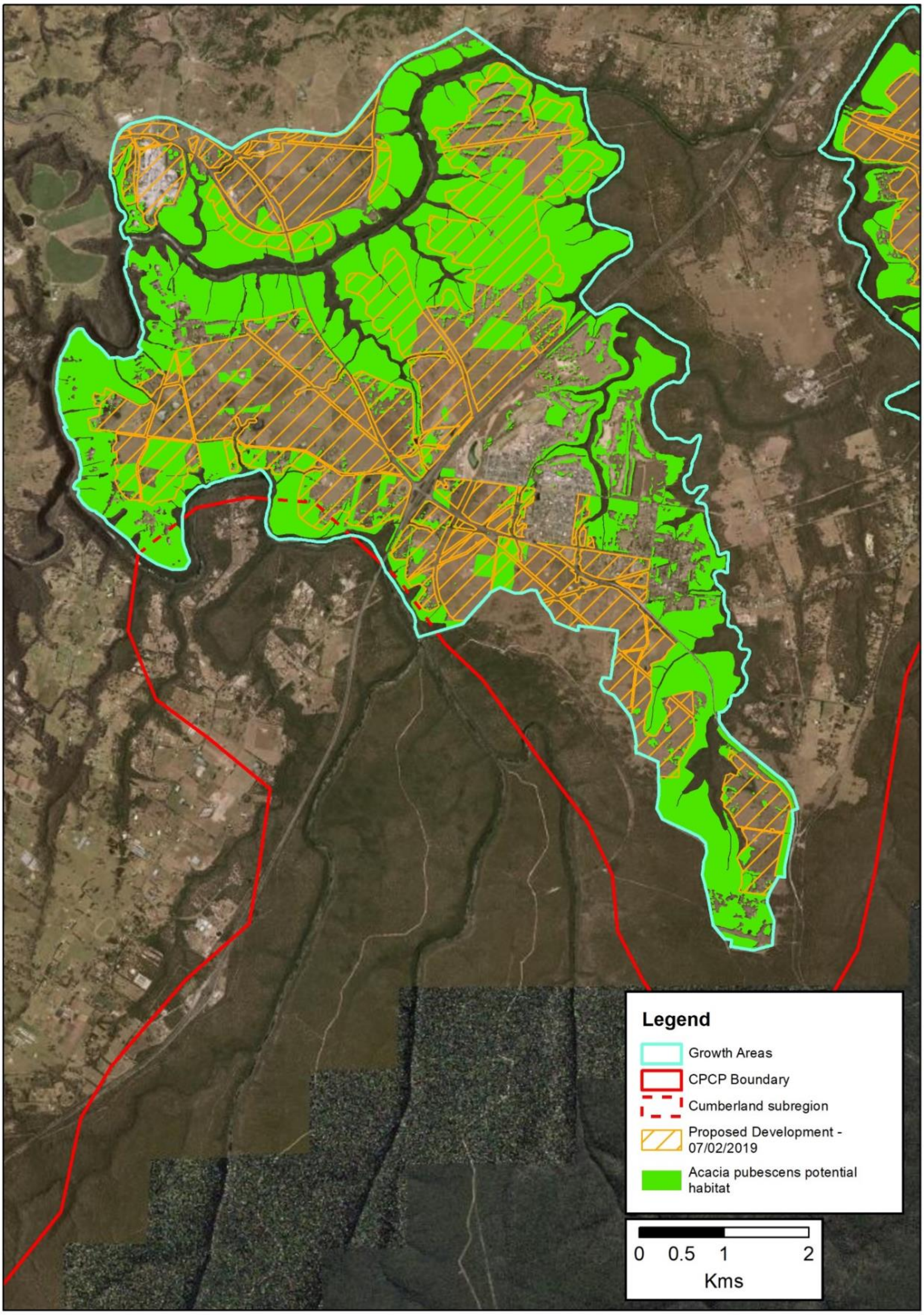
Table 16. Potential habitat and proposed removal of potential habitat by Growth Area

Growth Area	Area of potential habitat (ha)	Area of potential habitat removal (ha)	% area of potential habitat removal by GA
Greater Penrith to Eastern Creek	2640.4	105.6	4.0
Western Sydney Aerotropolis	721.4	325.4	45.1
Greater Macarthur	2364.2	251.4	10.6
Wilton	1742.7	543.5	31.2
Transport corridors **(all GAs)**	-	277.7	3.7
TOTAL	**7468.8**	**1503.6**	**20.1**

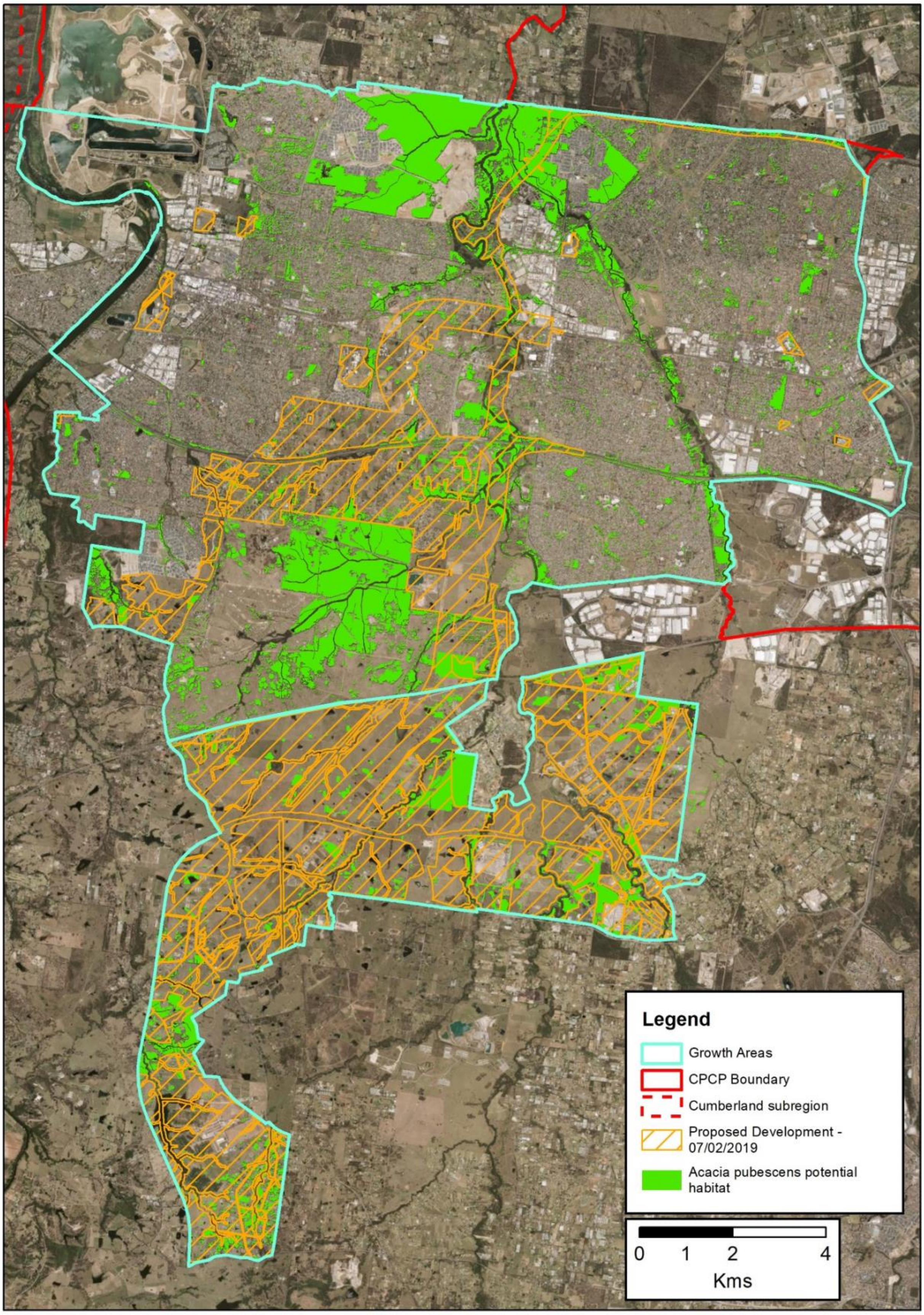
Map 9 Greater Macarthur - Potential habitat and proposed urban/transport habitat removal



Map 10 Wilton - Potential habitat and proposed urban/transport habitat removal



Map 11 Greater Penrith & Eastern Creek plus Western Sydney Aerotropolis
– potential habitat and proposed urban/transport habitat removal



5. Summary and conclusion

Within the four Growth Areas, *Acacia pubescens* is historically known from a single record in the Greater Macarthur Growth Area and from seven modern records (some apparent replicates) in a small area of the Greater Penrith to Eastern Creek Growth Area. Proximate records occur near all of the Growth Areas other than Wilton. Potential habitat exists across all of the Growth Areas and has been identified, ranked and mapped to generate ‘species polygons’ that inform calculations of biodiversity offsets and the design of the proposed urban footprint.

Based on current information, the proposed urban footprint and associated transport corridors of all four Growth Areas would destroy 1503.6 hectares of potential habitat for *A. pubescens*. This equates to 20.1% of the area of potential habitat identified in those Growth Areas. Not all of the area proposed for removal is of equal value as potential habitat, and different PCTs and condition classes have different probabilities of supporting *A. pubescens*. The actual extent of conflict between habitat for the species and proposed clearing for urbanisation is likely to be much smaller as the species is naturally rare and patchily distributed, even though it can be locally common where conditions are favourable.

As this species is relatively tolerant of significant disturbance and can persist as long-lived seedbank or as root suckers, it can occur in highly modified sites that may not be mapped as native vegetation, so are not captured by the PCT-based modelling of potential habitat used in this Report. It is likely that highly modified sites that might support the species in some form are of relatively low significance for it in the context of the much larger areas of more intact potential habitat that are excluded from urbanisation and associated clearing. It is also feasible that disturbance associated with urbanisation, particularly the creation of bushfire Asset Protection Zones between bushland conservation areas and housing, could advantage this species, especially where the habitat has not burnt for many years. More frequent, moderate intensity burning of bushland that represents known or likely habitat for this species, may, within limits, also advantage it compared to low frequency and/or very cool burning.

The positioning of the bushland/urban interface and associated infrastructure such as APZs should have regard to this species’ habitat and ecology, and appropriate buffers and other strategies are required to prevent direct and indirect harm to this species as a result of the urbanisation of adjoining lands. For example, potential habitat should not be compromised by the placement of housing nearby as might prevent that habitat being managed for conservation, especially in terms of bushfire risk management. DPE has informed me that APZs would be accommodated within the proposed urban footprint, not in the non-biocertified bushland areas that may adjoin it.

The absence of records of this species from areas of potential habitat does not mean it could not be present. This is because:

- not all areas have been surveyed historically or recently;
- all surveys have a range of limitations, and recent efforts were likely constrained by drought;
- not all discoveries of threatened species are disclosed; and
- large areas of potential habitat are highly likely to have fire regimes that do not favour this species, meaning it may currently occur in very low numbers, in dense and inaccessible habitat, or as seedbank, yet could appear in substantial numbers after an appropriate fire or equivalent disturbance.

These factors have been considered in the preparation of the species habitat polygons that will inform DPE in relation to biodiversity offset obligations.

6. Information used in the assessment

6.1 DP&E or OEH resources

- BioNet data (internal access provided under license for use in this Expert Report and associated dataset cleaning for the purposes of species habitat modelling to meet EPBC Act requirements)
- Atlas of Living Australia on-line (partial use to check for records not in BioNet)
- EMU data (NSW Herbarium specimen database, provided by OEH)
- OEH on-line threatened species profile
- OEH Threatened Species Data Collection on-line
- OEH BioNet Vegetation Classification Database (previously known as VIS)
- EPBC Act Listing/Conservation Advice
- OEH PCT (vegetation) maps for Sydney Metropolitan and Cumberland Plain
- Field data from Biosis and Ecoplanning consultancies engaged by DPE
- GIS layers and maps provided by DPE and its contractors

6.2 References

Benson D. & McDougall L., 1996. 'Ecology of Sydney plant species Part 4: Dicotyledon family *Fabaceae*.' *Cunninghamia* 4(4): 553-752.

Bernhardt P., Kenrick J. & Knox R.B., 1984. 'Pollination biology and the breeding system of *Acacia retinoides* (*Leguminosae: Mimosoideae*).' *Annals of the Missouri Botanic Garden* 71: 17-29.

Department of Environment & Energy (Commonwealth – DEE), 2003. Species Profile and Threats Database website for *Acacia pubescens*. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=18800 [Accessed November 2018]

Kodela, P. G., 2016 (June). Acacia pubescens (Vent.) R.Br. *PlantNet* (NSW Flora Online) http://plantnet.rbgsyd.nsw.gov.au/cgi-bin/NSWfl.pl?page=nswfl&lvl=sp&name=Acacia~pubescens [Accessed 19 November 2018]

Martyn, J. 2018. *Rocks and Trees: a photographic journey through the rich and varied geology, scenery and flora of the Sydney region*. STEP Inc., Turramurra.

Moore, R., Peakall, R. & Clements, A. (1999). *Analysis of the genetic diversity of Acacia pubescens: an assessment of clonality and its conservation implications*. Unpublished report prepared for NSW NPWS Central Directorate, Hurstville.

NSW National Parks and Wildlife Service, 1997, *Urban Bushland Biodiversity Survey. Stage 1: Western Sydney*. NSW NPWS, Hurstville.

NPWS 1998 Atlas of NSW Wildlife data (now BioNet) (cited in NPWS 2003 in relation to habitat).

NSW National Parks and Wildlife Service, 2000. *Native vegetation maps of the Cumberland Plain, Western Sydney*. NSW NPWS, Hurstville.

NSW National Parks and Wildlife Service, 2003a (February), *Approved Recovery Plan for* Acacia pubescens *(Downy Wattle)*. NSW NPWS, Hurstville. https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Animals-and-plants/Recovery-plans/downy-wattle-acacia-pubescens-recovery-plan.pdf [Accessed, November 2018]

NSW National Parks and Wildlife Service, 2003b (January), Environmental impact assessment guidelines: Acacia pubescens (Vent.) R.Br., NSW NPWS, Hurstville. https://www.environment.nsw.gov.au/resources/nature/ApubescensEia0103.pdf [Accessed November 2018]

SEWPaC, 2012. *Interim Biogeographic Regionalisation for Australia, Version 7*. Department of Sustainability, Environment, Water, Population and Communities. http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html

Threatened Species Scientific Committee (Commonwealth), 2016. *Conservation Advice:* Acacia pubescens *(downy wattle)*. http://www.environment.gov.au/biodiversity/threatened/species/pubs/18800-conservation-advice-15072016.pdf [Accessed December 2018]

Whitney K.D. 2002, 'Dispersal for distance? *Acacia ligulata* seeds and meat ants *Iridomyrmex viridiaeneus'*. *Austral Ecology* 27: 589–595.

7. Acknowledgements

I acknowledge the contributions of DPE staff, particularly Dayle Green, Greg Steenbeeke and Christian Marando (GIS), and DPE contractor Darren James (GIS) in the preparation and refinement of this document and associated maps. My contractor, Rhys Grogan, also assisted with GIS output in the form of drafts of the 'species polygons'.

Consultant botanist, Robert Miller assisted with fieldwork at Kemps Creek, and provided information about field observations associated with searches for his target species and with opportunistic sitings of my target species.

OEH staff assisted with some aspects of data availability and with the processing of many amendments to BioNet records.

8. Statement of professional independence

Whilst I was engaged and funded by DPE to prepare this Expert Report, and draft reports and maps were reviewed by DPE staff, I was not coerced by DPE to amend my work in any manner that I did not otherwise agree with. I believe that I had appropriate professional independence in the preparation of this document and associated maps.

I also declare that I do not have any personal or commercial conflict of interest in the preparation of this Report. I do not own real estate or businesses with property in the Growth Areas, nor do I have other active clients with real estate or associated commercial interests in the Growth Areas.

9. Appendix 1. Author's *Curriculum Vitae*

Dr Steven Douglas (BSc., MEnv. Plan., PhD.)

I have over twenty years of experience as an ecologist and environmental planner, primarily in New South Wales, with some experience in the ACT, Victoria and South Australia. I have worked for all levels of government, for environmentalist non-government organisations (NGOs), and for a large number of private clients ranging from individuals to multinational firms, directly and as a subcontractor. I have often worked as a sole consultant but have also collaborated with other specialists and have sometimes been part of large teams involved in large-scale, even interstate projects.

I specialise in the detection, management and conservation of rare and threatened flora species and communities, and in associated ecological impact assessment and mitigation.

I have qualifications and experience in a range of general and specific ecological, social, organisational and 'sustainability' fields.

I have served on environment-related ministerial committees and have held other ministerial appointments in NSW, including those dealing with bushfire management.

I have published in journals dealing with plant conservation, environmental law and policy, social science, and ecological ethics. Aspects of my work have been published by government, prominent NGOs, and in the popular press and other media.

This CV only contains content directly related to my botanical expertise.

Employment summary

1996 to present:

Self-employed, trading as *Ecological Surveys & Planning* (www.ecologicalsurveys.net)

Through this enterprise, I have undertaken a large number of consultancies for public and private sector clients including environmental impact assessment and mitigation; threatened biota research, profiling and management; vegetation mapping; preparing management plans for conservation estate; providing environmental planning and catchment management advice; advising on bushfire risk management; acting as an expert witness in Land & Environment Court proceedings; and developing organisational sustainability policies and practices.

July 2017 to July 2018:

Senior Ecologist, NSW Office of Environment & Heritage (NVIS, Science Division)

My work on the project below led to OEH retaining my services to research and document problems with the description, interpretation and mapping of Threatened Ecological Communities (TECs) statewide. This project provides advice to OEH, the NSW Threatened Species Scientific Committee, and through those agencies, to the Commonwealth Threatened Species Scientific Committee. It identifies technical issues with the description of TECs and their mapping, as well as wider problems of how TECs are defined. It draws on a major project undertaken by OEH for the NSW EPA and Forestry Corporation, in which TECs of the east coast and ranges were assessed and mapped for regulatory purposes on forestry estate. However, my work includes many more TECs and recent information emerging from Save Our Species project panels.

November 2015 to July 2017:

Team Leader, NSW Office of Environment & Heritage (NVIS, Science Division)

This project in Wingecarribee Shire is the first in which OEH’s vegetation mapping team has worked at a very fine scale for a single local government area. The project entails auto-segmentation of digital aerial photography; supervising contract vegetation sampling; conducting strategic sampling; modelling of most vegetation communities; describing new communities; and extensive remote and on-ground map validation. I was hired partly because of my extensive familiarity with much of the vegetation of this geodiverse and biodiverse region. The role included supervision of two staff; liaison with consultants; and substantial networking with OEH and Wingecarribee Council staff. An update of vegetation classification will occur from mid 2019 onwards, and I have drafted a peer-reviewed journal article about the project that will be submitted for publication.

1995/6:

Project consultant, then Project Manager, Urban Bushland Biodiversity Survey (NPWS)

The Urban Bushland Biodiversity Survey was undertaken by the NPWS to compile comprehensive data on indigenous flora and fauna in twelve local government areas in Western Sydney. Contracted initially as a consultant to design and scope the project, I was later employed as Project Manager. Responsibilities involved an extensive literature review, preparation of a project plan and a background paper for the Survey and the overall management of the project including up to twelve staff and several consultants. The major focus was on coordinating research work, fauna and flora field surveys, and a community liaison and media campaign. Extensive flora survey work and scientific data analysis was undertaken. I provided a tour of important vegetation sites for the South Creek Catchment Management Committee. I also wrote media releases and conducted various media events including a live-to-air interview on ABC Radio National, and filming of a story in the field for the Totally Wild program.

1994:

Catchment Environment Officer (*Hawkesbury City Council*).

The project was funded by a grant from the former Hawkesbury-Nepean Catchment Management Trust and had the objective of identifying land uses on riverside properties to assess their potential to generate water pollution. The information on land use and riparian vegetation was primarily gained from aerial photo interpretation, limited land-based inspections and several water-based inspections, and was recorded in a GIS. Work site inspections, pollution control on agricultural lands, community meetings, site visits with landowners, and facilitating the formation of a Landcare group in the Sackville area.

1993/4:

Technical Officer (*Hawkesbury-Nepean Catchment Management Trust*).

Work included assisting with the preparation of a vegetation management strategy for the Trust and the outline of a revegetation strategy for South Creek. Other responsibilities involved providing scientific advice for development assessments, the preparation of hard copy and computer-based catchment maps, and advising on the implementation of revegetation projects in the catchment.

Ministerial appointments

- Appointed a member of the **National Parks & Wildlife Service Regional Advisory Committee** (South Coast) (2010-mid 2018). I opted not to reapply for this role after serving two terms. The restructure of the NPWS meant that the Committee would operate from Wollongong to the Victoria border and inland to the Tablelands. This was logistically fraught, and the role of RACs was evidently being diminished, with larger areas to manage but less meetings held.
- Appointed a member of the **NSW Sustainability Network** (2001), part of the Sustainability Advisory Council reporting to the Minister for Planning. I did not take up this position due to my relocating to Victoria.
- Nature Conservation Council representative on the former NSW **Native Vegetation Advisory Council** (1999-2001) reporting to the Minister for Land & Water Conservation under the Native Vegetation Conservation Act. I served as a member of the Regional Vegetation Planning Subcommittee, which amongst other matters, reviewed draft Regional Vegetation Management Plans and Codes of Practice for activities such as native forestry and timber plantations. I was particularly involved in reviewing and recommending amendments to the Code of Practice for plantation forestry. I resigned due to my relocating to Victoria.
- Nature Conservation Council representative on the former **Southern Catchment Management Board** (June 2000 - March 2001). I resigned due to relocating to Victoria. I expressed my dissatisfaction with the design of the catchment boards and recommended to the Minister that they be replaced with the Catchment Management Authority model used in Victoria. The Boards were later replaced with such Authorities.
- Nature Conservation Council representative on Baulkham Hills and Hornsby-Ku-ring-gai **District Bushfire Management Committees** (1995-2001).
- Australian Conservation Foundation representative on the former **Environmental Works Community Audit Committee** reporting to the Minister for Environment in relation to the Special Environment Levy imposed by the then Water Board (1993-5). I completed my term when the Committee concluded its business and dissolved upon acceptance of its final report by the Minister.

Tertiary qualifications & titles

Adjunct Research Fellow

School of Philosophical, Historical & International Studies, Monash University, 2014-16

Doctor of Philosophy

Fenner School of Environment & Society, The Australian National University, 2004-7

The research was undertaken in the transdisciplinary Human Ecology Program and covered fields such as ecological philosophy, ecotheology, environmental policy-making, policy evaluation, organisational change, and critical systemic analysis. My thesis was passed unanimously and unamended by one Australian and two USA-based professors. I was awarded a $10,000 Publication Fellowship by the Fenner School and have since published aspects of my research.

Master of Environmental Planning

Macquarie University Grad. Sch. Env., 1994-96

This course included environmental law and politics, community involvement in planning, environmental education, development approval processes, urban planning, EIA, environmental science/fieldwork and heritage management. The dissertation component involved a pioneering report on the significant flora of the Greater Cattai Region (Cattai subcatchment) in north-western Sydney and led to my being offered employment with the NSW NPWS to design and manage a biodiversity survey of western Sydney.

Bachelor of Science

Macquarie University, 1990-93

My degree majors are Resource and Environmental Management, Land Management, and Plant Biology/Ecology.

Graduate Certificate of Research Information Literacy

The Australian National University, 2004-7

This course included advanced word processing, citation management, literature gathering (including on-line literary databases and other Internet sources), on-line publishing, presentation software, and thesis production.

Professional memberships

- Founding member of the Ecological Consultants Association of New South Wales (did not renew due to my relocating to Victoria and later to the ACT).
- Member of the NSW Environmental Defenders Office (EDO) Scientific Advisory Service (continuing).

Threatened biota experience

The following threatened plant species and populations and threatened ecological communities (TECs) have been engaged with in the various forms and processes listed below. The list is not complete, and some processes are on-going. I also successfully nominated three Key Threatening Processes under the TSC Act: Bushrock Removal; Clearing of Native Vegetation; Competition from European Honey Bee.

Species / population	Work conducted
Acacia bynoeana	Fieldwork, research, successful nomination, monitoring, advice to authorities, expert witness, rediscovered lost population, documented new population near range limit, PAS2 review, SOS review panel, review and amendment of BioNet dataset. Recognised by OEH as a species expert under BC Act (Nov 2018).
A. gordonii	Fieldwork, successful nomination, advice to NPWS, PAS2 review, SOS research and monitoring program (fire ecology, BMtns NP), review and amendment of BioNet dataset.
A. prominens	Successful nomination of Endangered Population
A. pubescens	Fieldwork, contribution to Recovery Plan, confirmed disjunct southern populations, nominated population, PAS2 review, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Ancistrachne maidenii	Fieldwork, research, successful nomination, advice to NPWS, CAM review
Asterolasia elegans	Fieldwork, species profile, advice to Council and NPWS
Baloskion longipes	Research linked to *Carex klaphakei*, review of BioNet records, advice to OEH
Boronia deanei	Research, SOS review, CAM review, advice to OEH
Bossiaea oligosperma	SOS fieldwork, review of records (NW population), report to OEH, establishment of monitoring plots in Yerranderie SCA
Callistemon linearifolius	Fieldwork, research, successful nomination, advice to RMS and NPWS, PAS2 review
Callistemon megalongensis	Co-described new species, successful nominations (listing then upgrade), fieldwork, advice to Council and OEH, PAS2 review, SOS monitoring program (OEH, BMCC, on-going)
Callistemon purpurascens	Described new species, fieldwork, successful nominations, advice to Council and OEH, SOS monitoring project (2018 on-going)
Calotis glandulosa	Fieldwork (new and extended populations, Kosci NP), CAM review
Calotis pubescens	Fieldwork (new population, Kosci NP), CAM review

Species / population	Work conducted
Carex klaphakei	SOS research project and recommendation for monitoring; resolved errors in BioNet records
Commersonia prostrata	PAS2 / PKF research, fieldwork, advice to NPWS and OEH, documentation and monitoring of new and known populations for Forestry Corp, designed recovery actions for populations in Wingello and Penrose SFs
Cullen parvum	Fieldwork, located new NE population, report to NPWS
Dampiera fusca	Research, fieldwork, successful nominations, monitoring program for ACT Parks & Conservation, advice to NPWS and OEH, CAM review
Darwinia biflora	Fieldwork, research, contributor to Recovery Plan, PAS2 review, review and amendment of BioNet dataset.
Darwinia glaucophylla	Fieldwork, research, successful nomination, advice to NPWS, PAS2 review
Darwinia fascicularis ssp. *oligantha*	Fieldwork, research, successful nomination of population
Darwinia peduncularis	Research, successful nomination, CAM review
Dillwynia tenuifolia	Fieldwork, research, successful population nominations, advice to OEH
Epacris purpurascens var. *purpurascens*	Fieldwork, research, nomination, new SW range limit (Nattai NP), advice to NPWS/OEH
Eucalyptus aggregata	Research, successful nomination of species and population, fieldwork (Wingecarribee Shire) and advice to Council and OEH, CAM reviews
E. aquatica	Fieldwork, advice to Council and Forestry Corporation
E. sp. *Cattai*	Successfully argued for recognition of this entity as a new species, successful nomination, fieldwork, PAS2 review, advice to OEH, SOS project panel
E. kartzoffiana	Fieldwork, research, expert witness
E. macarthurii	Fieldwork, research, successful nominations, advice to Council and OEH
E. parvula	Fieldwork (Wadbilliga NP), CAM review
E. pulverulenta	Fieldwork (Bredbo Hills), CAM review
Galium australe	PAS2 research, recommended taxonomic review of most records in NSW based on Herbarium assessment, advice to OEH, CAM review
Grevillea juniperina ssp. *juniperina*	Fieldwork, research, advice to OEH (Colebee NR offset site)
Grevillea molyneuxii	Fieldwork, advice to OEH for CAM review
Grevillea parviflora ssp. *parviflora*	Fieldwork, research, expert witness, review and amendment of BioNet dataset.
Grevillea parviflora ssp. *supplicans*	Fieldwork, research, nomination, advice to NPWS
Grevillea raybrownii	Fieldwork, research, nomination and advice to NSWSC – listing pending
Gyrostemon thesioides	Successful nomination

Species / population	Work conducted
Helichrysum calvertianum	Fieldwork, research, nomination, advice to NSWSC – listing pending
Hibbertia fumana	Research, minor fieldwork, expert witness
H. incana (syn. *superans)*	Successful nomination of population then species
H. praemorsa	ROTAP, researched, fieldwork (informal)
H. puberula ssp. *furcatula*	Fieldwork (incidental) documenting new occurrence, advice to OEH/NPWS
H. puberula ssp. *puberula*	Research, minor fieldwork with R. Miller, expert witness
Homoranthus binghiensis	CAM review (recommended changing to CE)
Keraudrenia corrolata var. *denticulata*	Successful nomination of population
Lasiopetalum joyceae	Fieldwork, research, successful nomination, species profiling for Council and NPWS, PAS2 review
Leptospermum deanei	Fieldwork, research into hybridization with *L. trinervium*, advice to RBG, Council, OEH
Leucopogon fletcheri ssp. *fletcheri*	Fieldwork, research, successful nomination, advice to OEH and NPWS
Melaleuca deanei	Research, fieldwork, successful nominations, advice to NPWS/OEH and species profile for Council, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Olearia cordata	Fieldwork and report to NPWS, PAS2 review
Persoonia acerosa	Fieldwork, PAS2 review, SOS monitoring plots, advice to Council and OEH
Persoonia bargoensis	Fieldwork, research, successful nomination, PAS2 review, CAM review, review and amendment of BioNet dataset.
Persoonia hirsuta	Fieldwork, research, nominations of species and population, PAS2 review, review and amendment of BioNet dataset.
Persoonia glaucescens	Fieldwork, nomination, report to NPWS, PAS 2 review, CAM review, review and amendment of BioNet dataset.
Persoonia marginata	Fieldwork and report to OEH, CAM review
Persoonia mollis ssp. *revoluta*	Fieldwork, research, advice to OEH and Forestry Corp., nomination as Vulnerable - listing pending
Persoonia nutans	Fieldwork, nomination, advice to OEH, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Phyllota humifusa	PAS2 fieldwork and research; advice to NPWS, OEH, Council, Forestry Corp (monitoring plots, reduced APZ width), review of BioNet dataset.
Pimelea curviflora var. *curviflora*	Fieldwork, research, successful nomination, advice to OEH

Species / population	Work conducted
Pomaderris brunnea	Incidental fieldwork and documentation of new populations and range extension; review and amendment of BioNet dataset.
P. cotoneaster	Fieldwork, research, advice to Council, NPWS, OEH, liaise with ANBG seed collectors, CAM review
P. sericea	PAS2 research (review of records and habitat), recommended consideration of Presumed Extinct or at least CE
Pultenaea elusa	PAS2 research (review of records and habitat), recommended Presumed Extinct
P. glabra	SOS fieldwork and monitoring plots. Review of Mts Wilson/Irvine records resulted in these being reallocated to an undescribed species given the interim name, *P. monticola*.
P. parviflora	SOS fieldwork and report to OEH (Colebee NR offset site); review and amendment of BioNet dataset.
P. pedunculata	Fieldwork, research, expert witness, CAM review
Solanum armourense	PAS2 fieldwork, research, report, advice to OEH, CAM review
S. celatum	Fieldwork, research, new populations (new range limit and habitat), advice to OEH, CAM review
Tetratheca glandulosa	Fieldwork, PAS2 review, advice to OEH and Cwlth DEE re conservation status
Triplarina nowraensis	SOS fieldwork, review of BioNet records, advice to OEH/NPWS, establishment of monitoring plots
Zieria involucrata	Fieldwork, input to Recovery Plan, CAM review
Zieria murphyi	Liaise with ANBG, fieldwork, advice to OEH

Threatened Ecological Communities (TECs)

My work for OEH in reviewing all NSW and EPBC Act TECs in the State has given me at least some familiarity with most of these entities and builds on already-strong knowledge of some. I have also been an expert witness in cases involving some of these communities – some entailing basic reviews and advice, and others involving in-depth considerations. All of the EPBC Act parallel listings are not included here unless I was involved in a particular nomination:

Ecological community	Nature of engagement
Blue Gum High Forest	Successful nomination, expert witness
Blue Mountains Basalt Cap Forest	SOS panel
Blue Mountains Shale Cap Forest	Successful nomination, SOS panel
Blue Mountains Swamps	Fieldwork, mapping, advice to BMtns Council, modelling
Castlereagh Scribbly Gum Woodland	Successful nomination, advice to DEE re Cwlth listing, expert witness
Cooks River / Castlereagh Ironbark Forest	Advice to DEE for EPBC Act listing
Cumberland Plain Woodland	Correction of OEH mapping, fieldwork, assessments, advice to Councils and NPWS
Eastern Suburbs Banksia Scrub	Major review for DEE Recovery Plan update, advice to OEH
Elderslie Banksia Scrub Forest	Major review for DEE Recovery Plan, SOS panel
Illawarra Lowlands Grassy Woodland	DEE review panel for EPBC Act listing
Lowland Grassy Woodland & Forest of SE Corner Bioregion	Successful nomination
Maroota Sands Swamp Forest	Successful nomination, SOS panel
Melaleuca armillaris Tall Shrubland	fieldwork, mapping, advice to OEH
Montane Peatlands & Swamps	Fieldwork, modelling and mapping, advice to OEH
Mount Gibraltar Forest	Detailed review for modelling and mapping, and advice about revised listing, advice to DEE re Upland Basalt Eucalypt Forest inclusion of NSW TECs
O’Hares Creek Shale Forest	Research and review for modelling and mapping
Pittwater & Wagstaffe Spotted Gum Forest	Successful nomination
Riverflat Eucalypts Forest on Coastal Floodplains	Successful nomination (component), research, modelling and mapping (limited extent)
Robertson Basalt Tall Open-forest	Modelling and mapping, advice to NSW SC

Ecological community	Nature of engagement
Robertson Rainforest	Modelling and mapping
Shale/Gravel Transition Forest	Mapping, TEC review
Shale/Sandstone Transition Forest	First to describe this concept c. 1996 based on Masters research. Formally published as a concept in NPWS (1997, UBBS). Successful nomination, research, major review and advice to DEE for EPBC Act listing, modelling and mapping
Southern Highlands Shale (Forest &) Woodland	Major contributor to DEE listing, drafting of Listing and Conservation Advices, advice to OEH about revision of NSW listing, modelling and mapping. Contracted to prepare listing for upgrade to CE.
Subtropical & Temperate Coastal Saltmarsh (EPBC Act)	Funded to prepare successful nomination
Sun Valley Cabbage Gum Forest	Successful nomination, mapping, advice to Council, SOS project panel
Swamp Sclerophyll Forest on Coastal Floodplains	Allied major research project cited in the Final Determination, TEC review (gap analysis)
Sydney Turpentine Ironbark Forest	Successful nomination, mapping, advice to Councils and to OEH/SC about revision
Tablelands Basalt Forest	Research, expert witness, advice to OEH about revision, modelling and mapping
Tablelands Snow Gum…Grassy Woodland	Fieldwork documenting new occurrences, modelling and mapping, advice to OEH
Upland Basalt Eucalypt Forest (EPBC Act)	Major contributor to DEE listing of this composite community that includes several NSW TECs. Draft Listing and Conservation Advices
Western Sydney Dry Rainforest and Moist Shale Woodland	SOS panel, TEC review

Publications / presentations / media

Ecology / conservation / environmental law & policy / ecological ethics

Refereed journal articles

Douglas, S.M. and Wilson, P.G. 2015. "Callistemon purpurascens (Myrtaceae): a new and threatened species from the Blue Mountains region of New South Wales, Australia". *Telopea* 18: 265-272

Douglas, S.M. 2000. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link". *Australasian Journal of Natural Resources Law & Policy,* 6(2)

Conference proceedings

Douglas, S.M. 2003. "Ecological offsets – what's the idea?" in Morrison, C. (Ed.) *Urban bushland and remnant vegetation: toolkits for a sustainable future – conference proceedings*. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 2001. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link"; in Newton, S. (Ed.) *Bushland or buildings? The dilemma for biodiversity conservation in urban areas* – conference proceedings. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 1998. "The Threatened Species Conservation Act; a consultant's perspective" in *On the brink; your bush, their habitat, our Act.* Threatened Species Network, Nature Conservation Council of NSW, and Environmental Defenders Office, Sydney

Book chapters

Douglas, S.M. 1999. "Development & Sydney's threatened biota" in *Greenprint for Sydney: an environmental strategy for the 21st Century*. Total Environment Centre, Sydney, NSW

Professional reports

Douglas, S.M. & Anderson, J.R.B. 2002. Eucalyptus robusta *(Swamp Mahogany) communities and their conservation status in New South Wales*. Swamp Mahogany Project, Central Coast Community Environment Centre, Newcastle University Campus, Ourimbah

Douglas, S.M. 1997. "Local Government Area Reports: Baulkham Hills Shire", in James, T. (Ed.) *Urban Bushland Biodiversity Survey* (Stage 1, Western Sydney) Flora Appendices Vol. 2. NSW National Parks & Wildlife Service, Hurstville

Edited but not refereed publications

Douglas, S.M. 2014. "When biosecurity is threatened from within: the case of the native environmental weed, Pittosporum undulatum". *Australasian Plant Conservation,* 23(2)

Douglas, S.M. 2009. "Black Gum: a threatened tree of upland New South Wales and Victoria." *Australasian Plant Conservation*, 17(4)

Douglas, S.M. 2009. "Species profile and monitoring of Dampiera fusca". *Australasian Plant Conservation,* 17(3)

Douglas, S.M. 2006. "Endangered plant discovered" (St. Clements Retreat, Galong). *Biodiversity Research Newsletter*, 20, p.4, July, NSW Department of Environment & Conservation, Hurstville.

Douglas, S.M. 2006. "Endangered plant discovered (*Cullen parvum*) at St. Clements Retreat, Galong". News of Friends of Grasslands, November-December, p7

Douglas, S.M. 2005. "Phoenix flora: a post-fire discovery in the ACT". *Australasian Plant Conservation*, 13(3)

Douglas, S.M. 2004. "Phoenix flora" (re Dampiera fusca). *Journal of the Australian Native Plant Society Canberra Region*, 14(2), December

Douglas, S.M. 2003. "Mysteries of the Megalong Valley: another rare plant for the Blue Mountains." *Australasian Plant Conservation*, 12(1)

Douglas, S.M. 2001. "Land of the living dead – tree decline in urban areas". *Environment NSW* (newsletter of the Nature Conservation Council of NSW), September

Douglas, S.M. & Newton, S. 2000. "Bushland weeds – more on native weeds". *Environment NSW*, December

Douglas, S.M. 2000. "Regional Parks". *National Parks Journal* Vol. 44 (5 & 6) (journal of the National Parks Association of NSW)

Douglas, S.M. 1996. "Community biodiversity surveys". *National Parks Journal,* 40(3)

Douglas, S.M. 1996. "Mapping our urban bushland". *The Gardens*, Spring (journal of the Royal Botanic Gardens, Sydney)

Douglas, S.M., Bolesic, T. and Ware, K. 1994. "Healing the Hawkesbury: start with bushland protection". *National Parks Journal*. 38(4)

Public media coverage

2004, November 6. "Bright flowering spot after fire" - discovery of Dampiera fusca – a new genus and nationally significant species for the ACT and a new northern limit for the species. *Canberra Times*

2004. Live-to-air interview re discovery of *Dampiera fusca* in Namadgi NP, *ABC 666* AM Radio, Canberra

1996. Live to air interview re NPWS Urban Bushland Biodiversity Survey, *ABC 2BL* AM Radio, Sydney

1996. Pre-recorded TV segment re discovery of several nationally threatened plants in the one location during surveys for NPWS UBBS. *Totally Wild* program, Channel 10, Sydney

Consultancy projects

Short descriptions of the many larger projects that I have been involved in are available at http://ecologicalsurveys.net/?page_id=10, and a list of smaller projects is at http://ecologicalsurveys.net/?page_id=14

Voluntary and other works

- Assist **International Union for the Conservation of Nature (IUCN)** with a review of the conservation status of *Proteaceae* in eastern Australia (Melbourne, 2019).
- Assist **NSW Environmental Defenders Office** with a review of NPWS monitoring proposals to assess the effects of permitting horse riding in declared Wilderness areas (Kosciusko National Park) (2014).
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Noxious Weeds Act 1993 (in 2011)
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Threatened Species Conservation Act 1995 (in 2010)
- Assist discoverers (**Blue Mountains Bushcare**) of a previously undescribed *Epacris* species (*E. apungens* Coleby & Brown) in south Leura to prepare an article for the journal, *Telopea*, describing this species and its ecology
- Assist **NPWS** with a search for the ultra-endemic and rare rainforest plant, *Thismia clavarioides*, in Morton National Park (2010)
- Expert panel member assisting **Hawkesbury-Nepean CMA** with its Draft Climate Change Vulnerability Assessment for selected threatened ecological communities of the NSW Southern Highlands (2010)
- Assist PhD student, David Field (**University of Wollongong and CSIRO**) with information about the ecology, distribution, and conservation status of *Eucalyptus aggregata* (Black Gum) (2007)
- Fieldwork assisting with group preparation of vascular plant species lists in numerous NPWS and ACT Parks reserves in the Southern Tablelands area. **Australian Native Plants Society** (2003-2007)
- Searches for *Euphrasia scabra* (critically endangered) in Packers Swamp and Nunnock Swamp. Discovered new population (3rd in NSW) in unnamed swamp, SE Forests National Park. **Friends of Grasslands** (2004)
- Assistant part-time editor of "*Danthonia*" (now *Australasian Plant Conservation*), the journal of the **Australian Network for Plant Conservation** Inc., Canberra (2002-2003)
- Assist PhD student, David Clunas (**University of Wollongong**) with review of his research in the ecology of the nationally Rare, *Pultenaea villifera* var. *villifera* (2002)
- Provide technical assistance to four final year undergraduate Environmental Science students (**Australian Catholic University**) working in Marramarra National Park, (c. 2000)
- Discovery of and subsequent surveys for *Persoonia hirsuta* ssp. nov. 'Yengo NP'. **NPWS/RBG**
- Vascular flora and fauna (microchiropteran bats) surveys within Pilliga Nature Reserve. **NPWS** Coonabarabran
- Supervisor for undergraduate dissertation, "Environmental rehabilitation of Peats Crater and Peats Bight in Muogamarra Nature Reserve" (D. Maestri), **Southern Cross University** (1997)
- Co-supervisor for undergraduate dissertation "Riparian Vegetation of upper Cattai Creek" (D. Buckle). **Southern Cross University** (1997)
- Preliminary flora assessment for proposed subdivision and development; Red Gum Avenue, Pennant Hills. The bushland area was subsequently added to Berowra Valley Regional Park. **Friends of Berowra Valley Bushland**
- **NSW National Parks Association** (NPA) Biodiversity Audit, proposed Bargo River National Park. Team Leader, Vegetation - threatened flora
- Guided interpretive walk of Fred Caterson Reserve. **Cattai Catchment Management Committee**
- **NSW NPA** audit of Greater Sydney proposed conservation reserves and additions - assistant and author of NW Sydney reserve proposals
- **NSW NPA** Biodiversity Audit of the proposed Dyarrabin Nature Reserve (~2000 ha) - Project Co-ordinator
- **NSW NPA** Proposal for the creation of Dyarrabin Nature Reserve; revised submission and report of the second NPA Biodiversity Audit
- Preliminary flora study of Crown lands (Functional Area 1), Cattai Ridge Road, Halcrows Road, Hillside/Glenorie; submission to Director NPWS and to Baulkham Hills Council. **NSW NPA**
- Flora survey of Morans Rock Crown lands for proposed addition to Wollemi National Park. **NSW NPA**

- Proposed Welcome Reef Dam (Shoalhaven River north of Braidwood) **-** assist with flora and fauna surveys. **NSW NPA**. Much of the area is now within Nadgigomar Nature Reserve
- Flora survey of surplus Department of Education lands at Ellerman Park, Round Corner. The local community proposed that the area become a reserve to protect a critically endangered plant community present on the site. **Friends of Ellerman Park**
- Flora survey of Crown lands at South Maroota for proposed Crescent Reach Nature Reserve (later declared as the Maroota Ridge State Conservation Area), **NSW NPA**
- Calangara Nature Reserve Proposal in Kenthurst. Survey and report to **NSW NPA**
- Preliminary Survey of bushland in Holland Reserve, Glenhaven
- Survey of Crown Reserve (now part Scheyville NP), Pitt Town; report to **NSW NPA**

Expert report – Cumberland Plain Land Snail

Expert report on the Cumberland Plain Land Snail, *Meridolum corneovirens* (Pfeiffer, 1851) in the Penrith, Western Sydney Aerotropolis, Greater Macarthur and Wilton Growth Areas, Stephanie A. Clark, December 2018

Strategic assessment for Cumberland Plain Conservation Plan

Expert report on the Cumberland Plain Land Snail, *Meridolum corneovirens* (Pfeiffer, 1851) in the Penrith, Western Sydney Aerotropolis, Greater Macarthur and Wilton Growth Areas.

Prepared for the New South Wales Department of Planning & Environment

Stephanie A. Clark

December, 2018

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Contents

1. Introduction

1.1 Project context

The Department of Planning and Environment is currently preparing a strategic assessment to identify development impacts and conservation outcomes within four new urban growth areas on the Cumberland Plain in Western Sydney. Expert reports may be used as part of the threatened species assessment as outlined in the Biodiversity Assessment Method (BAM).

The BAM requires surveys for all 'Species Credit Species' (SCS) identified as likely to occur in the study area unless an expert report is prepared, or the species is assumed to be present. The Department of Planning and Environment engaged Biosis and Ecoplanning to undertake surveys for candidate SCS within the growth areas in accordance with the BAM and Office of Environment and Heritage (OEH) threatened species survey guidelines. Surveys were undertaken over the period November 2017 to November 2018.

1.2 Purpose of the expert report

Large areas of suitable habitat were unable to be surveyed due to land access issues and the snail is an uncommon species that can easily be misidentified. For these reasons an expert report on *Meridolum corneovirens* was required to supplement the data collected as part of the survey effort.

The purpose of this report is to provide an assessment of the current status and potential presence of *Meridolum corneovirens* within four defined Growth Areas of Western Sydney and to determine whether:

a) The species is unlikely to be present and thus requires no further assessment; or
b) The species is known or likely to be present, and if so the report must provide estimates of potential habitat within the Growth Areas and the proposed urban development zones.

1.3 The study area

The strategic assessment covers four growth areas in Western Sydney:

- Greater Penrith to Eastern Creek Urban Investigation Area
- Western Sydney Aerotropolis Growth Area
- Greater Macarthur Growth Area
- Wilton Growth Area

The Greater Penrith to Eastern Creek and Western Sydney Aerotropolis Growth Areas are located in the western part of the Sydney Metropolitan Area between Llandilo in the north and Bringelly in the south and Emu Heights in the west and Eastern Creek in the east. The Greater Macarthur and Wilton Growth Areas are located in the south western part of the Sydney Metropolitan Area, between Casula in the north and Wilton in the south and Tahmoor in the west and Holsworthy in the east (see Figure 1).

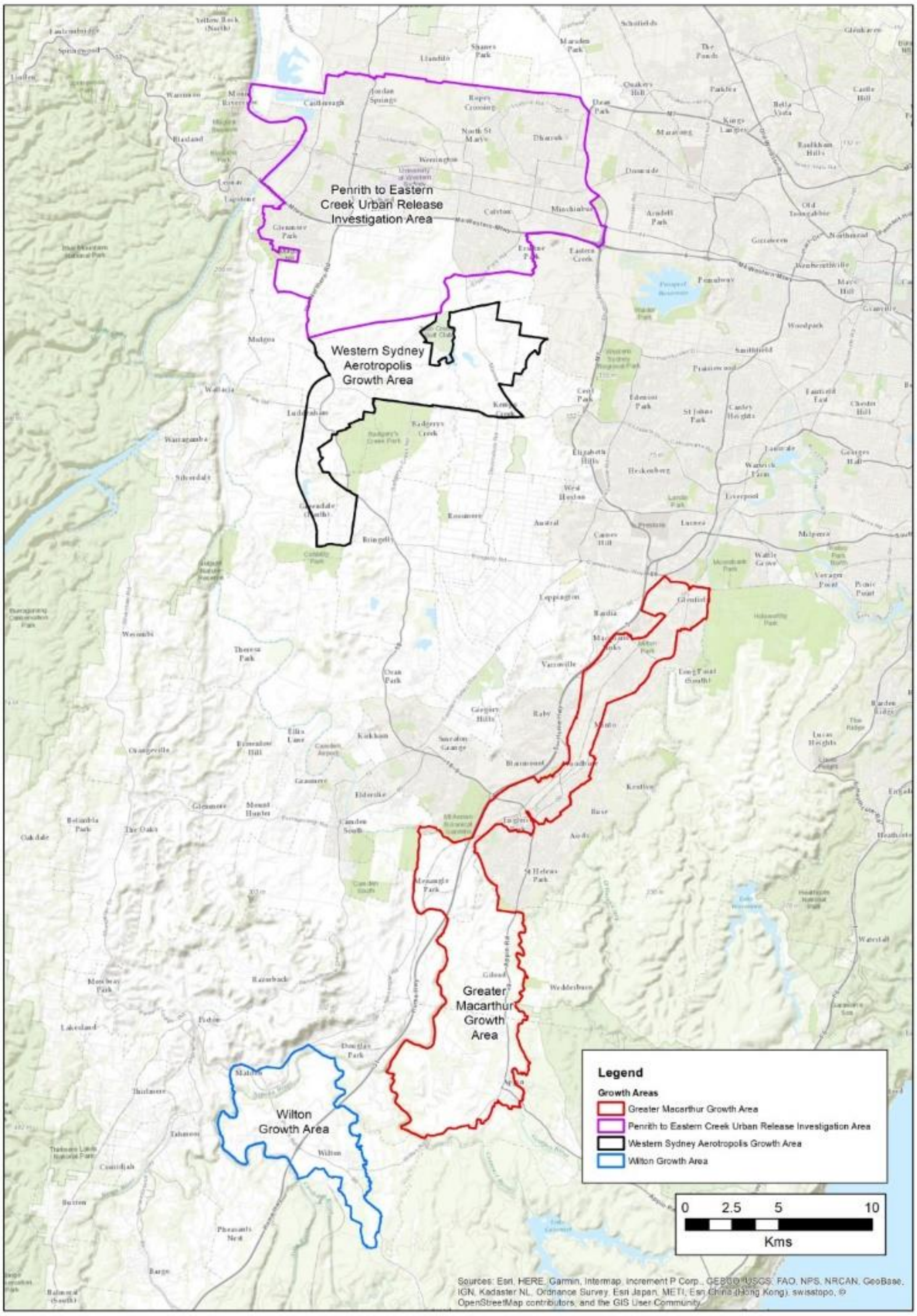

Figure 1. Showing the location of the four growth areas.

1.4 Reasons for use of an expert report

An expert report for *Meridolum corneovirens* is required as part of the threatened species assessment for the Cumberland Plain Conservation Plan for the following reasons:

1. Large areas of habitat were not able to be surveyed. Not all land holders allowed ecologists to enter their property and conduct BAM surveys or targeted fauna surveys. This restricted the opportunity to visit all potential areas of habitat within the proposed development footprint, especially within the Greater Macarthur Growth Area. The initial surveys focussed on flora species and did not specifically target *Meridolum corneovirens.*
2. Section 4.4 of the NSW Guide to Surveying Threatened Plants (OEH 2016) provides for the consideration of 'site survey and an expert report' where areas are large. This species has been searched for during the survey but is very cryptic. Preparation of an expert report will supplement the field surveys to identify the area of occupancy and likely density of individuals.
3. The species' relatively small size, its cryptic habitat, its ability to remain dormant in unfavourable environmental conditions and it can be easily overlooked/missed by non-specialists.

1.5 Credentials of expert

Dr Stephanie Clark is an invertebrate taxonomist with more than 30 years of experience in the identification and taxonomy of molluscs (and in particular gastropods). She currently consults worldwide on invertebrate identification through her business Invertebrate Identification Australasia.

Dr Clark was the first expert to be approved by OEH as an Expert under section 6.5.2.4 of the Biodiversity Assessment Method on the 15 May 2018 (valid for the next six years). A resume is included in the Appendix.

2 Species information

2.1 Species description

The shell is globose to subglobose in shape (Figure 2), up to about 24mm in height and 29mm in width. Spire moderately elevated. Aperture roundly ovate, up to about 14mm in height and 19mm in width. Total number of whorls 4.8–5.7. Last teleoconch whorl rounded, or with slight angulation; up to about 21mm in height. Shell sculpture consists of coarse growth lines and weak pustules. Teleoconch periostracal sculpture of weak zigzag ridges. Protoconch sculpture weakly pustulose. Shell uniform brown to tan or olive green, darker coloured individuals not uncommon. Red umbilical patch typically absent, occasionally faintly present. Red subsutural band very thin. Inner lip white (rarely pale pink), strongly reflected, largely occluding umbilical depression in adults, lip thin and not reflected in juveniles. Outer lip moderately deflected below midline of last whorl. Umbilicus closed to slightly open in adults, open in juveniles (modified from Clark, 2009).

The colour of the body of the snail is grey and the mantle is pale yellow (typical) to yellow.

Figure 2. Specimen of *Meridolum corneovirens* from Mulgoa.

2.2 Life cycle

Little is known of the biology, fecundity and longevity for the species. It is a hermaphrodite and capable of selfing, it lays clutches of about 20-25 small, round, white eggs in moist, dark places (Clark, 2009, Ridgeway *et al*., 2014), such as at the base of grass clumps and under logs (Figure 3). The snails probably live between 2-5 years but can certainly estivate in the soil or under logs etc for several months, especially when conditions are dry, such as those prevailing in Sydney in 2018. They feed predominately on fungi, but have been observed eating fresh dead individuals of *M*. *corneovirens* and other carrion, paper, plant detritus and old shells (Clark, personal observations; Ridgeway *et al*., 2014).

The snails are generally active at night or on moist, warm overcast days.

A  **B**. 

Figure 3. A. *Meridolum corneovirens* laying eggs in a grass clump at Mount Druitt. B. Three egg clutches of *Meridolum corneovirens* that were found under a log at Kemps Creek.

2.3 Distribution and abundance

Meridolum corneovirens is endemic to the Cumberland subregion in the western portion of Sydney, from Pitt Town in the north to Tahmoor in the south and from Georges Hall in the east to Mowbray Park in the west (Clark, 2005; 2009, NSW OEH Cumberland Plain Land Snail – profile). The total number of individuals of *M*. *corneovirens* across its range is unknown, nor the densities that the species can occur. The species can be relatively common when suitable habitat is present. However, most known populations are found on relatively small, isolated patches of habitat that are often surrounded by some combination of industrial, agricultural or urban development.

2.4 Habitat requirements

Meridolum corneovirens is wholly restricted to western Sydney and is primarily associated with the critically endangered Cumberland Plain Woodland ecological community. However, it has also been found in the following listed ecological communities: Moist Shale Woodland, Shale Gravel Transition Forest, Shale Sandstone Transition Forest, Cooks River/Castlereagh Ironbark Forest, Castlereagh Scribbly Gum Woodland, Castlereagh Swamp Woodlands and the margins of River-flat Eucalypt Forest. It can be found in leaf litter, grass tussocks, under logs and non-natural debris such as cardboard and old furniture etc. Where conditions permit it will bury into loose soil up to 10 cm such as under logs and around the bases of trees (Clark, 2009; Ridgeway et al., .2014).

3 Description of the study area

3.1 Land use history

From the early 1800s there has been extensive clearing of the native vegetation for agricultural, industrial and urban development, which has resulted in a significant reduction in the extent of the native vegetation, leading to increased fragmentation and isolation of the remaining remnants. This increased fragmentation has led to a loss of biodiversity and to the spread of invasive and non-indigenous species.

The extensive clearing, fragmentation and degradation of the remaining vegetation remnants has led to a reduction in the distribution, extent and abundance of *M. corneovirens* that existed prior to European settlement.

3.2 Landscape context

The majority of the study area consists of gentle undulating hills and valleys and is bounded by the sandstone cliff lined valleys of the Nepean River on the western, southern and south western boundaries and the Georges River on the south eastern boundary and the Cecil Hills Ridge and the Castlereagh sand deposits along the northern and eastern boundaries.

3.3 Native vegetation communities

Meridolum corneovirens inhabits a range of vegetation types across the study area, although most typically it is found in the Cumberland Plain Woodlands.

Meridolum corneovirens has been recorded from the following plant communities which are found within one or more of the four growth areas:
724 – Broad-leaved Ironbark – Grey Box – *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain;
725 –Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion;

830 - Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain;
835 - Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain;
849 - Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain;
850 - Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain;
1395 - Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain;

Meridolum corneovirens will potentially be found in any remaining intact or relatively intact remnants / patches of suitable habitat, especially if there is a well-developed leaf litter layer, plenty of woody debris on the ground and few exotic/invasive species. It can also be found at the boundaries of plant communities that do provide suitable habitat and those that typically do not such as where Cumberland Plain Woodland adjoins Swamp Oak Floodplain Forest in the western parts of the Cumberland Subregion.

4 Assessment of species presence and habitat

4.1 Existing records and surveys

Meridolum corneovirens has previously been recorded from a number of locations across the Greater Penrith to Eastern Creek, Western Sydney Aerotropolis and Greater Macarthur Growth Areas but not to date in the Wilton Growth Area (Clark, 2009, Bionet, 2018, Clark, personal observations from 1998-2002) (Figures 4-6).

To the best of the author's knowledge there have been no region-wide surveys for *M. corneovirens* across the four growth areas or the entire range of the species since 1999 when the author was asked by NPWS to survey 130 sites across the greater Sydney area. During this survey the species was detected at 61 sites, of which 14 fall within the growth areas defined here (10 in Penrith, 4 in Greater Macarthur).

The majority of the previous records are from targeted surveys for development sites by the author and other consultants, general collecting by the author (89 sites), colleagues and other random observations by the general public, local and state government personnel.

4.2 Surveys completed for the biocertification

Targeted fauna surveys were completed by Biosis during the period November, 2017 to November, 2018. Surveys on foot covered a total area of 100 hectares across the four growth areas calculated by applying a 20m buffer either side of GPS survey tracks. This represents around 5% of the future development footprint (where surveys were concentrated) and around 1% of the total vegetated habitat within the growth areas (GIS analysis supplied by DPE, November 2018).

Meridolum corneovirens was found at three locations by Biosis staff. Two of these locations were previously known to the author, being south of Goldsmith Ave and Wianamatta Regional Park (formerly known as the ADI site). However, the conditions since the beginning of the biocertification process have been extremely dry and warm with well below normal rainfall. Although Ecoplanning and Biosis have conducted extensive surveys across the study area, the statistics above confirm that the vast majority of these surveys were botanical in nature and not targeted toward fauna species such as *M. corneovirens*.

The targeted fauna surveys that have been conducted by Ecoplanning and Biosis have been hampered by issues such as limited access to properties, extremely dry conditions, concentrating limited staff resources towards surveying for the larger threatened vertebrate species and a lack of specialised knowledge about *M. corneovirens*, resulting in low detection rates. In addition, there is a very similar looking, closely related species, *M. sheai* Clark, 2009, which can be found in the shale-sandstone transition forest and sandstone forest community types within the Greater Macarthur and Wilton Growth Areas.

4.3 Surveys completed for this assessment

The extended dry period, cold night time temperatures and access issues since 6 June, 2018 has made detecting *M. corneovirens* relatively difficult. Nonetheless, between 6-30 June and 30 October to 15 November, 2018, the author detected evidence for *M. corneovirens* at 23 locations (8 in the Greater Penrith to Eastern Creek Growth Area; 2 in the Western Sydney Aerotropolis Growth Area and 13 in the Greater Macarthur Growth Area) (Figures 4-6).

Attempts were made to verify a number of BioNet records from around Gordon Lewis Oval, Appin and along the southern side of the Nepean River, west of Elladale Creek, Appin but because of the extremely dry and cool conditions no evidence for the species was found. The author was unable to access the Macquarie Road Reserve, Ingleburn, due to the area being fenced off. Campbelltown City Council was contacted and were happy to provide access but unfortunately this was not possible on the day and it was decided to organise a site visit at a future to be determined date.

The vast majority of the individuals of *M. corneovirens* encountered were empty shells and fragments, while less than 20 living specimens, all juveniles and subadults were observed at 10 sites (four in the Greater Penrith to Eastern Creek and six in the Greater Macarthur Growth Areas). The largest number of living individuals observed at a site was 10 (juveniles and subadults) at Goldsmith Ave (within the Greater Macarthur Growth Area), after heavy rain earlier in the day. At the other nine locations only one or two living snails were observed and all were buried in the leaf litter or under logs and woody debris.

Within the Wilton Growth Area relatively little of the potential habitat was accessible and the only occasion that *Meridolum* was found was at the Shingle Hill property off Picton Rd on 20 June, where two very long dead specimens of what appear to be *M. sheai* were found. The day before staff from Biosis had recorded the presence of a number of individuals of *M. corneovirens* from the more open areas of the property between a farm dam and Picton Rd, but on later examination of some voucher specimens these were identified as *Cornu aspersum*, the Common Garden Snail.

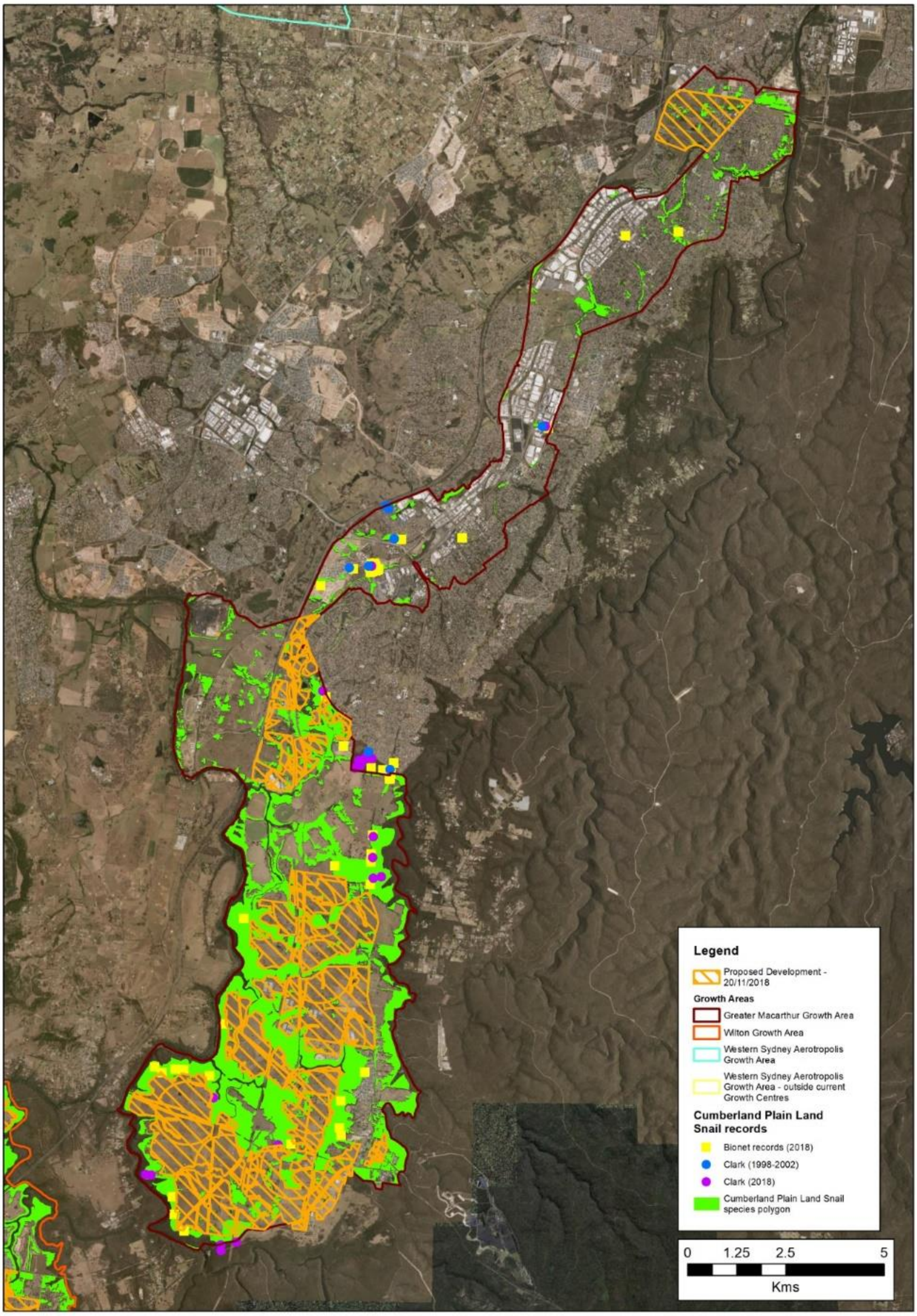

Figure 4. Map of the Greater Macarthur Growth Area showing the records of *Meridolum corneovirens* and the species polygons are in green. The yellow squares are the BioNet records (2018), the purple dots are records found during the current survey and the blue dots are records found by the author between 1998 and 2002.

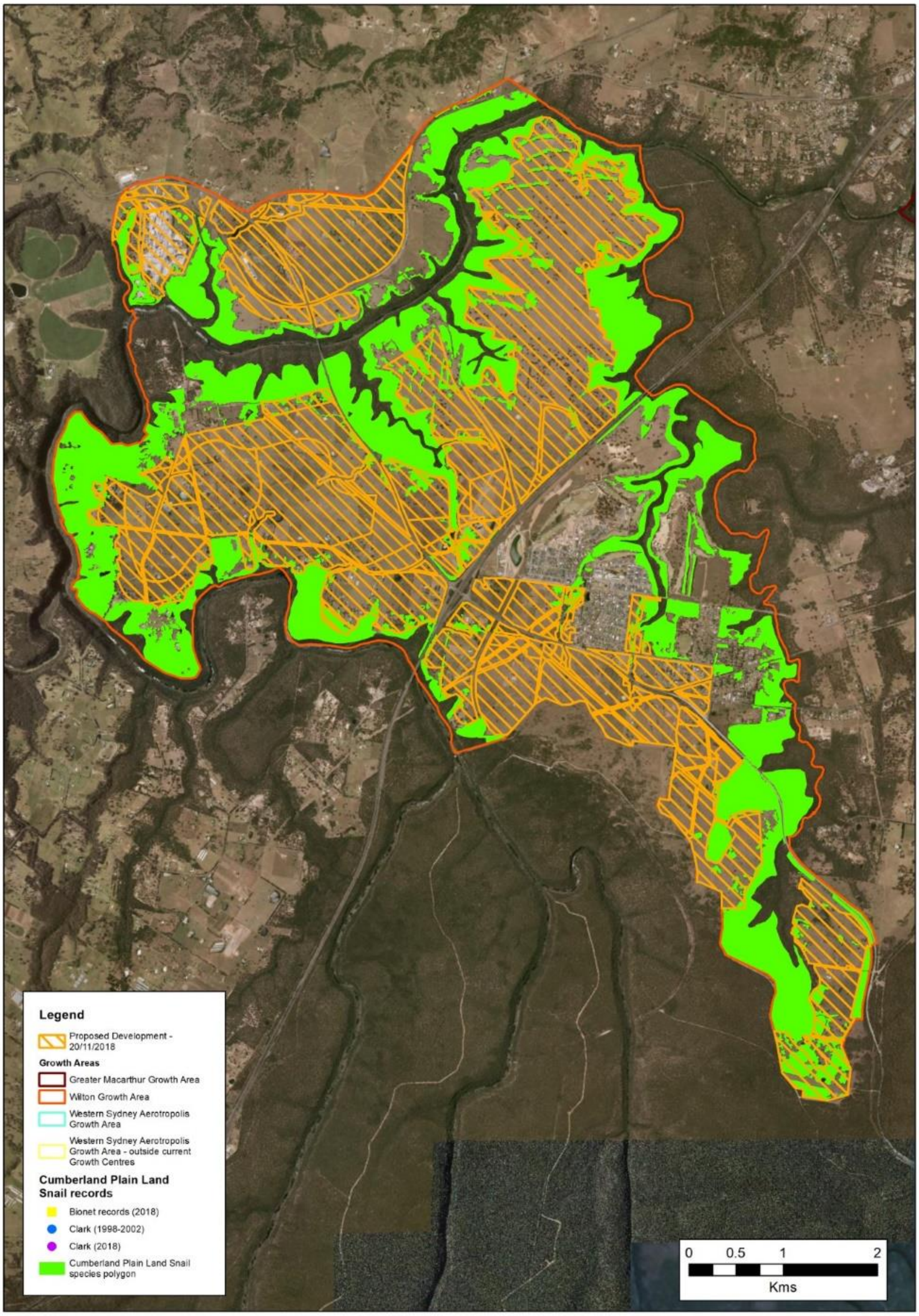

Figure 5. Map of the Wilton Growth Area showing the species polygons in green. Currently no records for *M*. *corneovirens* have been found in the area. However, the closely related species *M*. *sheai* has been recorded within and just outside of the growth area in 2017-2018.

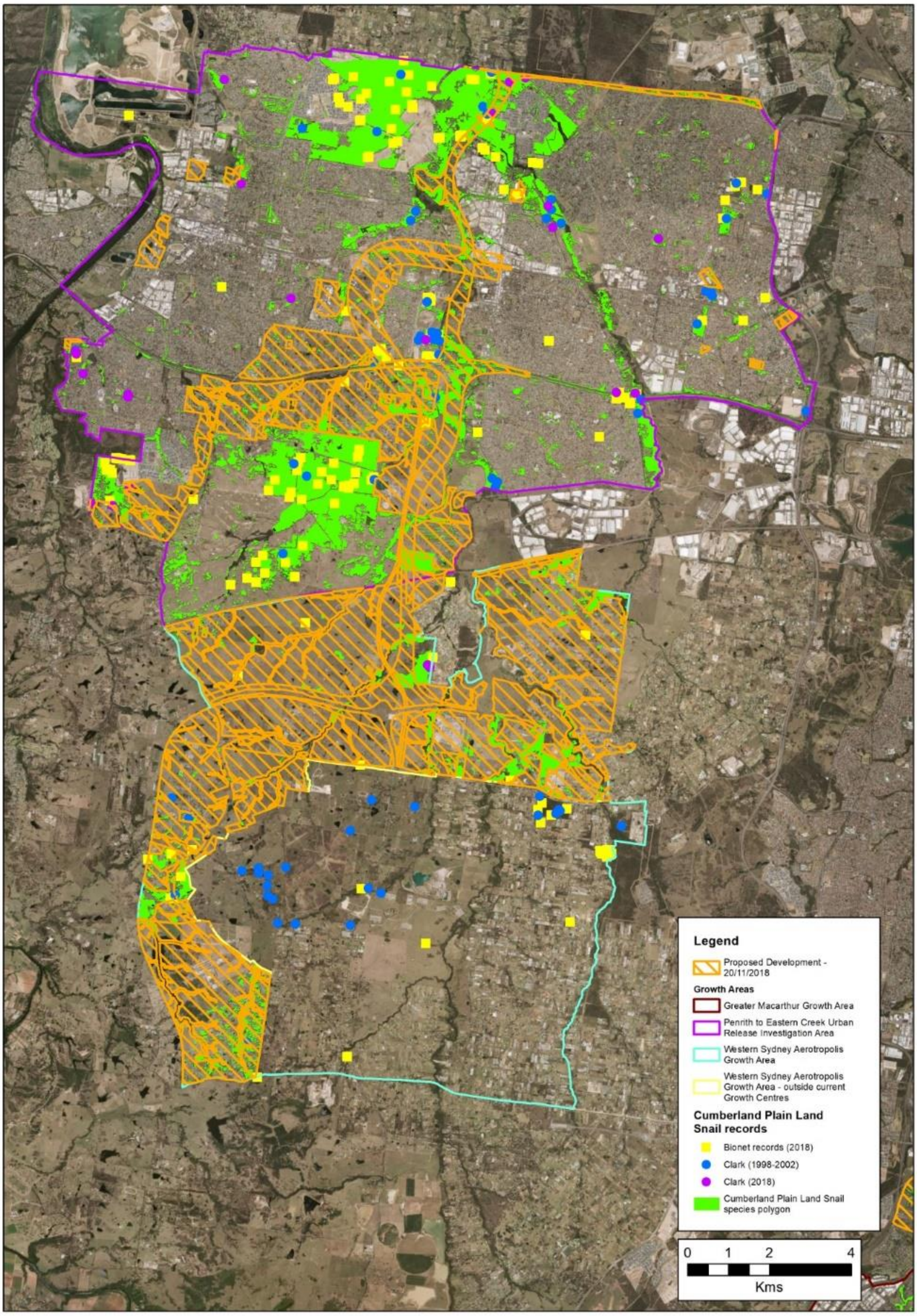

Figure 6. Map of the Penrith and Western Sydney Aerotropolis Growth Areas showing the species polygons in green. The yellow squares are the BioNet records (2018), the purple dots are records found during the current survey and the blue dots are records found by the author between 1998 and 2002.

4.4 Assessment of species presence

Likelihood of species presence

There are 13 records of *M. corneovirens* that fall within the future development footprint of the Greater Penrith to Eastern Creek Growth Area, mostly in the transportation corridors. There are six records that fall within the future development footprint of the Western Sydney Aerotropolis. While, no records were found within the future development footprint for the Greater Macarthur and Wilton Growth Areas (Figures 4-6).

However, there is potential for *M. corneovirens* to be found in areas of suitable habitat within the biocertification areas that have yet to be surveyed, or that have been surveyed but conditions were not conducive to detecting the species at the time of the survey, especially if there is plenty of leaf litter and woody debris.

Justification for determining presence

The species polygons (Figures 4-6) are based on a combination of the vegetation communities where the species has been found during the current survey and previous surveys, and the assumption that where suitable habitat is present within the growth areas that the species is likely to be present but due to a variety reasons (such as access issues and extremely dry conditions) the species has not been detected.

4.5 Assessment of suitable habitat

Suitable habitat within the growth areas

Suitable habitat was presumed to include all the PCT's mentioned above that had been mapped as either intact or thinned that occurred across the four growth areas.

Species polygons

Figures 4-6 show the species polygons for *M. corneovirens* across the four growth areas.

Estimate of area of habitat

Across the four growth areas there is a total of 6953.3 hectares of potential habitat for *M. corneovirens* (Table 1), with a total of 987.0 hectares found within the future development footprint, of which:

- 2421.3 hectares occur within the Greater Macarthur Growth Area of which 215.5 hectares occur within the future development footprint
- 2788.3 hectares occur in the Greater Penrith to Eastern Creek Growth Area of which 351.0 hectares occur within the future development footprint
- 592.9 hectares occur within the Western Sydney Aerotropolis and of which 259.0 hectares occur within the future development footprint
- 1150.8 hectares occur within the Wilton Growth Area of which 161.6 hectares occur within the future development footprint.

The total area in hectares of each of the different PCTs listed above in which *M. corneovirens* can potentially be found across each of the growth areas are listed in Table 1. The Greater Penrith to Eastern Creek Growth Area contains the largest area of suitable habitat as well as the highest number of records for *M. corneovirens*.

PCT	GMGA	GPECGA	WSA	WGA	Totals
724 intact		69.2	3.3		72.5
724 thinned		65.7	49.5		115.2
725 intact		87.4	19.8		107.2
725 thinned		33.9	16.4		50.3
830 intact	2.2	2.8			5.0
830 thinned	16.4				16.4
835 intact	56.4	321.4	13.4		391.2
835 thinned	121.3	496.6	111.2		729.1
849 intact	94.9	430.7	29.3	4.2	559.1
849 thinned	176.5	1225.5	344.2	70.3	1816.5
850 intact	86.8	0.2			87.0
850 thinned	133.8	52.9	5.8		192.5
1395 intact	1296.2			543.2	1839.4
1395 thinned	436.8	2.0		533.1	971.9
Totals	2421.3	2788.3	592.9	1150.8	6953.3

Table 1. Lists the area of each of the different PCTs (in hectares) that provide known or suitable habitat for *M. corneovirens* across the four growth areas. GMGA - Greater Macarthur Growth Area; GPECGA - Greater Penrith to Eastern Creek; WSA - Western Sydney Aerotropolis; WGA – Wilton Growth Area.

5 Information used in this assessment

The information used to make the above assessment is drawn from the literature (Clark, 2005, 2009; Cumberland Plain Land Snail – profile) and the authors' personal observations and knowledge of the species built up over the past 30 years. The author also prepared the original Cumberland Plain Large Land Snail as it was then called, threatened species information and environmental impact assessment guidelines information sheets in 1999.

Additional records were obtained by searching the BioNet and ALA (Australian Living Atlas) databases. Biosis and Ecoplanning provided records that they found during the surveys they carried out for the current project.

Vegetation mapping for the growth areas was provided by DPE.

GIS analysis of the PCT's and preparation of the species polygons following the authors' requirements were provided by Darren James (DAJ Environmental).

6 References

Clark, S.A. 2005. Systematics, spatial analysis and conservation genetics of *Meridolum corneovirens* and related forms (Gastropoda: Camaenidae) from the Sydney Region of Australia. Ph.D. Thesis, University of Western Sydney, Richmond, Sydney, New South Wales. pp. i-xiii, 1-256.

Clark, S.A. 2009. A review of the land snail genus *Meridolum* (Gastropoda: Camaenidae) from central New South Wales, Australia. *Molluscan Research* **29(2)**:61-120.

Cumberland Plain Land Snail – profile. New South Wales Office of Environment & Heritage. Last accessed Aug 2018.
https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10526

Ridgeway, P.A., Kurtis, L., Dion, P. and Visintina, A. 2014. Indications of diverse behavioural ecologies in the morphologically conservative Australian land snails *Pommerhelix* and *Meridolum* (Stylommatophora: Camaenidae). *Molluscan Research* **34(1)**:25-39.

7 Appendix: Curriculum Vitae of Stephanie Clark

PERSONAL

Business address	Faulconbridge, NSW 2776
Mobile	0426 204 240
E-mail:	meridolum@ozemail.com.au
Citizenship	Australian and American

EDUCATION

Ph.D., 2005. University of Western Sydney, New South Wales, Australia. Taxonomy and conservation.
M.Sc., 1998. Macquarie University, New South Wales, Australia. Taxonomy and genetics.
B.App.Sc., 1990. University of Technology, Sydney, New South Wales, Australia. Major biochemistry.

PROFESSIONAL EXPERIENCE

Current and/or completed:

1997 - present. Consultant work (Invertebrate Identification Australasia - Owner) for various Australian and United States councils, government agencies (State, Commonwealth and Federal), environmental consultancies, mining companies and developers on short and medium term projects dealing mostly with molluscs and insects (particularly endangered species assessments).

Oct 2017 - Completed Biodiversity Assessment Method (BAM) course.

Aug 2017 – Sept 2017. Conduct one day snail identification workshops for the Department of Agriculture & Water Resources, biosecurity biomonitoring sections in Sydney, Melbourne and Perth.

Sept 2016 - Mar 2017. Identified almost 4000 lots of North American land and freshwater molluscs for the Field Museum of Natural History, Chicago, IL.

July 2016 – Dec 2016. Formally describe the US federally endangered freshwater snail, the Banbury Lanx for the Boise Office of the US Fish and Wildlife Service.

Feb 2015 – Mar 2016. Preparing a list of all the names, synonyms and combinations applied to the non-marine molluscs of North America, for the Field Museum of Natural History, Chicago, IL.

Oct 2014 – Feb 2016. Prepare a status report for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) on the Shortface Lanx (*Fisherola nuttallii*) in Canada.

Jan 2013. Conducted a one day workshop on the identification of the endangered Cumberland Land Snail (*Meridolum corneovirens*) for the Ecological Consultants Association of NSW, Mount Annan, NSW, Australia.

June 2011 – present. Contracted with Deixis Consultants to write a Field Guide to the freshwater Molluscs of the Pit-Sacramento Rivers, California by the Cantara Trustee Council Grant Program.

GRANTS

Clark, S.A. and Harris, P. State of Alabama Department of Conservation and Natural Resources - Distribution, life history, conservation and systematics of Alabama's Pebblesnails. Oct 2004 - Sept 2006. $26,930.

Clark, S.A. Hawkesbury Postgraduate Research Award - PhD, University of Western Sydney. Jan 2000 - Oct. 2002. $47,250.

Ponder, W.F. and Clark, S.A. Australian Biological Resources Study - Interactive CD-Rom guide and key to the freshwater Mollusca of Australia. Jan 1999 - Dec 2001. $90,000.

PROFESSIONAL SOCIETIES

American Malacological Society;
Conchological Society of Great Britain and Ireland;
Malacological Society of London;
Malacological Society of Australasia;
Member of the IUCN SSC Mollusc Specialist Group;
The Ecological Consultants Association of New South Wales.

RESEARCH INTERESTS

Systematics, population and conservation genetics of invertebrates particularly terrestrial and freshwater molluscs.

EXPERIENCE

I have over 30 years' experience in the collection, identification and taxonomy of marine, estuarine, freshwater and terrestrial molluscs in 28 countries and 41 US states. I have over 12 years' experience using allozyme electrophoresis to study speciation and population genetics particularly of molluscs but also some work with reptiles and spiders and at least 5 years' experience analysing DNA data. I have about 6 years' experience preparing material for and using a scanning electron microscope and have dissected individuals from several hundred populations of freshwater and terrestrial molluscs.

LEGAL EXPERIENCE

I have served as an expert witness for the Land and Environment Court of New South Wales on six occasions since 1997 and have provided expert testimony for several other cases.

PROFESSIONAL ACTIVITIES

Research Associate at the Field Museum of Natural History, Chicago, Illinois, June, 2010 to present.

Vice President of the Chicago Shell Club, Chicago, Illinois, May, 2010 to May, 2016.

Courtesy Postdoctoral Researcher, Division of Malacology at the Florida Museum of Natural History, Gainesville, Florida, September, 2009 to 2016.

Invited participant at the IUCN Red List workshop assessing the Red List status of the world's freshwater molluscs, organised jointly by the Zoological Society of London, the Encyclopedia of Life (EOL), International Union for Conservation of Nature (IUCN), and the IUCN SSC Mollusc Specialist Group. Held in London, United Kingdom, February, 2010.

Served on the Status Review Panel for the federally endangered Idaho Springsnail (*Pyrgulopsis robusta*), in Boise, Idaho, for the United States Fish and Wildlife Service, Western Region, October, 2005.

TELEVISION

Short interview about my PhD project on the endangered endemic Sydney land snail *Meridolum corneovirens*, aired on ‘Totally Wild’ (a children’s educational program on wildlife and the environment), Australia wide, 7 May 2002.

Short interview regarding the endangered endemic Sydney land snail *Meridolum corneovirens* and how the Olympic Coordinating Authority (OCA) has helped in its conservation, aired on ‘A Current Affairs’ (a prime time news and current affairs program) Australia wide on the 15 September, 1998.

RADIO

Short interview with Brian Bury, 4BC, Brisbane, about Australian native snail diversity aired Nov. 2002.

NEWSPAPER/INTERNET

Several interviews about molluscs, endangered species and rediscovering a species previously thought to be extinct, with national, local and internet media outlets, both in Australia and the United States since 2002.

Some examples:
ABC News: When Birds Overshadow Snails -- And Why That's a Problem
http://abcnews.go.com/Technology/story?id=734467&page=1

http://www.cofc.edu/~fwgna/archive/9May05.html

PUBLICATIONS

Keenan, S.W., Audrey T. Paterson, A.T., Niemiller, M.L., Slay, M.E., Clark, S.A. and Engel, A.S. 2017. Observations of the first stygobiont snail (Hydrobiidae, *Fontigens* sp.) in Tennessee. *Proceedings of the 17th International Congress of Speleology* **2017**:91-94.

Campbell, D.C., Clark, S.A. and Lydeard, C. 2017. Phylogenetic analysis of the Lancinae (Gastropoda, Lymnaeidae) with a description of the U.S. federally endangered Banbury Springs lanx. *ZooKeys* **663**:107-132.

Ponder, W.F., Hallan, A., Shea, M. and Clark, S.A. 2016. Australian Freshwater Molluscs. The snails and bivalves of Australian inland waters. Interactive key http://keys.lucidcentral.org/keys/v3/freshwater_molluscs/

Johannes, E.J. and Clark, S.A. 2016. Freshwater mollusc declines, local extinctions and introductions in five northern California streams. *Tentacle* **24**:22-25.

Campbell, D., Clark, S.A., Johannes, E., Lydeard, C. and Frest, T. 2016. Molecular phylogenetics of the freshwater gastropod genus *Juga* (Cerithioidea: Semisulcospiridae). *Biochemical Systematics and Ecology* **65**:158-170.

Gerber, J. and Clark, S.A. 2015. First record of the predatory land snail *Streptostele* (*Tomostele*) *musaecola* (Pulmonata: Streptaxidae) in the continental United States. *American Conchologist* **43(4)**:26-28.

Hauk, A., Clark, S.A., McCravy, K.W., Jenkins, S.E. and Lydeard, C. 2015. A Survey of Terrestrial Gastropods of the Alice L. Kibbe Life Science Station in West-Central Illinois. *Northeastern Naturalist* **22(2)**:299-306.

Bieler, R., Mikkelsen, P.M., Timothy M. Collins, T.M., Glover, E.A., González, V.L., Daniel L. Graf, D.L., Harper, E.M., John Healy, J., Kawauchi, G.Y., Sharma, P.P., Staubach, S., Strong, E.E., Taylor, J.D., Tëmkin, I., Zardus, J.D., Clark, S., Guzmán, A., McIntyre, E., Sharp, P. and Giribet, G. 2014.

Investigating the Bivalve Tree of Life – an exemplar-based approach combining molecular and novel morphological characters. *Invertebrate Systematics* **28(1)**:32-115.

Clark, S.A. 2009. Revision of the genus *Posticobia* (Mollusca: Caenogastropoda: Rissooidea: Hydrobiidae s.l.) from Australia and Norfolk Island. *Malacologia* **51(2)**:319-341.

Clark, S.A. 2009. A review of the land snail genus *Meridolum* (Gastropoda: Camaenidae) from central New South Wales, Australia. *Molluscan Research* **29(2)**:61-120.

Ó Foighil, D., Lee, T., Campbell, D.C. and Clark, S.A. 2009. All voucher specimens are not created equal: a cautionary tale involving North American pleurocerid gastropods. *Journal of Molluscan Studies* **75(3)**:305-306.

Waggoner, J., Clark, S.A., Perez, K.E. and Lydeard, C. 2006. A survey of terrestrial gastropods of the Sipsey Wilderness (Bankhead National Forest), Alabama. *Southeastern Naturalist* **5(1)**:57-68.

Ponder, W.F., Clark, S.A., Eberhard, S. and Studdert, J.B. 2005. A radiation of hydrobiid snails in the caves and streams at Precipitous Bluff, southwest Tasmania, Australia (Mollusca: Caenogastropoda: Rissooidea: Hydrobiidae s.l.). *Zootaxa* **1074**:1-66.

Perez, K.E., Ponder, W.F., Colgan, D.J., Clark, S.A. and Lydeard, C. 2005. Molecular phylogeny and biogeography of spring-associated hydrobiid snails of the Great Artesian Basin, Australia. *Molecular Phylogenetics and Evolution* **34(3)**:545-556.

Clark, S.A. 2005. Systematics, spatial analysis and conservation genetics of *Meridolum corneovirens* and related forms (Gastropoda: Camaenidae) from the Sydney Region of Australia. Ph.D. Thesis, University of Western Sydney, Richmond, Sydney, New South Wales. pp. i-xiii, 1-256.

Lydeard, C., Cowie, R.H., Ponder, W.F., Bogan, A.E., Bouchet, P., Clark, S.A., Cummings, K.S., Frest, T.J., Gargominy, O., Herbert, D.G., Hershler, R., Perez, K.E., Roth, B., Seddon, M., Strong, E.E., Thompson, F.G. 2004. The global decline of nonmarine mollusks. *Bioscience* **54(4)**:321-330.

Clark, S.A. 2004. Native snails in an urban environment – conservation from the ground up. In: *Urban wildlife: more than meets the eye*. Eds. Lunney, D. and Burgin, S., Royal Zoological Society of New South Wales, Mosman, NSW, Australia, pp. 78-81.

Clark, S.A., Miller, A.C. and Ponder, W.F. 2003. Revision of *Austropyrgus* (Gastropoda: Hydrobiidae); a morphostatic radiation of freshwater gastropods in south-eastern Australia. *Records of the Australian Museum, Supplement* **28**:1-109.

Clark, S.A. and Richardson, B.J. 2002. Spatial analysis of genetic variation as a rapid assessment tool in the conservation management of narrow range endemics. *Invertebrate Systematics* **16(4)**:583-587.

Ponder, W.F., Clark, S.A. and Dallwitz, M.J. 2000. Freshwater and Estuarine Molluscs. An interactive, illustrated key for New South Wales. CD-ROM, CSIRO Publishing, Melbourne, Australia.

Miller, A.C., Ponder, W.F. and Clark, S.A. 1999. Freshwater snails of the genera *Fluvidona* and *Austropyrgus* (Gastropoda, Hydrobiidae) from northern New South Wales and southern Queensland, Australia. *Invertebrate Taxonomy* **13(3)**:461-493.

Ponder, W.F., Clark, S.A. and Miller, A.C. 1999. A new genus and two new species of Hydrobiidae (Mollusca: Gastropoda: Caenogastropoda) from south Western Australia. *Proceedings of the Royal Society of Western Australia* **82(3)**:109-120.

Clark, S.A. 1997. Taxonomy and biology of *Posticobia* (Gastropoda: Hydrobiidae). M.Sc. Thesis, Macquarie University, North Ryde, Sydney, New South Wales. pp. 1-199.

Ponder, W.F., Colgan, D.J., Terzis, T., Clark, S.A. and Miller, A.C. 1996. Three new morphologically and genetically determined species of hydrobiid gastropods from Dalhousie Springs, northern South Australia, with the description of a new genus. *Molluscan Research* **17**:49-106.

Expert report – *Dillwynia tenuifolia*

Expert report for *Dillwynia tenuifolia*, Paul Rymer, March 2019

Cumberland Plain Conservation Plan

Expert report for *Dillwynia tenuifolia* March 2019

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Contents

Cumberland Plain Conservation Plan

Expert report for *Dillwynia tenuifolia*

1. Introduction

1.2 Purpose of the expert report

The Department of Planning and Environment is currently preparing a strategic assessment to identify development impacts and conservation outcomes within new urban growth areas on the Cumberland (Interim Biogeographic Regionalisation for Australia [IBRA] subregion) in Western Sydney. Expert reports may be used as part of the threatened species assessment as outlined in the Biodiversity Assessment Method (BAM).

This document outlines the need for an expert report for the threatened plant species *Dillwynia tenuifolia* and the suitability of the expert who is proposed to prepare the report. The expert report is intended to supplement the data collected as part of the current survey effort.

1.3 Project context

The NSW Government is identifying areas for future urban development and associated infrastructure in Western Sydney. These future urban areas cover four priority growth areas: Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These new growth areas are all located within the Cumberland Plain Interim Biogeographic Regionalisation for Australia (IBRA) sub-region.

As part of the planning for the priority growth areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify development and conservation outcomes for the growth areas.

1.4 The study area

The study area is the Cumberland, Western Sydney, focusing on the urban growth areas: Wilton, Greater Macarthur, Western Sydney Aerotropolis and Penrith to Eastern Creek (Figure 1).

Greater Penrith & Eastern Creek Growth Area (GPECGA)

A large portion of this Growth Area is already urbanised, with several areas of industrial land use. Significant rural and peri-urban areas remain in the central north, the centre, and the southwest. Large areas of remnant vegetation are present in the far north (former Australian Defence Industries site, now in part Wianamatta Regional Park), and the Orchard Hills Defence facility. Mining of alluvium for sand and soil continues in the far northwest of the area in the Penrith Lakes locality.

Western Sydney Aerotropolis Growth Area (WSAGA)

This Growth Area adjoins the Greater Penrith & Eastern Creek area, extending south to the locality of Greendale, west of Bringelly. It is currently largely rural, with villages at Luddenham and Kemps Creek. Most rural areas are pastoral, but there are significant areas of more intensive rural use, including poultry and egg production, a large cattle feedlot and associated fodder cropping, and some market gardens and enclosed fruit and vegetable production. Quarrying occurs at the localities of Badgerys Creek and Kemps Creek.

Greater Macarthur Growth Area (GMGA)

The GMGA occurs in southwestern Sydney on predominantly shale soils that have been heavily cleared for agriculture and urban or industrial use. The northernmost section has long-established urban and commercial / industrial land use, while the southern section is largely rural (pastoral, minor cropping), with some villages and primarily subsurface mining (e.g. coal and coal seam gas). It extends from urban Glenfield in the north, to the rural village of Appin in the south.

Wilton Growth Area (WGA)

The Wilton Growth Area is the most southerly of the four Western Sydney Growth Areas dealt with in this Report. It extends from the village of Douglas Park in the north, to the village of Wilton in the south. It is primarily rural (pastoral) area with some more intensive agriculture, significant but mostly underground mining (primarily coal), and some long-established villages. The Hume Highway dissects this Growth Area.

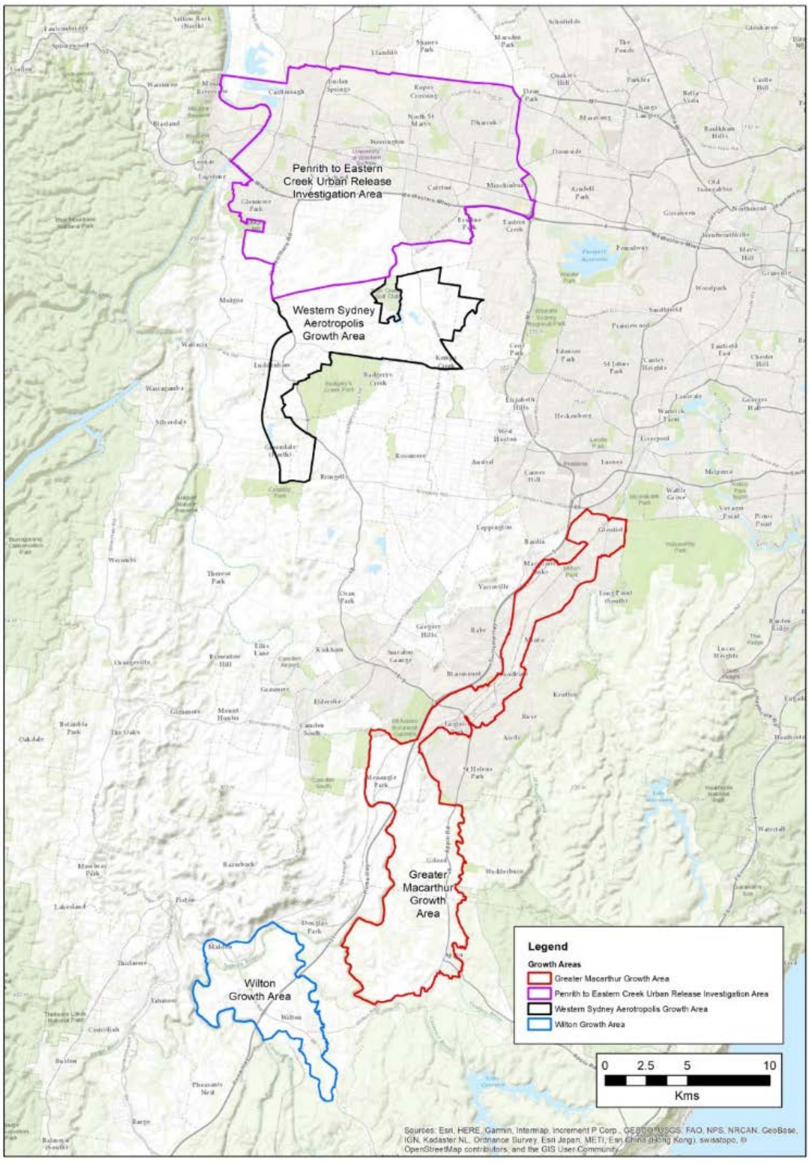


Figure 1: Map of the urban growth areas in Western Sydney

1.5 Reasons for use of an expert report

An expert report for *D. tenuifolia* is required as part of the threatened species assessment for the Cumberland Plain Conservation Plan for the following reasons:

1. Areas of habitat were not able to be surveyed. Not all land holders allowed the ecologists to enter their property and conduct BAM surveys. This restricted the opportunity to visit all potential areas of habitat within the proposed development footprint.
2. Section 4.4 of the NSW Guide to Surveying Threatened Plants (OEH 2016) provides for the consideration of 'site survey and an expert report' where areas are large. Based on site surveys and Bionet data, the species is unlikely to occur within the Wilton or Greater Macarthur growth areas. However due to the cryptic nature of this species outside the peak flowering season an expert in the species is required to determine whether suitable habitat exists.

1.6 Credentials of expert

Dr Paul Rymer is a senior lecturer at the Hawkesbury Institute for the Environment, Western Sydney University. He teaches and researches plant biology with a focus on conservation biology. Paul has contributed to the understanding of the biology and management of several threatened species, including *D. tenuifolia* and *Persoonia bargoensis* that were the focus of his postgraduate research. He has published his work in peer reviewed scientific journals, and provided reports to land managers.

2 Species information

2.1 Species description

"*Dillwynia tenuifolia* is a low spreading pea-flower shrub to a metre high. Its leaves are small and narrow (linear-terete, soft, 4-12mm long, with the tip often bent downwards). The wide orange-yellow and red pea-flowers are usually single, at or near the tips of the branches. Seed pods are brownish, egg-shaped, 4-5mm long with reticulate seeds. Both the singular orange flowers and the stem hairs distinguish it from the similar and more common yellow-flowered *Dillwynia glaberrima* and *D. floribunda*."
https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10226

2.2 Life cycle

Dillwynia tenuifolia is a fire sensitive (Auld 1996), perennial, woody, leguminous shrub (Harden 1991). Flowering occurs sporadically throughout much of the year, with a peak in flower production from August to October. Flowers are hermaphroditic and protandrous, and are commonly found individually on lateral branchlets. Seeds mature in December when they are released into the soil. Seed are physically dormant with a hard seed coat, requiring cracking (via physical disturbance or the heat of fire) to allow water to enter and germination to proceed. Seed can remain viable in the soil for several decades (Auld 1996), such that large soil stored seed banks can accumulate in healthy populations and regeneration may occur even when the standing population has expired some time before.

2.3 Distribution and abundance

Dillwynia tenuifolia is an endemic species that forms large populations within a restricted geographic range and specific habitat [predominately the Castlereagh Ironbark Forest (9e); (Benson 1992)]. It is limited to New South Wales, with the core distribution on the Cumberland , west of Sydney, and disjunct populations in the Lower Blue Mountains and Lower Hunter Region (records in the National Herbarium of NSW).

The core distribution is in the Cumberland from Windsor and Penrith east to Dean Park near Colebee. Other populations in western Sydney are recorded from Voyager Point and Kemps Creek in the Liverpool LGA, Luddenham in the Penrith LGA and South Maroota in the Baulkham Hills Shire. Disjunct localities outside the Cumberland include the Bulga Mountains at Yengo in the north, and Kurrajong Heights and Woodford in the Lower Blue Mountains.
https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10226

2.4 Habitat requirements

Dillwynia tenuifolia is predominately found in the Castlereagh Ironbark Forest (9e); (Benson 1992) on shale-transition soils.

"In western Sydney, may be locally abundant particularly within scrubby/dry heath areas within Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays. May also be common in transitional areas where these communities adjoin Castlereagh Scribbly Gum Woodland."
https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10226

3 Description of the study area

3.1 Land use history

The Cumberland, Western Sydney, has a long history of land clearing for agricultural, industrial and urban development. Less than 7% of the native vegetation remains, much of which is distributed in small isolated remnant patches.

3.2 Landscape context

The study area for this report comprises the growth areas of Greater Macarthur (Campbelltown and Appin) and Wilton (see Figure 1). It is located within the Cumberland subregion on Triassic Wianamatta Group Shales and transitional shale/sandstone areas in south-eastern parts of the Cumberland, Western Sydney. The eastern and southern margins are within the Sydney Cataract subregion defined by the Triassic Hawkesbury Sandstone plateau. The study area is within the Hawkesbury-Nepean and Georges River catchments.

Greater Macarthur Growth Area

The Greater Macarthur PGA extends from Glenfield in the north to Appin in the south. The northern zone is already well developed with remnant vegetation largely restricted to creek-lines or small patches associated with open space reserves. Southern parts of the area, south of Rosemeadow, comprise primarily agricultural lands with larger patches of remnant vegetation associated with the Nepean and Georges Rivers, and associated tributaries.

Wilton Growth Area

The Wilton PGA occurs to the south of the Greater Macarthur Growth Area extending from Douglas Park in the north to south of Wilton. The boundaries closely follow the Nepean River in the north and west, and a tributary Allens Creek in the east. Away from the river and creeks the higher areas are largely cleared for agriculture and hobby farms. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The Woronora sandstone plateau (within the Upper Nepean State Conservation Area) forms the southern boundary. The Hume Highway dissects the growth area.

Greater Penrith to Eastern Creek Growth Area (GPECGA)

The GPECGA is a relatively large area that extends from Rooty Hill, Minchinbury and Hassell Grove in the east, across the Cumberland to the Hawkesbury-Nepean River in the northwest, then south through Jamisontown, Glenmore Park, to the intersection between The Northern Road and the Warragamba Water Supply Pipelines in the far south-west. The predominant geology is Wianamatta Shale on flat to gently undulating terrain that has been extensively cleared for agriculture, and later for housing and industrial use, with some remnant vegetation on current and former Defence holdings. The shale soils support(ed) Cumberland Plain Woodlands. Overlying the extensive shale deposits are small areas of weathered Tertiary alluvium e.g. Shalvey and Willmot, that are much more common to the north. These support(ed) the Castlereagh Woodlands complex of vegetation types, which is strongly associated with several threatened plant species. More common are broadly linear deposits of Quaternary alluvium along watercourses such as South Creek and Eastern Creek, and on the flood terraces of the Hawkesbury-Nepean River. Other lithologies occur but are very rare and of very small extent.

Western Sydney Aerotropolis Growth Area (WSAGA)

The WSAGA abuts the GPECGA’s southernmost border near the locality of Sovereign (east of Mulgoa), then extends south past Greendale, northeast to the locality of Badgerys Creek, east to Kemps Creek, and northward to the vicinity of Mount Vernon, excluding Twin Creeks Golf Course and associated settlement. The lithology and soils are broadly similar to that of the GPECGA, being effectively just an extension of that area to the south to incorporate the developing Badgerys Creek Airport and environs. The area is even more severely cleared of native vegetation, except along some streams and on rare occurrences of steeper terrain. It contains no NPWS reserves, with the nearest being the small Kemps Creek Nature Reserve, outside the Area to the southeast. Gulguer Nature Reserve and Bents Basin State Conservation Area occur to the southwest of Greendale

3.3 Native vegetation communities

There are 14 different vegetation communities (PCTs) found in the urban growth areas. The PCTs are associated with different soils and topology, as well as history of land use and disturbance. The four growth areas differ in the composition of PCTs (Table 1).

Table 1. Area of PCTs by Growth Area (highlighting the PCTs D. tenuifolia is associated)

PCT	PCT name *	Greater Macarthur	Greater Penrith to Eastern Creek	Western Sydney Aerotropolis	Wilton	TOTAL (ha)
724	Broad-leaved Ironbark – Grey Box – Melaleuca decora grassy open forest on clay/gravel		138.3	52.9		191.3
725	Cooks River Castlereagh Ironbark Forest		127.5	39.9		167.4
781	Freshwater wetland		65.4	3.5		68.9
830	Forest Red Gum – Grey Box shrubby woodland on shale	18.8	2.8			21.5
835	Forest Red Gum – Rough-barked Apple grassy woodland	186.6	826.3	162.9		1175.8
849	Grey Box – Forest Gum grassy woodland on alluvial flats	444.5	1794.0	550.1	289.8	3078.3
850	Grey Box – Forest Gum grassy woodland on shale (southern)	269.9	80.8	7.7	164.5	522.9
883	Hard-leaved Scribbly Gum – Parramatta Red Gum healthy woodland	0.9	6.5			7.4
1081	Red Bloodwood – Grey Gum woodland	7.5			66.7	74.2
1105	Rive oak open forest of major streams	44.4	94.2			138.6
1181	Smooth-barked Apple – Red Bloodwood – Sydney peppermint healthy open forest on slopes of dry sandstone gullies	414.8			365.9	780.7
1292	Water Gum – Coachwood riparian scrub along sandstone streams	1.3			38.5	39.8
1395	Narrow-leaved Ironbark – Broad-leaved – Grey Gum open forest	1895.5	2.0		1429.1	3326.6
1800	Swamp Oak	4.1	118.4	110.1		232.6
TOTAL (ha)		3288.3	3256.2	927.1	2354.5	9826.1

* of the Cumberland, Sydney Basin Bioregion

Each vegetation polygon was assigned to one of four vegetation condition categories by DPE based on LiDAR and nearmap remote sensing data, along with field validation:

1. Intact - Visual inspection of the Nearmap imagery showed significant patches of continuous canopy and the CHM (Canopy Height Model) showed vegetation returns for both the upper and mid storeys.

2. Thinned – Visual inspection of the Nearmap shows patches of continuous canopy but less dense and the CHM presented only canopy and ground returns.

3. Scattered trees – Visual inspection of Nearmap imagery and LiDAR canopy polygons showed one or a few likely native trees surrounded by cleared land.

4. Grassland – Treeless areas which were visually assessed to be potential native grassland and were not in areas of improved pasture or cropland.

4 Assessment of species presence and habitat

4.1 Existing records and surveys

BioNet records for *D. tenuifolia* generally support the description of the distribution in 2.3. There are a number of outlier points that may be mis-identifications if not significant expansion of geographic range.

Notably, *D. tenuifolia* is absent from the Wilton and Greater Macarthur growth areas. There is however an outlier record immediately to the southeast of Wilton and there is similar vegetation to that in which the species is found in the core distribution.

Western Sydney Aerotropolis growth area, includes a significant population of *D. tenuifolia*. There is a cluster of records in Kemps Creek, which is the most southerly population of the species. The Kemps Creek population is listed as a Threatened population.

There are clusters of records in the Greater Penrith to Eastern Creek urban growth area around St Marys. A large number of records from Marsden Park, Shanes Park, Llandillo, Cranebrook on the northern edge of the GPECGA. Further to the north there are large populations from Richmond to Windsor.

4.2 Surveys completed for the biocertification

Surveys completed by Biosis and Ecoplanning on behalf of DPE were provided (Figure 2).

They include 11 records of *D. tenuifolia* in Kemps Creek (-33.86978667, 150.7902583, ALT 70.5 m). All of which are within the Western Sydney Aerotropolis growth area.

Figure 2: Map of D. tenuifolia records provided by BIOSIS aaround Kemps Creek in WSAGA

An additional two records of *D. tenuifolia* were provided from Dr Peter Weston at the Royal Botanic Gardens Sydney, who observed the species while undertaking field surveys for other expert reports.

GJ3 - Castlereagh Nature Reserve, Northern Rd, Londonderry, 33°40'44.9"S, 150°44'37.3"E, 52 m, Tertiary alluvium, brown, gravelly clay-loam, 0°, dry sclerophyll forest, sparse shrubby understory. This record is north of the GPECGA.

GJ7 - Bill Anderson Reserve, Kemps Creek site 2, 33°52'53.2"S, 150°47'19.0"E, 66 m, Bringelly Shale, red-brown sandy loam, <5°N, disturbed dry sclerophyll woodland, moderately dense shrubby understory.
This record is immediately south of the Western Sydney Aerotropolis growth area.

4.3 Surveys completed for this assessment

My own records of occurrence and knowledge of habitat preference of *D. tenuifolia*, combined with those provided through DPE via email and in the spatial portal were used to plan field work and target sites for assessment. I plotted the target sites on Google Earth for use in the field via my smartphone (Figure 3).

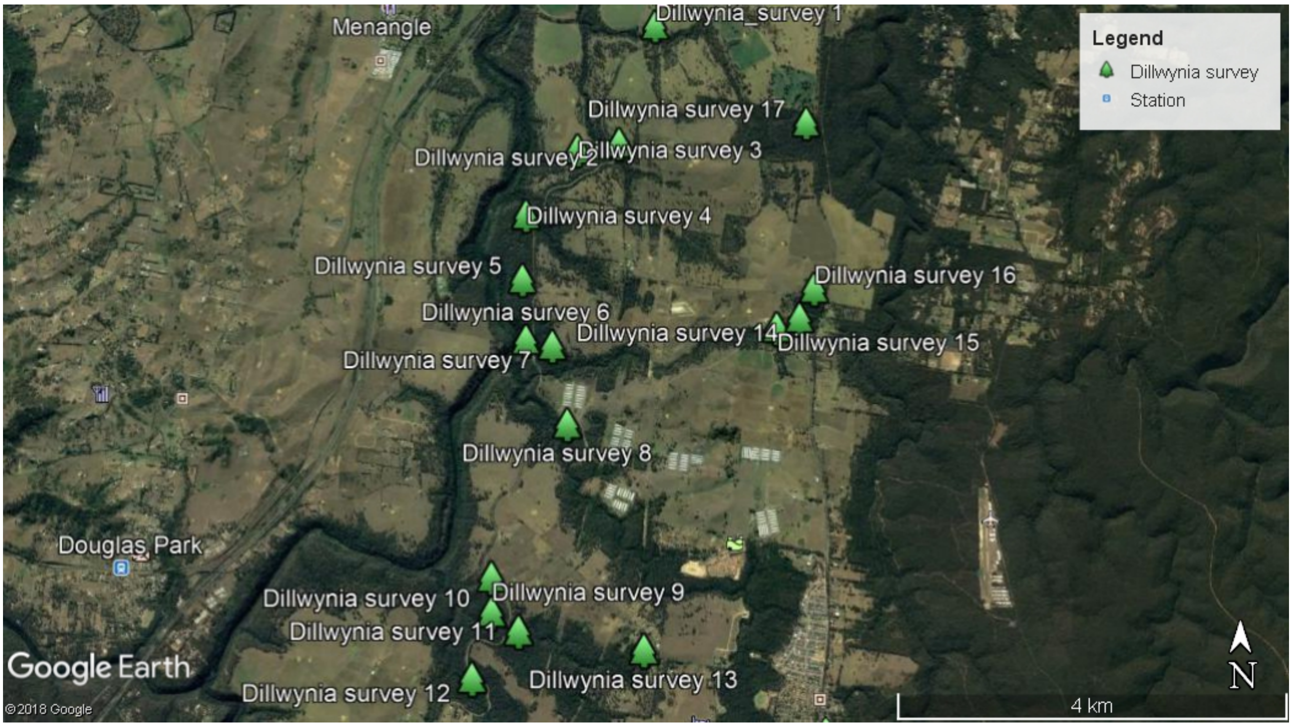


Figure 3: Map of planned survey sites in the Greater Macarthur Growth Area.

The target site was located on the ground via google map navigation tool. In many cases access to the site was prevented by locked gates, or private property owners not providing permission. Additional sites were sought on the ground in adjacent areas, and others based on alternative records of occurrence from the Atlas of Living Australia.

A full list of sites where ground surveys have been conducted are in the appendix.

Ground surveys were conducted on foot with a visual search of the suitable habitat. The search effort at each site varied by the survey area and typically ranged from 15-60min. Some sites were much larger and represented a series of occurrence records that were traversed on foot (c. 2 hour). A random walk was used to cover as much ground as possible searching for the target species. The search included living and dead plants, along with examination of the leaf litter / upper soil profile for plant fruits and seeds.

A photo was taken of the site along with a screenshot of the map to confirm the survey was conducted. When a target plant or other significant plant was located a photo was taken with a map screenshot for the location details.

4.4 Assessment of species presence

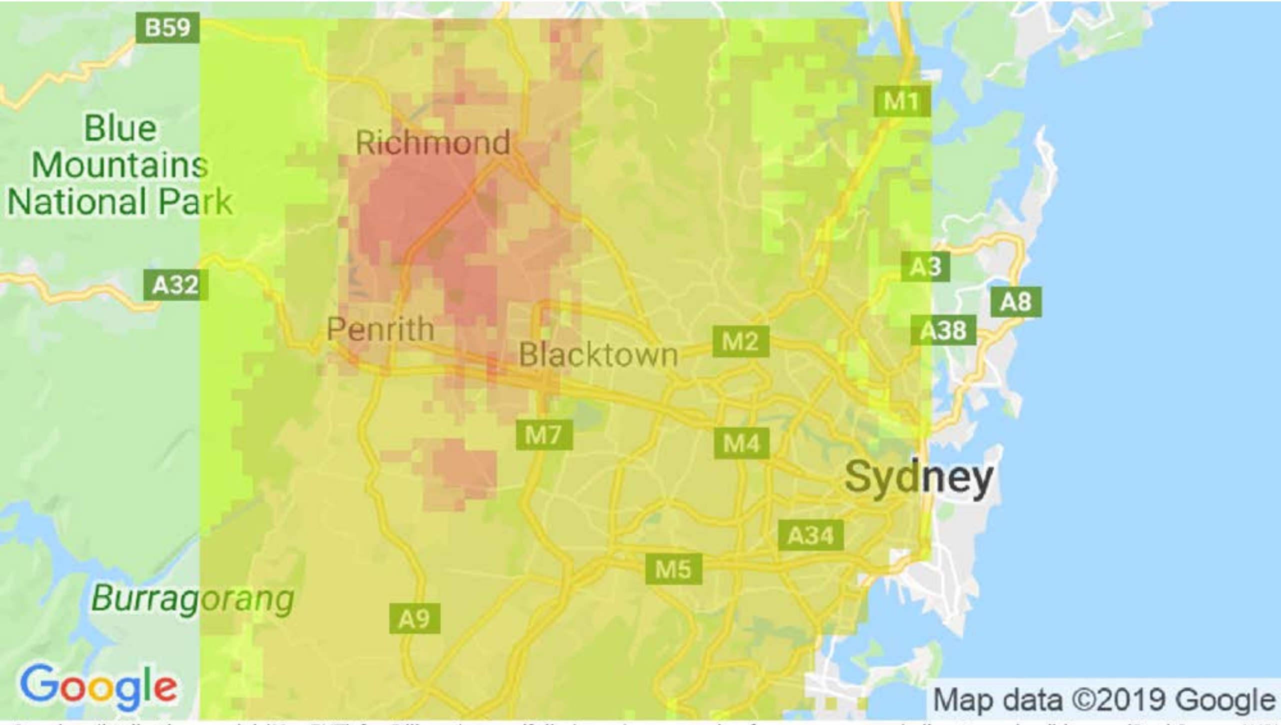
Likelihood of species presence

Species Distribution Models (SDM) have been conducted to estimate the suitable habitat for D. tenuifolia in the Cumberland bioregion. The SDM used records of occurrences from field surveys along with spatially valid records from the Atlas of Living Australia (ALA; www.ala.org.au) combined with temperature, rainfall and soil GIS layers to conduct a MaxENT model predicting habitat suitability at 1km grid scale. Mean annual temperature was the most important variable in the SDM followed by precipitation seasonality, annual precipitation, and temperature seasonality (Table 2). While soil layers contributed a lower percentage to the overall SDM they were important in refining the local patterns within the Cumberland.

Table 2: The relative importance of the variables in the MaxENT species distribution model.

Variable	**Percent contribution**	**Permutation importance**
Temperature - annual mean (Bio01) (el874)	31.5	63.1
Precipitation - seasonality (Bio15) (el882)	20.2	12.6
Precipitation - annual (Bio12) (el893)	19.3	1.7
Temperature - seasonality (Bio04) (el892)	17.4	3.3
Drainage - average (el670)	5.1	10.2
Clay % (el814)	3.5	0.7
Phosphorus - plant-available pre-European (el811)	2.4	5.9
Moisture - average (el669)	0.5	1.9
Carbon - organic (el665)	0.2	0
Nitrogen - plant-available pre-European (el831)	0	0.6

The SDM for *D. tenuifolia* provided an accurate prediction of the habitat suitability within the Cumberland (Figure 4). The predicted habitat suitability was tested with 25% of the observation records, demonstrating the SDM accuracy at >95%. Furthermore, the main populations within the Cumberland are all within areas of high habitat suitability. Some of the areas predicted as suitable for *D. tenuifolia* do not have any valid occurrence records (notably Penrith), while other areas native vegetation has been converted into industrial or urban developments. The species persistent soil seedbank and ability to persist in small degraded sites (e.g. roadside verges) would support the integrity of the SDM habitat suitability for low quality vegetation classes (Figure 4).



Species distribution model (MaxENT) for Dillwynia tenuifolia based on records of occurrence and climate and soil layers (Paul Rymer WSU

Figure 4: Dillwynia tenuifolia habitat suitability in the Cumberland predicted based on the MaxENT species distribution model. Grid cells with darker red colours are more suitable (max 85%), orange intermediate (~30%), and yellow/green is the lowest suitability (min 5%).

URBAN GROWTH AREAS

Dillwynia tenuifolia is not likely to occur in the Wilton or Greater Macarthur growth areas. The field surveys targeting areas with previous records, and in potential habitat, did not find any *D. tenuifolia* plants in this area. The SDM confirmed there is low habitat suitability in Wilton or Greater Macarthur growth areas.

Western Sydney Aerotropolis Growth Area

The most southerly known population of *D. tenuifolia* is found in Kemps Creek partly within the Western Sydney Aerotropolis Growth Area.

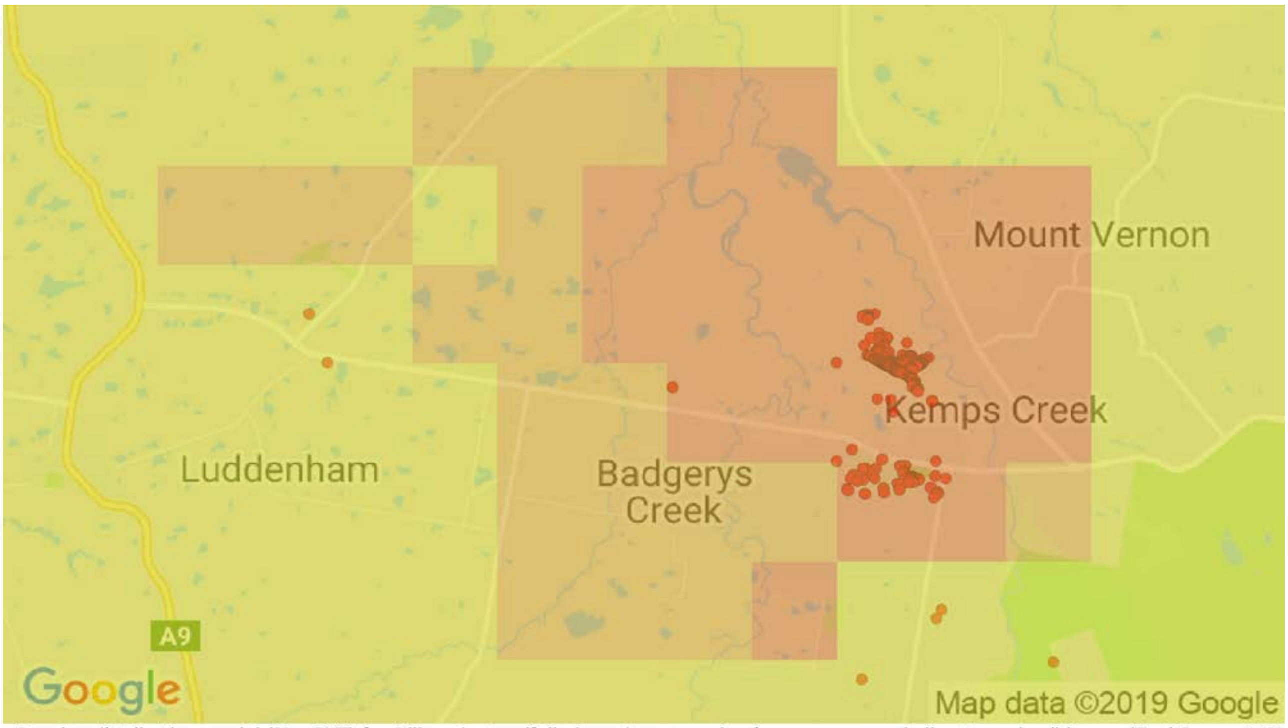
An 'Endangered Population' has been declared under the NSW Biodiversity Conservation Act 2016 for the area bounded by Western Road, Elizabeth Drive, Devonshire Road and Cross Street, Kemps Creek in the Liverpool Local Government Area. It is managed under the OEH Saving Our Species program. Which is immediately to the south of the Western Sydney Aerotropolis Growth Area. Major threats include weeds, inappropriate fire regimes, illegal dumping and development of adjacent sites (https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10225).

Field surveys confirmed a large population of *D. tenuifolia* in the Kemps Creek area (see observation records in the appendix). There is a patch south of Elizabeth Drive, Kemps Creek, in a large remnant block of native vegetation between Western Road and Cross Street. The Kemps

Creek population of *D. tenuifolia* continues north of Elizabeth Drive (inside the Western Sydney Aerotropolis Growth Area) along Clifton Avenue where there is second patch in remnant native vegetation on either side of Clifton Avenue (lot 90 (west) and lot 316 (east)).

Historic and contemporary development in this area has impacted on the extent of occupation and the population size of *D. tenuifolia*. Long periods between fire in the remnant vegetation may have reduced the standing population of plants, however it is likely there is a viable soil stored seedbank from which plants could re-establish following fire or soil disturbance.

The SDM confirms the Kemps Creek area as having high habitat suitability (Figure 5). This corresponds to the Castlereagh Ironbark Forest and shale-transition soils, along with the large clusters of recent and historic sightings in the area.



Species distribution model (MaxENT) for Dillwynia tenuifolia based on records of occurrence and climate and soil layers (Paul Rymer WSU

Figure 5: Dillwynia tenuifolia habitat suitability focusing on the Kemps Creek population. Grid cell colour indicates suitability: darker red (max 85%), orange (~30%), yellow/green (min 5%). Red points are the records of occurrence for D. tenuifolia.

The Western Sydney Aerotropolis Growth Area draft plan (https://www.planning.nsw.gov.au/Plans-for-your-area/Priority-Growth-Areas-and-Precincts/Western-Sydney-Aerotropolis/Map) has zoned the Kemps Creek population in predominantly 'Flexible Employment' and marginally 'Non Urban Land'. The route of the proposed M12 motorway would go over the northern Clifton Avenue patch, representing more than half of the Kemps Creek population. While this is outside of the area specified as the Kemps Creek Endangered Population, the northern patch of the Kemps Creek population (Figure 5) is likely to be part of the same genetic population, which is genetically isolated from the core distribution (Rymer etal. 2002). Development in the surrounding area has been listed as a threat to the viability of the Kemps Creek Endangered Population. Negative impacts include a reduction in the effective population size with loss of plants in the adjacent area, increased nutrient and weed loads, inappropriate fire regimes and altered hydrology.

GPECGA has a large number of records of occurrence and some well-established populations of *D. tenuifolia*. Field surveys have validated the occurrence of plants in Minchinbury, St Marys, Ropes Crossing and Shanes Park. The SDM highlights these areas as high habitat suitability for *D. tenuifolia* (Figure 6). There is also substantial populations of *D. tenuifolia* to the north of Penrith to Eastern Creek, notably the Shanes Park population on the northern edge. As with other areas in the Cumberland historic and contemporary development has impacted on the extent of occupation and the population size of *D. tenuifolia*, however improved land management and ecological restoration could re-establish viable populations. On the other hand, urban development can have negative impacts on adjacent remnant vegetation and plant populations through increased nutrient and weed loads, inappropriate fire regimes and altered hydrology.

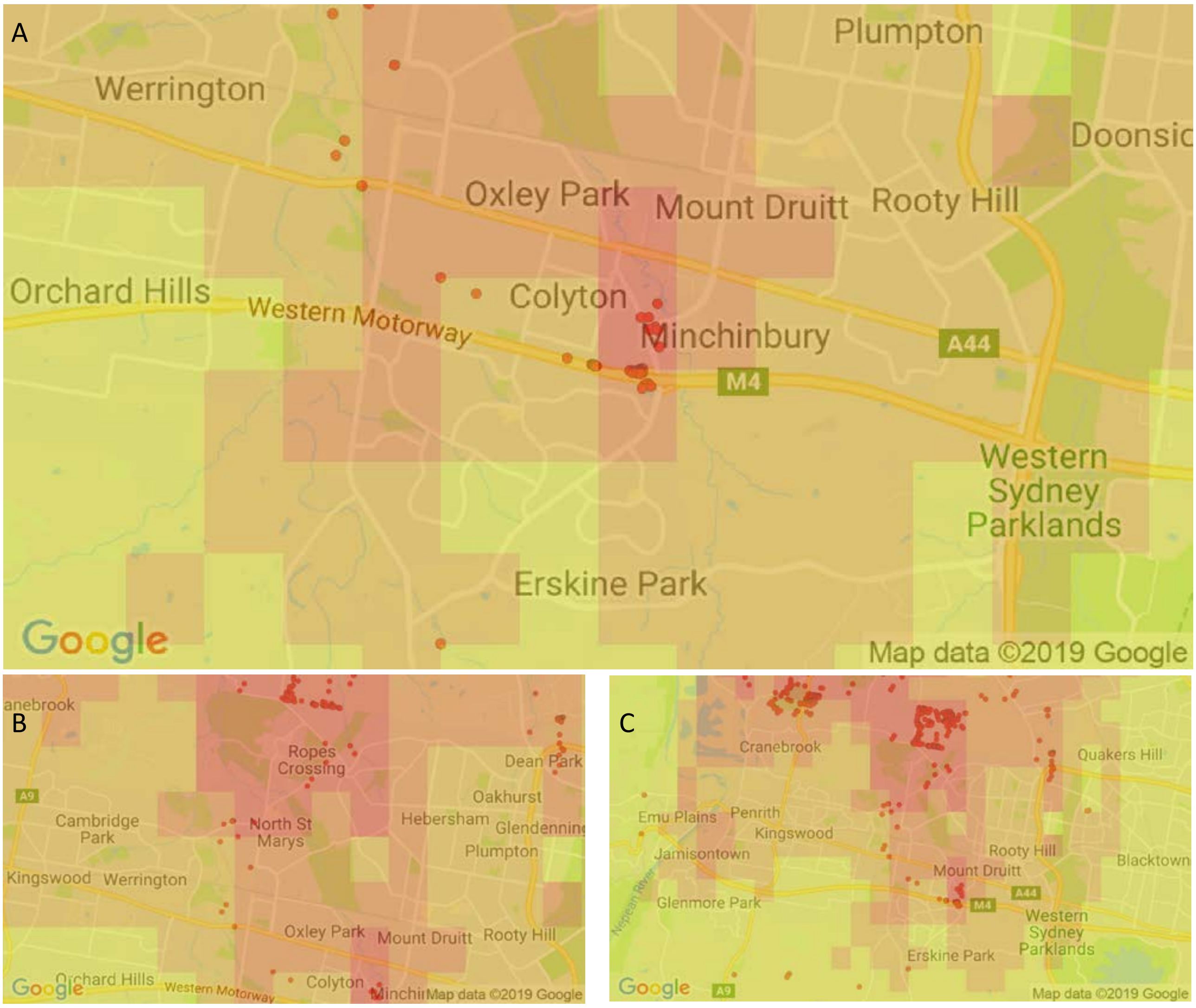


Figure 6: *Dillwynia tenuifolia* habitat suitability focusing on (A) Minchinbury, (B) Penrith and Eastern Creek area, and (C) surrounding area. Grid cell colour indicates suitability: darker red (max 85%), orange (~30%), yellow/green (min 5%). Red points are the records of occurrence for *D. tenuifolia.*

Justification for determining presence

Based on the field surveys, collated records of occurrence, and species distribution models I have assessed the likelihood of species occurrence on the proposed growth areas. Several of the records available in BioNet are incorrect in the species identification, or location information. Priority of records:

1. Current survey documented species being present
2. Records from trusted surveys with taxonomic expertise
3. Records in BioNet from multiple years and collectors
4. Other records were questioned for integrity

4.5 Assessment of suitable habitat

Suitable habitat within the growth areas

Dillwynia tenuifolia is associated with the "Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays" classified in PCTs 724, 725, 849, and 883.

Populations of *D. tenuifolia* can develop large soil stored seedbanks, which can persist as viable seed for several decades. As such populations can remain viable in intact and degraded vegetation (scattered, thinned) in interconnected large and small patches, including roadside plants (Figure 7).

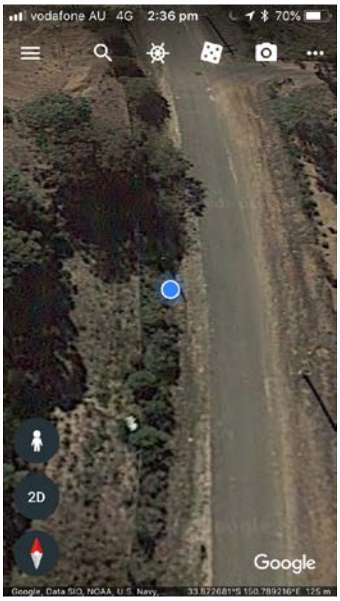


Figure 7: Roadside population of D. tenuifolia recorded along Clifton Avenue, Kemps Creek.

Species polygons

A map of species polygons for the Western Sydney Aerotropolis and Penrith to Eastern Creek growth areas was produced by Darren James (dajenvironmental) based on the area of occurrence (2km grids) overlayed with the PCTs (listed above) (Figure 8).

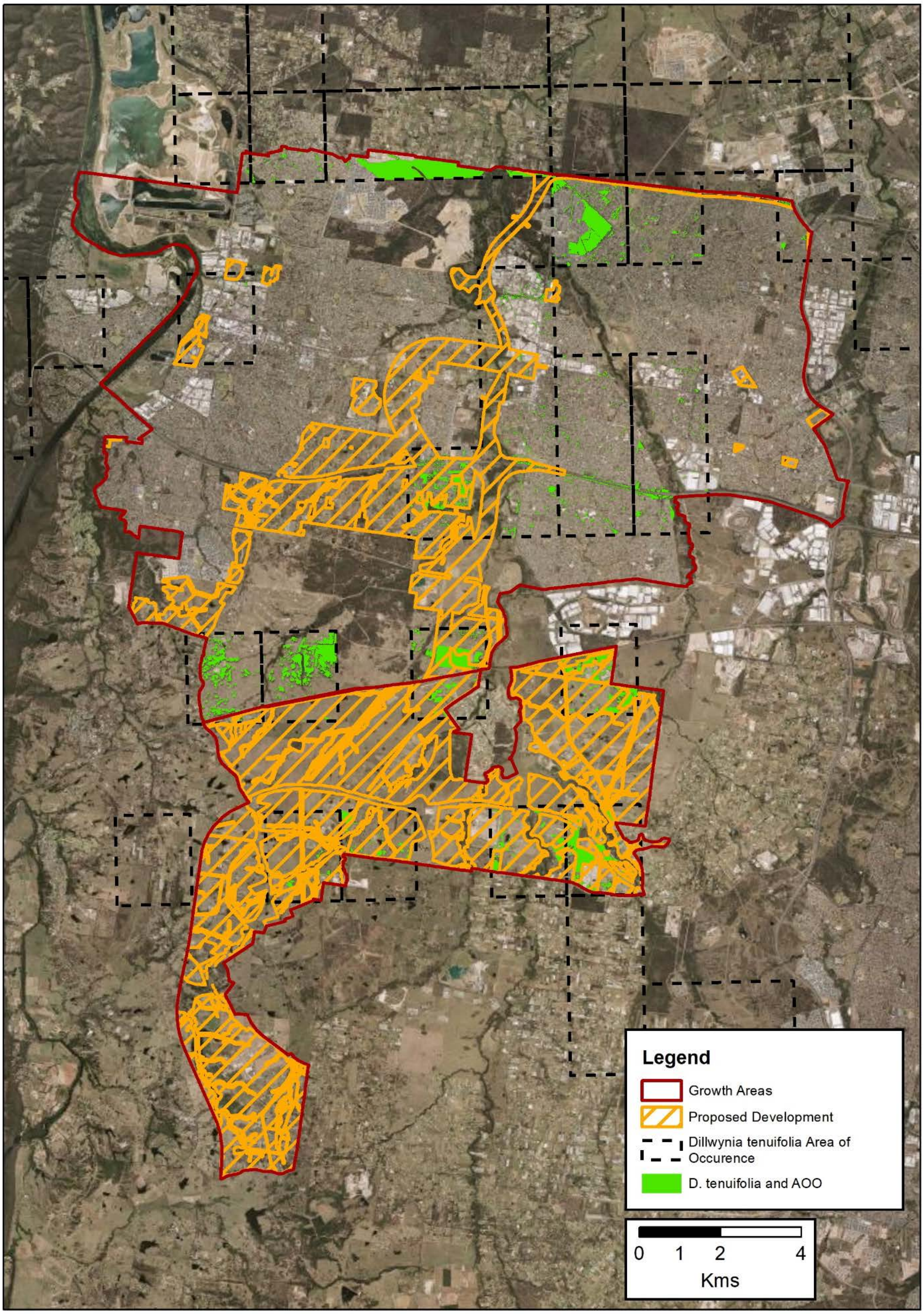


Figure 8: Map of vegetation polygons in areas and habitat that D. tenuifolia is known to occur.

5 Areas in growth areas

The total area of *D. tenuifolia* habitat within the Greater Penrith and Eastern Creek (GPEC), and Western Sydney Airport Growth Areas is estimated to be 606 ha and 225 ha, respectively (total 831 ha; Table 3). *Dillwynia tenuifolia* had the greatest habitat area within the growth areas in the Grey Box - Forest Red Gum grassy woodland (68% total area; 564 ha PCT 849), with intermediate habitat area in Cooks River Castlereagh Ironbark Forest and Broad-leaved Ironbark - Grey Box vegetation (16% [133 ha] PCT 725; 15% [127 ha] PCT 724), and less than 1% in Hard-leaved Scribbly Gum Parramatta Red Gum woodland (6.5 ha PCT 883) (Table 3). The majority of vegetation was in the condition thinned or scattered trees (Table 3). This reflects the overall abundance of the PCTs in the growth areas (Table 1).

Table 3: The total area of D. tenuifolia habitat within the Greater Penrith and Eastern Creek (GPEC), and Western Sydney Airport Growth Areas by vegetation zone (PCT) and condition.

PCTs	Condition	GPEC	Western Sydney Airport Growth Area	Grand Total
724	Intact	21.5	3.3	24.8
724	Scattered Trees	3.1	0.1	3.2
724	Thinned	53.5	45.8	99.3
725	Intact	59.4	21.1	80.5
725	Scattered Trees	6.0	2.8	8.8
725	Thinned	29.3	14.4	43.7
849	DNG	4.8	24.5	29.2
849	Intact	11.0	22.2	33.2
849	Scattered Trees	33.7	40.9	74.6
849	Thinned	377.2	50.0	427.2
883	Intact	6.4	0.0	6.4
883	Thinned	0.1	0.0	0.1
Grand Total		**605.9**	**225.0**	**830.9**

The habitat area impacted was greater in the Western Sydney Aerotropolis Growth Area (121.3ha) than the Greater Penrith and Eastern Creek Growth Area (101.2 ha) (total 222.5 ha; Table 4), despite only representing approximately a quarter of the total habitat area for *D. tenuifolia* in the urban growth areas (Table 3). The Grey Box - Forest Red Gum grassy woodland is the most impacted (164.4 ha PCT 883) then Broad-leaved Ironbark - Grey Box (39.1 ha PCT 724) followed by Cooks River Castlereagh Ironbark Forest (18.1 ha PCT 725). Overall 26% of the habitat would be impacted within the growth areas; 29% PCT 883, 30% PCT 724 and 14% PCT 725. The majority of the vegetation condition was thinned.

Table 4: The D. tenuifolia habitat area impacted in the growth areas by PCT and condition.

PCT	Condition	GPEC	Western Sydney Airport Growth Area	Grand Total
724	Intact	1.0	0.0	1.0
724	Scattered Trees	0.1	0.1	0.2
724	Thinned	19.6	18.3	37.9
725	Intact	2.8	0.4	3.2
725	Scattered Trees	0.0	2.5	2.5
725	Thinned	7.0	6.4	13.4
849	DNG	4.8	21.5	26.3
849	Intact	1.4	6.6	8.0
849	Scattered Trees	1.6	34.7	36.3
849	Thinned	62.9	30.9	93.8
Grand Total		**101.2**	**121.3**	**222.5**

6 Information used in this assessment

Data, maps and information provided by DPE and project partners can be found in the appendix.
Vegetation mapping, field surveys and planning information provided via spatial viewer BioNet records

7 References

Auld T.D. (1996). Ecology of the Fabaceae in the Sydney region: fire, ants and the soil seedbank. Cunninghamia 4(4): 531-552.

Benson, D.H. (1992). The natural vegetation of the Penrith 1:100 000 mapsheet

Cunninghamia 2(4) 541 – 596.

Harden G.J. (1991). Flora of New South Wales. N.S.W. University Press, Kensington

OEH (2016). Species Sighting Data Standard, BioNet Web Services, Version 5. ISBN 978-1-76039-417-2. OEH 2016/0405, July 2016

Rymer, P.D., E.C. Morris & B.J. Richardson (2002). Breeding system and population genetics of the vulnerable plant Dillwynia tenuifolia (Fabaceae). Austral Ecology. 27:241-248.

Rymer, D. (1999). The Reproductive Biology And Population Genetics Of The Rare And Threatened Plant, Dillwynia tenuifolia (FABACEAE). Honours Thesis, University of Western Sydney, Hawkesbury.

Tozer MG (2003) The native vegetation of the Cumberland, western Sydney: a systematic classification and field identification of communities. Cunninghamia 8, 1-75.

8 Appendices

Curriculum vitae

Paul Rymer

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Brief career history of Dr Paul Rymer

Research Interests: Ecology and evolution, biodiversity hotspots, weeds, and climate change.

Qualifications

- PhD, University of Wollongong, 2006
- BSc (Honours), University of Western Sydney, 2000

Employment

- Lecturer in Ecological Genetics, Western Sydney University, 2014
- Research Lecturer, University of Western Sydney, 2011
- Associate Researcher, Royal Botanic Gardens Sydney, 2010
- Marie Curie Incoming International Fellow, Imperial College London, 2008
- Postdoctoral Researcher, University of Oxford, 2006

Main Research grants

2017 NSW Environmental Trust “Assisted migration under climate change”

2016 HIA Green Cities “Which plant where and why database”

2016 HIA Pollination “Healthy bee populations for sustainable pollination in horticulture”

2015 ARC Linkage “Do hotter and drier regions harbour adaptive variation for climate change?”

2014 ARC Linkage “Identifying regions of high drought mortality risk for tree species in NSW”

2013 NSW Environmental Trust “Grey Box psyllid induced mortality”

2013 UWS Partnership Program “Adaptive potential to climate change” DPaW

2012 UWS Partnership Program “Genetic issues in restoration” Greening Australia

2009-2007 Marie Curie Fellowship “Pollinators drive flora speciation”

Evidence for quality of research outputs:

I have published 33 peer-reviewed scientific journal articles, with an H-index of 11. My work on plant speciation and population genomics attracted some attention, with Linder (Molecular Ecology DOI: 10.1111/j.1365-294X.2010.04798.x) highlighting its importance in the field. My recent work has been published in several high quality journals, including Molecular Ecology, Molecular Phylogenetics and Evolution, New Phytologist and Global Change Biology. A book chapter on plant markers for conservation genetics was requested by the preeminent Geneticist Robert Henry.

Teaching

I have actively contributed to undergraduate and postgraduate teaching at several institutions, and currently I am teaching Botany, Principles of Evolution, and Biological Adaptation to Climate Change at WSU. I have supervised six MSc research projects at Imperial College London, University of Oxford, and University of Wollongong. I am currently supervising five PhD, three Masters, and several undergrad research projects.

Other research leadership and community roles:

Much of my research has been applied to understanding plant rarity (and conversely invasiveness), which has produced valuable information for land managers. The findings of my work have been directly incorporated in recovery plans for endangered species. My work on neotropical trees has been used to develop best practice guidelines for seed sourcing for natural restoration. I have contributed as a scientific expert to the Priorities Action Statement 2 process for OEH management of threatened species. I have taken up a committee positions for the development of recovery plans, Cumberland Conservation Corridor Reference Group (Department of the Environment), and Greening Australia’s Grassy Groundcover Research Project advisory group (Greening Australia). Outreach to high school students through the development of material for the HSC Agriculture syllabus (Department of Education).

Dr Paul Rymer – ten most relevant publications

1. Flores-Rentería L, Rymer PD, Riegler M. (2017) Unpacking boxes: integration of molecular, morphological and ecological approaches reveals extensive patterns of reticulate evolution in the box eucalypts. Molecular Phylogenetics and Evolution, 108, pp. 70-87

Complex evolutionary histories are unpacked through a multi-faceted approach where incomplete lineage sorting is the dominant pattern in widespread species.

2. Blackman CJ, Aspinwall MJ, Tissue DT, Rymer PD (2017) Genetic adaptation and phenotypic plasticity contribute to greater leaf hydraulic tolerance in response to drought in warmer climates. Tree Physiology https://doi.org/10.1093/treephys/tpx005

Intraspecific variation in hydraulic traits are revealed among provenances and growth temperatures. We show support for local adaptation to hot climates through enhanced resilience to drought.

3. Huang G, Rymer PD, Duan H, Smith RA, Tissue DT (2015) Elevated temperature is more effective than elevated [CO2] in exposing genotypic variation in *Telopea speciosissima* growth plasticity: Implications for woody plant populations under climate change. Global Change Biology 21 (10), pp. 3800-3813 [Cited 1, JIF 8.044]

Coastal genotypes from mesic climates were found to have a greater capacity to increase growth in response to warming and elevated CO2 campared the non-responsive upland genotype. The finding support the prediction that upland taxa will be under threat with climate change.

4. Drake JE, Aspinwall MJ , Pfautsch S, **Rymer PD**, Reich PB, Smith RA, Crous KY, Tissue DT , Ghannoum O & Tjoelker MG (2014) The capacity to cope with climate warming declines from temperate to tropical latitudes in two widely distributed *Eucalyptus* species. Global Change Biology, 21 (1), pp. 459-472 [Cited 15, JIF 8.044]

This paper provides support for the hypothesis that climate change will negatively affect the warm edge of a species' distribution more than trees from moderate- or cool origins. The climatic gradient explored along the east coast of Australia provides insights into the importance of physiological tolerance and gene flow for resilience to climate change.

5. **Rymer PD**, Sandiford M, Harris SA, Billingham MR, Boshier DH (2013) Remnant *Pachira quinata* pasture trees have greater opportunities to self and suffer reduced reproduction due to inbreeding depression. *Heredity* doi: 10.1038/hdy.2013.73 [Cited 9, JIF 3.805]

Habitat fragmentation is a key threatening process. This study shows how trees can respond to altered mate availability through labile selfing and enhanced pollen movement with implication for conservation.

6. ***Rymer PD**, Dick CW, Vendramin GG, Buonamici A, Boshier D (2013) Recent phylogeographic structure in a widespread 'weedy' Neotropical tree species, *Cordia alliodora* (Boraginaceae). *Journal of Biogeography*. [Cited 18, JIF 4.590]

A species with the largest continuous latitudinal range (40°S-40°N) across major geographic and environmental barriers was genetically characterised revealing the species origin, historical dispersal patterns and regions of adaptive variation.

7. McPherson H, van der Merwe, M, Delaney SK, Edwards MA, Henry RJ, McIntosh E, Rymer PD, Milner ML, Siow J, Rossetto M.(2013) Capturing chloroplast variation for molecular ecology studies: A simple next generation sequencing approach applied to a rainforest tree. BMC Ecology 13, 8 [Cited 46, JIF 2.360]

A novel approach was developed to sequence complete chloroplast genomes for phylogenetic and population genomic analyses.

8. ***Rymer PD**, Johnson SD, Savolainen V (2010). Pollinator behaviour and plant speciation: can assortative mating and disruptive selection maintain distinct floral morphs in sympatry? *New Phytologist* 188(2): 426-436. [Cited 17, JIF 7.672]

This paper was the first to demonstrate the utility of molecular markers in understanding pollinator behaviour and the speciation process within populations.

9. ***Rymer PD**, Manning JC, Goldblatt P, Powell MP, Savolainen V (2010). Evidence of recent and continuous speciation in a biodiversity hotspot: a population genetic approach in southern African gladioli (*Gladiolus*; Iridaceae). *Molecular Ecology* 19(21): 4765-4782. [Cited 29, JIF 6.494]

Highlighted by Peter Linder (Uni Zurich) as novel in understanding the ongoing speciation process and the origin of biodiversity hotspots. A reviewer commented "putting the ecology back into molecular ecology"

10. *M. Rossetto, D. Crayn, A. Ford, P. Ridgeway, **P.D. Rymer** (2007) The comparative study of range-wide genetic structure across related, co-distributed rainforest trees reveals contrasting evolutionary histories. *Australian Journal of Botany*, 55, 416-424. [Cited 19, JIF 1.355]

A comparative study that identifies broad patterns of genetic structure in rainforest trees. We explored the effect of different life-histories and geographic barriers were shown to determine gene flow.

Expert report – Green and Golden Bell Frog

Expert report for the Green and Golden Bell Frog (*Litoria aurea*), Francis Lemckert, 2019

Strategic assessment for Cumberland Plain Conservation Plan - Expert report for the Green and Golden Bell Frog (*Litoria aurea*)

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1. Introduction

The NSW Government is identifying areas for future urban development and associated infrastructure in Western Sydney. Four priority Growth Areas (GA) have been nominated in South Western Sydney:

- Wilton Growth Area
- Greater Macarthur Growth Area (Campbelltown and Appin)
- Western Sydney Airport Growth Area (Aerotropolis)
- Greater Penrith to Eastern Creek Growth Area.

The locations of these four GAs are provided in Figure 1. All are located within the Cumberland Subregion Interim Biogeographic Regionalisation for Australia sub-region.

1.1 Purpose of the expert report

Section 6.5.2 of the Biodiversity Assessment Method sets out the following essential requirements for the preparation of an expert report:

- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- estimate the number of individuals or area of habitat (whichever unit of measurement applies to the species/individual) for the biodiversity certification assessment area, including a description of how the estimate was made
- demonstrate what information was considered, rejected and discounted in relation to the determination made in the expert report
- identify the expert and provide evidence of their expert credentials.

The report needs to determine whether:

- The species is unlikely to be present, in which case no further assessment is required, or
- The species is likely to be present in which case the expert report must provide estimates of habitat area within the biodiversity certified development footprint.

1.2 Project context

The Department of Planning and Environment (DPE) has been tasked with preparing the Cumberland Plain Conservation Plan (the Plan) that will identify development and conservation outcomes within each of the above four listed GAs. The Plan will be strategically assessed and approved using Biodiversity Certification (Biocertification) enabled under the *Biodiversity Conservation Act 2016* (BC Act) and strategic assessment and approval to be carried out under *the Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The strategic assessment process will lead to:

- the identification of a preferred conservation outcome for the Cumberland Subregion
- an assessment of the likely impacts of proposed urban development
- identification of mitigation measures that deliver good conservation outcomes
- a streamlined development approval processes.

A biodiversity assessment report will be pepared to assess the conservation benefits and development impacts of the Plan and determine the acceptability of the conservation outcomes in the context of the above state and national legislation. The current approach is that DPE will prepare a single, integrated assessment report that addresses the requirements of both the BC Act and the EPBC Act. A core aspect of the conservation program will be the development of offsets for impacts on threatened biodiversity.

Biocertification is being used to identify conservation areas within the Cumberland Subregion that meet the criteria to be purchased for the required offsetting. Biocertification will ensure that biodiversity values are assessed, and conservation issues resolved early in the planning process. Certification supports a more streamlined and cost-effective land-release process than site-by-site assessment.

1.3 The study area

The location of the Cumberland Subregion and the four Growth Areas is provided in Figure 1. Information for each of these areas was determined from a range of data layers including:

- Native vegetation: CumberlandPlainWest_2013_E_4207 & SydneyMetroArea_2013_v2_0_E_3817
- LEP Layers Land Zoning (LZN)
- Altitude: Central West Sydney Surrounds 2m Contours & Contours 50m, Outer Sydney South 2m Contours, Central West Sydney Surrounds 2m Contours and Outer Sydney North 2m Contours
- Waterbodies: Roadnet MDS 2018
- Biodiversity Certification Land: Subject Lands for the Biocertification of Sydney Region Growth Centres SEPP and related EPIs (GrowthCentreLandCertification)

The Wilton Growth Area (hereafter WGA) is centred around the township of Wilton, which is approximately 63 km southwest of Sydney and covers an area of approximately 4082 ha. The WGA is approximately 23 km from the coast at its eastern boundary and covers an altitudinal range of 64 to 300 m ASL. Approximately 1824 ha (45%) of the WGA is covered in retained native vegetation, which is essentially confined to the southern end of the GA adjacent to an area of dissected escarpment. The majority of the WGA is rural agricultural land used for a variety of activities including grazing, hobby farming and cropping (Figure 2). There is relatively little road development across the majority of the WGA, with the major roads being restricted to the northern end where there is also the main centre of urbanisation (accounting for approximately 20% of the WGA). The WGA contains significant permanent streams in the form of the Nepean River that runs along or within its western and northern boundaries and Allens Creek that forms the northern half of its eastern boundary. Shepherds Creek runs off Allens Creek and into the central part of the GA. These stream all have largely retained riparian vegetation, albeit often highly disturbed, and so retain the potential to serve as significant corridors for vegetation dependent biodiversity. Numerous artificial water bodies (> 200) are mapped throughout the GA, with the exception of the area of the Wilton Township itself. Many more unmapped water bodies are present through the creation of farm dams and reservoirs (Figure 2).

The Greater Macarthur Growth Area (GMGA) is centred around the township Campbelltown-Macarthur, approximately 43 km southwest of Sydney, but extending from West Appin in the South to Glenfield in the north (Figure 3). The GMGA covers an area of approximately 11046 ha, is approximately 24 km from the coast on its eastern border and covers an altitudinal range of 4 to 262 m ASL. Approximately 3038 ha (28%) of this GA remains covered in retained native vegetation, which is also concentrated at the southern end, with the southern half dominated by land used for rural agricultural purposes and, as for the WGA, there is relatively little road development across this area. The M1 motorway runs along the western edge of the GMGA and likely represents a significant barrier to dispersal for biodiversity. The northern half of the GMGA is highly developed and heavily fragmented by numerous roads. Urbanisation covers approximately 35% of the GMGA area. The most significant river within the GMGA is the Nepean River and its tributaries that are located in the southern end of the GCMA, with the main River forming a large part of the western boundary of the GA. Sections of the Nepean have retained riparian vegetation, but large parts of the banks are essentially cleared or the vegetation highly degraded. Peter Meadows Creek flows east to west in the northern part of the GA and ultimately joins into the Georges River and so also provides some degree of potential connectivity as a corridor for movement. Numerous artificial water bodies have been created within the rural portion of the GMGA (Figure 3).

The Western Sydney Aerotropolis Growth Area (WSAGA) is centred around the township of Badgery's Creek, approximately 41 km west of Sydney and so the coast (Figure 4). The WSAGA covers an altitudinal range of 32 to 120 m ASL. The WSAGA includes a section that is outside the current GAs that is excluded from assessment in this expert report (area indicated in Figure 4). Within the assessed area, there is relatively little retained natural vegetation (approximately 865 ha or 13%) that is highly fragmented and with no patch larger than 137 ha. The WSAGA is predominantly rural agricultural land, with overall percentages being 83% rural lands and 11% urbanised. Road development follows the same pattern being very limited across the WSAGA. There creeks present within the WSAGA have patchy retained riparian vegetation. As for the other GAs there are numerous artificial water bodies present in the rural land-use areas (Figure 4).

The Greater Penrith to Eastern Creek Growth Area (GPEC) is located approximately 50 km west of Sydney (Figure 5). The GPEC is relatively flat, covering an altitudinal range of 8 to 102 m ASL. Retained native vegetation cover is minimal (3229 ha = 17%) and fragmented, but with a largest retained area of 549 ha. Unlike the other GAs, the majority of the GPEC is urbanised land (11867 ha = 64%) and rural lands account for only 3501 hectares (18%). There is substantial road development across the majority of the GPEC, which is likely to form a barrier to movement for any species existing within this GA. The Penrith Lakes form an obvious area of once natural wetlands (Figure 5), but much is highly modified for recreational use and this modification continues to increase. This system only partially falls in the GPEC. Major creeks or rivers within the GPEC are the Nepean River on the western boundary, the Ropes Creek system that runs through the eastern part of the GPEC and South Creek that runs through the centre of the GPEC. The riparian vegetation along these larger streams varied in extent and condition and they run usually through highly urbanised environments, preventing frogs from moving between them or to any other water bodies within the matrix, reducing their value as corridors. Artificial water bodies are scattered across the GPEC, but are not in the same numbers as to for the other GAs (Figure 5).

1.4 Reasons for use of an expert report

Section 6.5.2.8 b of the Biodiversity Assessment Method (OEH 2017) places two specific requirements for where an expert report can be used instead of surveys:

- an expert report can only be used instead of a survey for species to which species credits apply
- an expert report may be obtained instead of undertaking a species survey at a development site, clearing site, land to be biodiversity certified or a biodiversity stewardship site.

The GGBF meets the first criteria, being a species credit species under the *Biodiversity Conservation Act 2016*. For the second point, this report is being prepared for the consideration of impacts in the area of the Cumberland Plain Conservation Plan as part of a strategic biodiversity assessment involving biodiversity certification under the *Biodiversity Conservation Act 2016* and Strategic assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999*. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. Hence it meets the criteria as land to be biodiversity certified.

The GGBF is known to inhabit the types of landscapes present within all four of the GAs and records exist across much of the Cumberland Subregion (Figure 1). Insufficient field survey has been carried out to adequately assess the presence of the GGBF within the GAs, with extensive areas of potential habitat occurring on private lands that cannot be accessed. In addition, the spring/summer period over 2017/2018 had below average rainfall and rainfall is critical to initiate calling and reproduction in the GGBF. The conditions were sufficiently unfavourable to prevent an adequate survey outcome even in those areas that could be accessed (see Section 1.6). Activity of the GGBF at the best available reference site of Sydney Olympic Park indicated that very little calling took place over the designated survey period, minimising the chances of detecting any populations present within the four Growth Areas.

On that basis, an expert report was determined to be required for this species.

Credentials of expert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness for the assessment of the impacts of alleged illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI for legal considerations over the potential for forestry operations to impact on rock outcrop dependent species. At the broadest level Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional

Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his MSc and PhD on the ecology and management of frogs in this region and has published over 70 papers (or book chapters) in Australian and International peer-reviewed journals. He has been used by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs. He is member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He co-supervised two PhD students, a Master of Applied Science Student and three Bachelor of Science (Honours) students who completed theses addressing issues of frog biology and conservation.

Dr Lemckert can demonstrate his expertise on the GGBF through the following publications and reports:

Lemckert, F.L., & Mahony, M.J. 2018. The status of Decline and Conservation of Frogs in Temperate Coastal South-eastern Australia. **Pp 59-72** In: *Amphibian Biology Volume 11 - Conservation and Decline of Amphibians: Eastern Hemisphere (Australia, New Zealand and Pacific Islands)*. H. Heatwole and J. Rowley (Eds.). CSIRO Publishing, Melbourne.

Lemckert, F.L. 2017. *Surveys for the Green and Golden Bell Frog at Meroo for the Saving our Species Research Program*. Report to NSW Office of Environment and Heritage.

Mahony, M.J., Hamer, A.J., Pickett, E.J., McKenzie, D.J., Stockwell, M.P. Garnham, J.I., Keely, C.C., Deboo, M., O'Meara, J., Pollard, C.J., Clulow, S., **Lemckert, F.L.**, Bower, D.S., & Clulow, J. 2013. Identifying conservation and research priorities in the face of uncertainty: a review of the threatened bell frog complex in eastern Australia. *Herpetological Conservation and Biology* **8:**519-538.

Penman, T.D. & **Lemckert F.L.** 2008. Monitoring the green and golden bell frog: current problems and an alternative approach. *Australian Zoologist* **34:**373-378.

Hero, J-M., Gillespie, G., Cogger, H., **Lemckert, F.** & Roberston, P. 2008. *Litoria aurea*. Pp 256 In: *Threatened Amphibians of the World.* S.N. Stuart, M. Hoffman, J.S., Chanson, N.A. Cox, R.J. Berridge, P.J. Ramani & B.E. Young (Eds). Lynx Edicions, Barcelona, Spain.

Hero, J-M., Gillespie, G., Cogger, H., **Lemckert, F.** & Robertson, P. 2004. *Litoria aurea*. The IUCN Red List of Threatened Species 2004: e.T12143A3325402. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T12143A3325402.en. Downloaded on 17 May 2018.

Lemckert, F.L. 1998. *Survey report for the green and golden bell frog at Badgerys Creek, NSW*. Unpublished report for Biosis Pty. Ltd.

Lemckert, F.L. 1996. Surveys for the green and golden bell frog, *Litoria aurea*, by the State Forests of New South Wales. *Australian Zoologist* **30:**208-213.

In addition, he is recognised as an expert in the species having been engaged by:

- NSW Office of Environment and Heritage to be part of the expert panel determining the categorisation of this species under the Saving Our Species (SOS) program and in determining the populations requiring specific management to meet the SOS requirement to have a viable population maintained 100 years into the future.
- NSW Roads and Maritime Services to conduct expert surveys for this species in the area around Sydney Airport, Gerringong, Shortland to Sandgate, South Nowra and Berry to Bomaderry, locating the species at Gerringong and South Nowra (2011-2016).
- Port Kembla Coal Terminal to conduct annual ongoing monitoring of this species as part of a Green and Golden Bell Frog Management Plan (2014-2017).
- John Holland Group and Daracon to provide expert advice and survey for this species at Kooragang Island for a rail and road corridor upgrade (2015-2016).
- EPBC surveys for the GGBF at Port Kembla to determine the presence/absence of this species in relation to a proposed development along Masters Road (2014).
- Repeat surveys at Wollongong Golf Course as part of pre-clearing of drainage culverts (2013).
- Provided expert opinion on the status of this species during assessments undertaken for the IUCN in 2001 and 2016.
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for the Green and Golden Bell Frog during the NSW Government's Comprehensive Regional Assessment program (2000-2001).
- Distribution surveys through its historic range between Sydney, NSW, and the Gippsland area of eastern Victoria, as part of a project to look at overlap zones and pre-mating isolating mechanisms between the GGBF and the Southern Bell Frog (*Litoria raniformis*) (1986-1987).

Specific to the Growth Areas, Dr Lemckert has:

- Carried out a series of surveys for the GGBF to meet EPBC standards for the development of the Franciscan Monastary Site on Narrellan Road at Blair Athol.
- Undertaken a survey for the GGBF in the study area for the proposed second airport at Badgery's Creek.
- Conducted biodiversity surveys in the Cordeaux catchment area as part of mine site impact assessments.

Dr Lemckert's full CV is provided as Appendix A of this report.

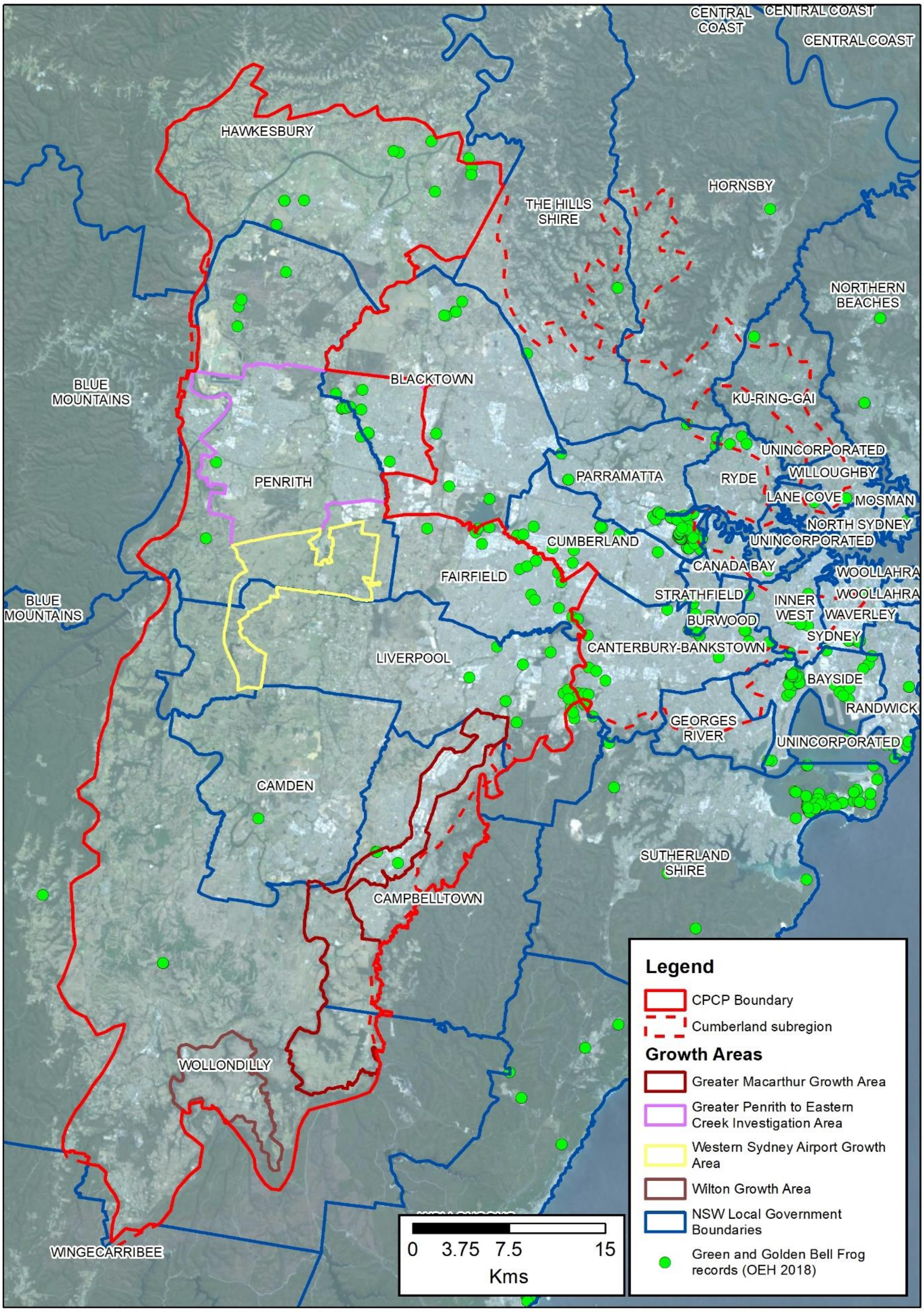


Figure 1. Location of the Cumberland Subregion and associated records for the Green and Golden Bell Frog

1.5 Species surveys conducted on behalf of the Department of Planning and Environment

The following information was provided for the survey process adopted for this project.

Land Access

The Department of Planning and Environment (DPE) sent letters to all landholders within the development footprint.

An initial 726 letters were sent to landholders within the Wilton and Greater Macarthur Growth Areas in late 2017 with a second letter following in March 2018. To increase the response rate, Biosis commenced targeted door-knocking in May 2018. From these efforts, just under 20% of landholders within these growth areas allowed access to their property. However, this included access to large parcels of land owned by major developers which allowed a reasonable amount of access, particularly for the Wilton Growth Area.

A total of 432 letters were sent to landholders across the WSAGA between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking, resulting in a response rate of 21%.

Targeted letters were sent to landholders in the GPEC from November 2017 and August 2018 and 177 landholders provided access to their properties. An additional three landholders provided permission via doorknocking (12% response rate). The Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council.

Targeted survey for threatened species

Field sampling was undertaken across the four growth areas by consulting ecologists from Biosis and Ecoplanning. Targeted survey for threatened fauna species has been conducted on lands where access has been granted, or through 'drive by' and 'over the fence' assessments. Targeted fauna survey conducted by Biosis focused on Gang-gang Cockatoo, Glossy Black-Cockatoo, Large-eared Pied Bat, White-bellied Sea-Eagle, Little Eagle, Square-tailed Kite, Cumberland Plain Land Snail, Southern Myotis, Squirrel Glider and Greater Glider. No frogs were included in this survey, but there was still the potential for the GGBF to be detected incidentally.

Extent of surveys

The extent of the surveys undertaken for fauna have been provided by Biosis and are provided in Appendix 1. The survey tracks indicate that a relatively broad area set of surveys have been conducted in each of each GAs, but that still extensive sections of each GA have had no coverage.

2 Species information

2.1 Species description

The GGBF is an endemic Australian tree frog that is a member of the family Hylidae. It is a relatively large species, ranging in an adult size for males of 57-69 mm and females 65-108 mm snout to vent length (Tyler and Knight 2009). The species gets its name from the typical colour of the body which is often a vivid green splotched with gold. However, in some individuals the back may be almost entirely green whereas other have dominant gold markings (See Plates 1-3 in Appendix 2). There is a pale creamish-white stripe running along the side, extending from the upper eyelids usually almost to the groin. The species also has blue or bluish-green markings in the thighs and groin. The snout is relatively pointy and the belly granular. There is rarely a mid-dorsal stripe, which distinguishes this frog from the Southern Bell Frog, *Litoria raniformis*.

Plate 1. Typical adult Green and Golden Bell Frog

2.2 Life cycle

The GGBF is considered to have a calling season that extends from spring to autumn (Lemckert and Mahony 2008). Within that period of time calling is tied strongly to rainfall events. The advertisement call is a “whaaark whaaark whaark whark” that is produced by the male. Calling occurs mainly at night, but occasionally males will call during the day when conditions are especially favourable (DEC 2005). The males call in groups floating on the surface of the water usually holding on to emergent vegetation, with males synchronising their calls with a lead calling male so that they all call essentially at the same time (Barker et al, 1995; Pyke and White 2001). This may help to confuse predators by masking individual calls. Male GGBF reach sexual maturity at around 45–50 mm snout-vent length (DEC 2005), which would usually be reached in the first season after metamorphosis.

Females of the GGBF reach sexual maturity at a snout-vent length of around 65 mm, which usually takes to their second season after metamorphosis (DEC 2005). Female GGBF produce a particularly large number of eggs for an Australian species, with Pyke and White (2001) suggesting an average clutch size is about 3700 eggs, but with van de Mortel & Goldingay (1996) recording a maximum clutch of 11,682 eggs. Egg size is around 4 mm in diameter.

Spawn is laid among aquatic vegetation, with it initially floating on the water surface as a mass, but sinking within 24 hours of being laid. The eggs typically hatch 2–5 days after ovipositing/fertilisation (Anstis 2013) with water temperature playing a role in development time (eggs hatch faster in warmer water) and can hatch in less than one day.

The tadpoles can tolerate salinity levels of six parts per thousand (ppt) without any apparent effects, while salinity of 8 ppt or higher decreases growth rates and increases mortality rates (Christy and Dickman 2002). The pH of a pond does not appear to affect the likelihood of the eggs to hatch (Pyke and White 2001).

Tadpoles grow at variable rates depending on conditions and availability of food. They can reach up to 80 mm in length before metamorphosis, although they will do so at smaller body lengths. Time to metamorphosis is variable and dependent on conditions and time of year, taking between two and eleven months, but with a mean of three months (Anstis 2013). Tadpoles may overwinter if breeding occurs late in autumn. They would be expected to typically eat algae and other aquatic vegetation and can often be seen sucking at the surface of the water, presumably to take in organic material floating on the water surface. But their actual diet has not been studied. As for most species, it is likely that tadpoles will also eat dead animal material if it is available, including other tadpoles.

2.3 Distribution and abundance

Broad distribution

The distribution has been recorded as from Yuraygir National Park on the far North Coast of NSW to around Lakes Entrance in south-eastern Victoria (White and Pyke 2008). Notably, Courtice and Grigg (1975) completed a detailed study of the distribution of the GGBF and in Gippsland found it only as far west as Marlo where it abutted and had a potential hybrid zone with *Litoria raniformis*, which was the species found to the west of that point. In the mid-1980s the species was recorded at least 60 km further west at Nowa Nowa and *Litoria raniformis* were no longer present in that location (F. Lemckert Pers. Obs.) and then 15 km further west at Lakes Entrance by White and Pyke (2008). This may suggest a slight westward expansion of the species in Victoria since the 1970s. Historically the species was known from a number of sites at least 50 km inland into the NSW ranges including at Bathurst (White and Pyke 1999), Bungendore (Humphries 1979) and 30 km inland at Ulong on the NSW north coast (Moore 1961). The furthest and now only extant "inland" population is near Hoskinstown in the Southern Tablelands of NSW (Osborne et al. 2008). Natural GGBF populations are also known from three islands off the coast of NSW; Bowen Island, Kooragang Island and Broughton Island (DEC 2005). Extra-limital populations have been introduced to New Zealand (Pyke et al. 2002), and New Caledonia and Vanuatu (Pyke and White 2001) with the species occurring in high densities in some areas (M. Mahony Pers. Comm.).

The extent of occurrence of the species in 1999 within Australia was estimated to be approximately 150,000 km² (Mahony 1999), but there are no more recent estimate and the extent of occurrence is probably continuing to reduce as populations are known to be continuing to decline (Mahony et al. 2013).

Distribution one the Cumberland Subregion

A total of 13146 records for the GGBF are available on the Cumberland Subregion (based on NSW BioNet records), with the broad distribution of these records being shown in Figure 1. This is a large number of records, but is highly skewed by the records from Sydney Olympic Park and the majority (>95 %) come from the eastern third of the Cumberland Subregion, none of which is included in the GAs. The records from the actual GAs are very limited, with just 12 record sites being available from the GPEC and two from the GMGA. The limited number of records in the western half of the Cumberland Subregion suggests that the GGBF may never have been common or widespread across this region, despite the apparently adaptable nature of this frog (see Section 2.4) and the presence of habitat that otherwise looks suitable for the GGBF.

The Draft NSW GGBF Recovery Plan (DEC 2005) lists one core populations for this species located within or near a Growth Area, being the St Marys population centred around St Marys, Mt Druitt, Prospect and Riverstone that is part of the GPEC.

Abundance

The GGBF was recorded as once being a very abundant and widespread frog (Goldingay 1996). Fletcher (1889) stated that this species was commonly be encountered in the Sydney area and Harrison (1922) noted that this species was “probably our best known frog” and was “known to me since childhood”. Extensive surveys for the species by Courtice and Grigg (1975) in the early 1970s recorded it very regularly and abundantly across coastal NSW and into southeast Victoria. However, there was a serious decline of the species in the 1980s, with the timing being uncertain, but with frogs having disappeared from many historic sites by 1987 (F. Lemckert Pers. Obs.). By 1996 the GGBF was regarded as rare by White & Pyke (1996) and its recorded declines recognised to be of concern (White 1995). Populations of over 1000 frogs were (and likely still are) present at Kooragang Island, Broughton Island and Homebush (Hamer et al. 2002), but the other locations it is known from are much smaller populations (DEC 2005). Even in 2005 the GGBF was recognised as having declined to less than 50 populations in NSW (DEC 2005) and the declines have been continuing (Mahony et al. 2013). The amphibian chytrid fungus has been implicated as the main driver of these severe declines (Mahony et al. 2013), although habitat loss (Goldingay 1996) and introduced predatory fish (Pyke and White 1999, Goldingay 2008) have also been suggested to have played significant roles in population declines and losses.

Over the short-term the GGBF can exhibit significant local population fluctuations when conditions result in high tadpole survivorship (eg, Daly 2014). The GGBF has a life cycle that fits what is termed to be an R-selected species (Hamer and Mahony 2007), producing large numbers of offspring and adults have relatively shorter lifespans. Hence, there is a relatively rapid turnover of individuals and survival of the local population depends on occasional very successful seasons, when population size and area utilised rapidly increase, interspersed with years of low recruitment when numbers fall away and there are local extinctions in less favourable areas of habitat. This is considered to be a typical pattern for amphibians (Alford and Richards 1999). In fact, The GGBF has been suggested to be a colonising species with a series of its attributes suit this lifestyle: habitat generalist, high fecundity, rapid growth, early sexual maturity, and relative high dispersal ability (Hamer & Mahony 2007). White and Pyke (1999) suggests that the GGBF rapidly move into areas of newly created breeding habitat that represent sites with little competition for the developing tadpoles from other species, are open and so provide good thermal environments and lack or have minimal predators such as dragonfly larvae or fish present. Such a lifestyle is atypical of frog species that have undergone significant broader declines.

Nearly all currently known populations within Australia are located within 10 kilometres of coastal locations (Mahony et al., 2013). This is most likely due to the inhibition of the amphibian chytrid fungus by salt, either through flooding or windborn, as the fungus in relatively intolerant of salt (Stockwell et al 2012). Hence more coastal locations are relative havens from the impacts of chytrid. As, salinity levels of at least 1–2 ppt can be beneficial to the GGBF because this kills pathogens such as the chytrid fungus. Interestingly, Christy and Dickman (2002) identified saltwater intrusion in coastal wetlands due to landscape changes to be a potential threat to GGBF breeding sites. Dryland salinity might then also represent a threat to GGBF should it occur, but this seems to be a minimal issue based on current evidence.

Plate 2. Examples of typical breeding habitat for the Green and Golden Bell Frog at: a) Wilton and b) Penrith Lakes – large permanent ponds with emergent and/or fringing vegetation.

Plate 3. Examples of habitat at Ropes Creek: a) Bushland for foraging and b) Dry creek bed that would flood to form breeding habitat.

2.4 Habitat requirements

Breeding Habitat

Breeding sites for the GGBF include a wide range of natural water bodies and the species has been recorded inhabiting all but fast flowing streams (Pyke & White 1996). It also inhabits many human-created environments, including highly disturbed sites such as abandoned mines and quarries (Pyke et al. 2002), as well as artificial wetlands that have been created at both Kooragang Island (Hamer et al. 2002) and Sydney Olympic Park (Darcovich and O'Meara 2008). Pyke & White (1996) undertook a review of the known breeding habitat of the GGBF and found that they preferred to breed in water bodies that were still, shallow, ephemeral, unshaded, with aquatic plants and free of the Plague Minnow (*Gambusia holbrooki*) and other predatory fish. This study also found that breeding occurs in a significantly higher proportion of sites with ephemeral (temporary) ponds, rather than sites with fluctuating or permanent ponds. Hamer et al. (2002) found a similar result for the GGBF populations at Kooragang Island where larger males would move to ephemeral water bodies to opportunistically breed at them, although reproduction was also associated with permanent water bodies. The frogs in that study also tended to remain relatively faithful to one water. The presence of the Plague Minnow does not exclude GGBF from breeding in a water body, but success appears to be dependent on the presence of more complex aquatic vegetation, which allows the GGBF to breed successfully (Hamer et al. 2002). Hence the Plague Minnow does still appear to have a significant role in determining the likely presence of the GGBF in most situations.

Non-breeding habitat

Non-breeding habitat for the GGBF is unusual for an Australian frog in that the species appears to remain generally associated with water bodies (remain within 50 metres) rather than dispersing away from water bodies into more terrestrial non-breeding habitats (100-300 metres from the breeding site), which is typical of most frogs (Lemckert 2004). Terrestrial habitats immediately adjacent to water bodies are used for foraging and shelter and preferably consist of grassy areas and vegetation no higher than woodlands and contain a range of diurnal shelter sites such as logs, rocks or dense vegetation (Pyke and White 1996). However, there are observations of GGBF using taller forests (eg. dry sclerophyll forest at Nowra; M. Greenlees Pers. Comm. and dense woodlands at Meroo, FL Pers. Obs.) and foraging in suburban backyards (DEC 2005), again demonstrating the apparent adaptability and lack of habitat specificity of this frog. Females have been observed to show site fidelity for shelter and foraging sites in areas adjacent to breeding sites (Hamer 1998, Pyke and White 2001).

Shelter sites are used when GGBFs are inactive and so vulnerable and are of added importance in providing secure over-wintering locations. Studies at Kooragang Island have suggested that females may use slightly different non-breeding areas to males and may have very important and specific over-wintering areas located in dense vegetation (M. Mahony Pers. Comm.). Whether this is the same for other populations is unknown, but there is evidence from Sydney Olympic Park that females there also concentrate in certain locations (J. O'Meara Pers. Com.).

Another unusual aspect of the GGBF is its well known habit of basking, typically within areas of aquatic vegetation, apparently to increase body temperatures (Pyke and White 2001). Basking in frogs is unusual (being generally nocturnal), but such activities in ectotherms typically allow for periods of greater activity or faster digestion of food items and, whilst the importance of this activity for its physiological requirements is not known, individual GGBF appear to bask regularly. On this basis, it is likely that basking is an important physiological activity for the GGBF. Basking typically occurs within or on the edge of emergent aquatic vegetation, which likely allows individuals the option to make a rapid escape from diurnal predators. The presence of water bodies that contain emergent vegetation are known important determinants of the presence of GGBF (Pyke and White 1996; Hamer et al. 2002) and form an important resource for the GGBF and in the consideration of their potential presence.

Whilst GGBF may retain a closer association with water bodies and appear to generally be faithful to a single water body for their general activities, they can move along and between different water bodies, particularly as part of migrations to and from breeding sites (Hamer et al. 2002). Studies have revealed that the species move distances of up to 1 kilometre (Hamer et al. 2008) and mark/recapture studies have found individuals moved up to 3 kilometres (Pyke & White 2001). Individual GGBF even have the potential to disperse as far as 10 kilometres (White & Pyke 2008). There are records of GGBFs several hundred metres from major drainage lines or other waterbodies (Gillespie 1996) and this may represent long-distance dispersal between water bodies. Hamer et al. (2008) noted that male GGBFs at Kooragang Island often moved > 200 metres to reach an ephemeral breeding site, crossing over extended grassland areas and other habitats including disturbed habitats.

Christy (2001) and Muir (2008) indicated that terrestrial movements of the GGBF are primarily undertaken through more open environments that contained patches of shelter such as rocks, logs or ponds or areas of thick vegetation. Such habitats provide relatively little impediment to the movements of frogs, but allow for individuals to seek shelter as required. Terrestrial movements are typically undertaken at night and are most likely associated with rainfall events (F. Lemckert Pers. Obs.) which would provide protection against desiccation.

Mahony (1999) cautions that the studies that have been carried out since the declines of the GGBF do not necessarily identify the actual preferred requirements of the species. He notes that the changed environment and factors causing the declines may have “altered” the optimal habitats for the species in comparison to their habitat use patterns prior to the declines. This is based on the fact that the use of ephemeral breeding sites was not noted for the bell frog group in earlier habitat descriptions. Such altered habitat use has been noted for other species such as *Litoria lorica* that now is only present in open rocky streams whereas it was once known as a rainforest stream species (Puschendorf 2011). This change is attributed to the impacts of the chytrid fungus, with the frog only surviving in a relatively extreme environment where the fungus is affected by the hotter conditions. Given the chytrid fungus appears also to have been at least a significant contributor (and probably the major one) to the decline of the GGBF, there is a significant potential that the GGBF is now living successfully only in a different set of environments to what it historically did. However, that is unlikely to ever be confirmed.

<u>Metapopulation dynamics</u>

A critical consideration in the likely presence/absence of the GGBF are metapopulation dynamics. The GGBF is considered to follow a classical metapopulation structure with the “local” population consisting as a series of patchy populations within the larger metapopulation. Individuals move regularly between a mosaic of wetlands across a broad area throughout a single breeding season (Hamer et al. 2008; Hamer & Mahony 2010). There is high site-specific population turnover with local extinctions being balanced by colonisations by regularly dispersing individuals, but with the overall population remaining stable. There are core sites that provide ongoing and regular reproductive success and that maintain long-term populations, but the major part of the population dynamics is driven by inter-year success of breeding at a range of available breeding sites, with years of very good reproductive success leading to opportunities to expand ranges and colonise new sites. On Kooragang Island, GGBF typically reside in permanent waterbodies where they exhibit high site fidelity, but during periods of high rainfall disperse over several hundred metres to breed at ephemeral water bodies that have flooded (Hamer et al. 2008). Reproductive activity (e.g. calling) typically occurs over several nights at these ephemeral waterbodies, with individuals returning to core permanent waterbodies. In times of poor rainfall, the core sites become the refuges for the species and Valdez et al. (2015) found that probability of occupancy of a site increased at large and permanent wetlands.

Following on from this is the identified need for connected sites to allow this population interaction. Hamer (2016) found that the presence of the GGBF at sites at Nowra was dependent on accessibility of ponds, a factor mediated both by the presence of vegetation and the extent of roads in the area, with the presence of roads providing a likely serious barrier to pond use. The presence of vegetation directly around ponds correlated significantly with the potential for greater species diversity. The type of pond available also was important, with the species avoiding steep sided concrete ponds. The apparent negative impacts of roads was confirmed in follow up work (Hamer 2018) where it was again found that the extent of accessible habitat (habitat close to ponds and not isolated from the pond by a road) positively influenced the likelihood of pond occupancy. Extinctions of GGBF were significantly more likely to occur at ponds in areas with higher densities of roads, but were significantly less likely at ponds with higher aquatic vegetation cover. The spatial arrangement of wetlands and the extent of wetlands measured in a 1 kilometre radius has been found to be an important predictor of pond occupancy by GGBF in studies by Hamer et al. (2002), Hamer and Mahony (2010) and Valdez et al. (2015) with more ponds, closer together ponds and already occupied ponds increasing the potential for the GGBF to be present or occupy a previously unoccupied pond (Puschendorf et al. 2011).

This information provides the following important points when trying to assess the potential presence of the GGBF in any area:

- The GGBF is more likely to be present where multiple suitable breeding sites are within a close enough proximity for frogs to migrate between them with relative ease
- The GGBF is more likely to be present where multiple non-breeding water bodies are present in an area and within close enough proximity to allow migration between them (and breeding sites) with relative ease
- The GGBF is more likely to be present where the connectivity of breeding and non-breeding habitat contains a matrix (vegetation and shelter) that facilitates migration
- The GGBF is more likely to be present at a location when there are other GGBF occupied ponds in close proximity.

Vegetation associations

The OEH profile records the GGBF to be associated with a broad range of vegetation formations and classes within the Sydney Basin Interim Biogeographic Region, the location of the GAs (https://www.environment.nsw.gov.au/threatenedspeciesapp/profileData.aspx?id=10483&cmaName=Sydney+Basin). These are:

Dry sclerophyll forests (shrub/grass sub-formation)

Cumberland Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

Sydney Coastal Dry Sclerophyll Forests
Sydney Hinterland Dry Sclerophyll Forests

Forested wetlands

Coastal Floodplain Wetlands

Freshwater wetlands

Coastal Freshwater Lagoons

Grassy woodlands

Coastal Valley Grassy Woodlands

Miscellaneous ecosystems

Highly disturbed areas with no or limited native vegetation
Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

Dry Rainforests

The most important feature to note is that this list of vegetation associations is relatively broad covering wetlands and swamps, woodlands, dry sclerophyll forests and dry rainforest. That is essentially all possible environments present within the Cumberland Subregion and reflects the understanding that the GGBF is a very adaptable species with little in the way of habitat limitations. This also conforms with the GGBF being recognised for its use of highly disturbed environments and areas without native vegetation. In the context of assessing the likely presence/absence and, if present, the abundance of this species, the type of vegetation present has little relevance. The value of vegetation is it being present to provide GGBF shelter and locations where food may be found.

2.5 Threats

The GGBF is listed as is listed as endangered under the BC Act and vulnerable under EPBC Act.

The IUCN lists the threats to the GGBF as "IUCN: "*The cause(s) of the apparent declines observed in populations of all taxa within the L. aurea complex are unclear (Gillespie et al. 1995).*

Investigations of disappearances among the group have primarily focused on L. aurea and L. castanea and two major directions in research have been pursued: the role of increased ultraviolet radiation; and the impact of the introduced fish, Gambusia (Mahony 1999). It is also possible that disease, such as a viral infection or chytrid fungus, might have contributed to the decline of this species (W. Osborne pers. comm.). Chytrid fungus was detected in this species in Hoskinstown and Homebush Bay in Sydney, New South Wales".

The OEH profile for this species lists the following as threats to this species:

- Alteration of drainage patterns and stormwater runoff.
- Frog Chytrid Fungus, a fungal pathogen.
- Predation by feral animals such as foxes.
- Herbicides and other weed-control measures.
- Road mortality, where populations are already small due to other threats.
- Predation by exotic fish such as Plague Minnow.
- Loss of suitable breeding habitat through alteration by infilling and destruction of wetlands.
- Current knowledge of the status of the population and threats to the population is poor.
- Species occurs on private land where land management practices may not be suitable for the species, e.g. grazing and loss of breeding habitat.
- Changes in salinity due to sea level rise. Frogs are unable to breed in waters with salt concentrations of greater than 6 parts per 1000.
- Overgrowth of pond vegetation leading to declining water temperature.
- Small population size.
- Lack of information regarding habitat permanency.
- Drying of breeding habitat as a result of increased temperatures and more frequent droughts.
- Lack of landscape connectivity leading to isolation of small populations.
- Heavy metal pollution.
- Four-wheel drives impacting habitat.

The SPRAT profile for this species lists the following threats:

- Habitat removal.
- Habitat degradation (which includes siltation, changes to aquatic vegetation diversity or structure reducing shelter, increased light and noise, grazing, mowing, fire).
- Habitat fragmentation.
- Reduction in water quality and hydrological changes (for example, pollution, siltation erosion and changes to timing, duration or frequency of flood events).
- Disease (for example, infection of the frog with chytrid fungus (*Batrachochytrium dendrobatidis*) resulting in chytridiomycosis).
- Predation by introduced predators including the Plague Minnow (*Gambusia holbrooki*), Cats (*Felis catus*) or Foxes (*Vulpes vulpes*).
- Introduction or intensification of public access to GGBF habitats.

In regards to the GAs, the following would be of relevance when considering impacts:

- habitat loss (through changes resulting from flooding)
- fuel reduction burning
- introduced aquatic predators (access to breeding streams)
- spread of the amphibian chytrid fungus.

One specific consideration for the likely presence and abundance of the GGBF is the location of a site relative to the coast with essentially all currently known populations located within 10 kilometres of the ocean (Mahony et al. 2013). This is likely to be a result of the impacts of the amphibian chytrid fungus, with the influence of salt closer to the coast inhibiting the growth of the fungus to a sufficient degree to minimise its otherwise very serious negative effects.

3 Description of the study area

3.1 Land use history

The following information has been derived from the Cumberland Plain Recovery Plan (DECCW 2010a). At the time of European settlement, the Cumberland Subregion would have consisted of extensive areas of grassy woodlands were present along with wooded areas including ironbark and turpentine forests, dry rainforests, and floodplain communities. Agricultural development commenced before 1800 and by the middle of the 19th century most of the region was either being grazed or was cultivated. Clearing for agriculture was later supplemented by clearing for residential, commercial and industrial purposes.

NPWS (2002) noted that only 13% of the pre-1750 extent of the region's vegetation remained as intact bushland, with an additional 12% occurring as scattered trees in disturbed areas. The majority (76%) of the remaining bushland is privately owned, and only 8% is protected within the formal reserve system. The region's bushland is also highly fragmented, comprising 2,446 individual remnants (DECCW 2010b), but the 81 largest remnants contain 51% of the remaining bushland. Many of these large, intact remnants occupy public land and so can be expected to be maintained into the foreseeable future. Larger remnants are typically more diverse and resilient than smaller remnants, being less susceptible to 'edge effects' and being less likely to be fully subjected to catastrophic events. Biodiversity loss caused by habitat fragmentation has been demonstrated to significantly increase once clearing levels exceed 70% of the landscape (Freudenberger et al. 1997; WALGA 2004) and this threshold has been passed on the Cumberland Subregion.

3.2 Landscape context

Cumberland Subregion

Tozer (2003) notes that the Cumberland Plain is based on the extent of soils derived from three main geological units: Wianamatta group shales, Tertiary alluvium and Holocene alluvium (in areas draining Wianamatta group shales). Tozer states that:

"*West of Parramatta, the Cumberland Plain forms an elongated ellipse stretching from Sackville in the north to Thirlmere in the south, with the western boundary marked by the monocline of the Blue Mountains to the west of Penrith. East of Parramatta the Plain is truncated by the*

Hornsby Plateau in the north and the Woronora Plateau to the south, and finally terminates near the city centre.

The Cumberland Plain comprises gently undulating plains and low hills, rising gradually from the flat, low lying areas just above sea level in the north to an altitude of around 350 m on the rolling hills of the Razorback Range in the south. Two low ridgelines project northward from this elevated southern region as far as Mount Druitt and Orchard Hills respectively. The eastern ridge forms a watershed between the drainage channels flowing north to the Hawkesbury River and those draining east into the Georges River. Separating the two ridges is the upper catchment of South Creek, which forms the major drainage channel of the Plain. Rising gradually to the north-west of the Plain, the broadly dissected Hornsby Plateau lies between 100 to 200 m above the northern half of the Plain. On the Hornsby Plateau, Wianamatta Shale soils are located predominantly along three broad ridgelines running approximately north-west from North Sydney to Hornsby and from Ryde to Castle Hill, and north from Castle Hill to Arcadia."

Tozer 2004 also provides the following summary of geology and soils, which in turn is derived from Chapman and Murphy (1989), Hazelton et al. (1990) and Bannerman and Hazelton (1990).

"*The oldest geological units outcropping within the study area are of sedimentary origin and were laid down during the middle Triassic period. Of these, the Wianamatta group is the dominant feature and occurs throughout the Cumberland Plain and on plateau tops and ridges on the Blue Mountains and Hornsby plateaus. It comprises claystone, siltstone, laminite and fine to medium grained lithic sandstone weathering to low fertility soils ranging in texture from loam to heavy clay. The Wianamatta group conformably overlies the discontinuous Mittagong Formation and Hawkesbury Sandstone. The former comprises inter-bedded and laminated, fine to medium-grained quartz sandstone and siltstone, and constitutes passage beds between the Wianamatta Group and the Hawkesbury Sandstone.*

Hawkesbury Sandstone weathers to form sandy–loam soils of very low fertility. The Mittagong Formation and Hawkesbury Sandstone outcrop on the margins of the study area especially along watercourses where the overlying shale has eroded during the development of a streambed.

On the Cumberland Plain, the Wianamatta group is overlain by unconsolidated sediments deposited in two geological periods. The deposition and reworking of silty-clayey sands and gravels along watercourses has been ongoing throughout the Quaternary period. These constitute some of the most fertile soils of the Plain and are particularly extensive on the floodplains of the Hawkesbury–Nepean River in the north of the study area. Sediments dating from the Tertiary Period occur in two main localities: to the south of Richmond in the north-west part of the study area and south of Liverpool in the south-east. These comprise sand, clay, gravel and volcanic breccia of both colluvial and alluvial origin and give rise to soils of low fertility. In the vicinity of Agnes Banks tertiary sediments are overlain by low parallel dunes of quartz sand eroded from the upper catchment of the Hawkesbury–Nepean and deposited by wind during the quaternary period. These sandy soils are of very low fertility."

Key climate statistics for the weather stations located within each GA are shown in Table 1. These data show a decreasing mean maximum from north to north and a corresponding increase in mean minimum temperatures, which is mainly due to the north to south increase in elevation.

Rainfall is relatively similar across the range except that the far northern area at Penrith Lakes has a distinctly lower mean rainfall.

The NSW BAM provides no mandatory applicable habitat constraints for the GGBF, but includes following indicative habitat constraints as being within 1 kilometre of semi-permanent/ephemeral wet areas, within 1 kilometre of swamps and within 1 kilometre of water bodies. This mirrors the understanding of the requirements of the species provided in Section 2.4.

Table 1. Key climatic statistics for weather stations in the Growth Areas (taken from the Bureau of Meteorology).

Weather station	Mean annual rainfall (mm)	Mean maximum temperature (°C)	Mean minimum temperature (°C)
Penrith Lakes AWS	718.6	31.0	5.3
Orchard Hills Treatment Works	832.7	28.5	5.3
Badgerys Creek McMasters F	794.3	28.6	3.8
Camden Airport	782.1	23.8	10.3
Picton Council Depot	800.9	23.4	8.8

Growth Areas

All four GAs contain at least some parts that provide a diversity of water bodies including streams and rivers in dissected gorges, streams on more open floodplains (historically probably chains of ponds), large numbers of farms dams and reservoirs and numerous ephemeral water bodies located amongst pasture lands. The lands also include industrial sites that may hold settling ponds and bunded areas for water collection as well as old quarries and excavations that hold water. All of these water bodies form potentially suitable breeding and shelter sites for the GGBF

3.3 Native vegetation communities

The remnant native vegetation of the Cumberland Subregion is very varied in nature and consists of wet and dry forests, woodlands with grassy and shrubby understories and wetland and riparian vegetation communities. The different PCTs listed as occurring across the four GAs are:

Dry sclerophyll forests (shrub/grass sub-formation)

- 724 Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion;
- 725 Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion.

Freshwater wetlands

- 781 Freshwater wetland.

Grassy woodlands

- 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion;
- 835 Forest Red Gum - Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion;
- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion;
- 850 Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion.

Dry sclerophyll forests (shrubby sub-formation)

- 774 Coast Banksia scrub on sand of the Elderslie area, Sydney Basin Bioregion;
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion;
- 1081 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion;
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion.

Forested wetlands

- 1105 River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion;
- 1292 Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion;
- 1800 Swamp Oak open forest.

4 Assessment of species presence and habitat

4.1 Existing records and surveys

The records of the GGBF available within the boundaries of the priority GAs are shown in Figures 2-5. These figures also provide the locations of records from areas immediately adjacent to the GAs, which are also be important to consider when meeting the requirement that multiple pond populations exist in close proximity and need to be linked in order to maintain metapopulation processes. The existing records demonstrate that:

- There are no records present within the Wilton GA itself or within 5 kilometres of its boundaries.
- The GMGA has a series of 4-5 GGBF records restricted to a very small area around Blair Athol. There are no other records inside or within 5 kilometres of the GA.
- The WSAGA has no records within its boundaries and only two individual records within 5 kilometres of its boundaries: one to the north east and the other the north west.
- The GPEC has a series of 11 records associated with Ropes Creek in its eastern half and a single record from Glenmore Park in its western half. There are also a series of other records scattered to the north east and west indicating that this GA is central to the records of the GGBF on the Cumberland Subregion.

The concentration of 4-5 very recent (2012-2014) records from a very small area at Blair Athol (Figure 3) provides some very recent records for the species. However, indications from the environmental officer at Campbelltown Council (Alex Cave) are that these records are of frogs that escaped a captive colony and that no original natural population was present. A population could potentially have established in that location, but all of the animals captured were juvenile frogs and no records have been obtained after 2014 indicating that the population disappeared.

The absence of records from some parts of the Cumberland Subregion may possibly be due to a lack of survey works, especially prior to the decline of the species in the 1980s. Various historic surveys will have been conducted across the region, although the extent of this work is poorly documented and generally unavailable to view. This will include surveys have been carried out around Badgery's Creek as part of a succession of assessments for the proposed second Sydney Airport site. I have personally conducted surveys in this area in the late 1990s as well as surveys at Orchard Hills, Blair Athol, Macarthur and along the Nepean River near Picton in areas included as part of this Biocertification process. None of these surveys provided any records of the GGBF and none of the surveys are freely available to the public to view. There would certainly be many more such surveys for developments that have no means of being accessed to properly assess survey effort. However, any records of GGBF should have been provided to the NSW BioNet and it would seem highly likely that the survey effort has been sufficient to reasonably indicate that the GGBF is at best rarely present within the assessed Biocertification lands.

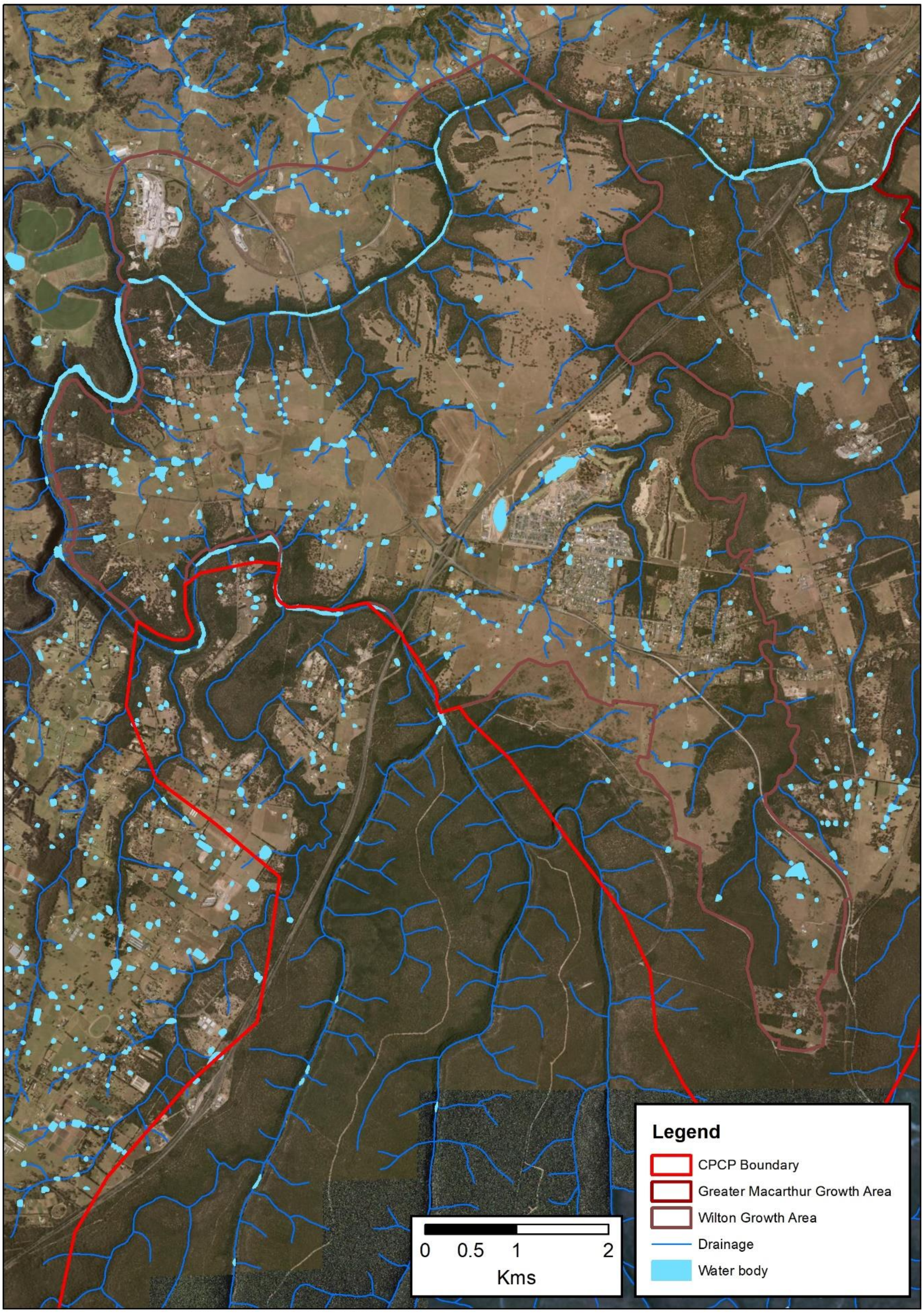


Figure 2. GGBF records from and mapped water bodies for the Wilton Growth Area

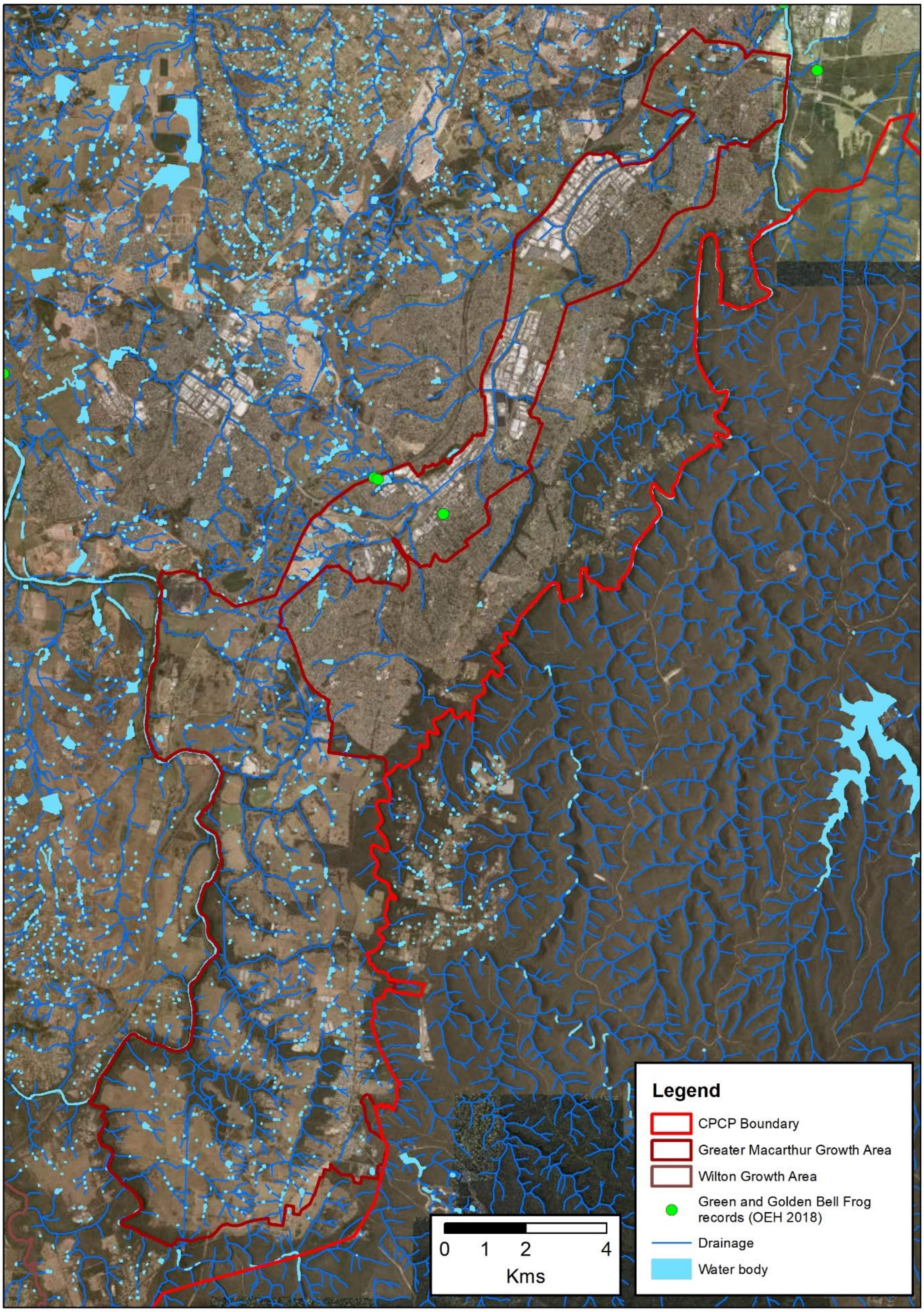


Figure 3. GGBF records from and mapped water bodies for the Greater Macarthur Growth Area

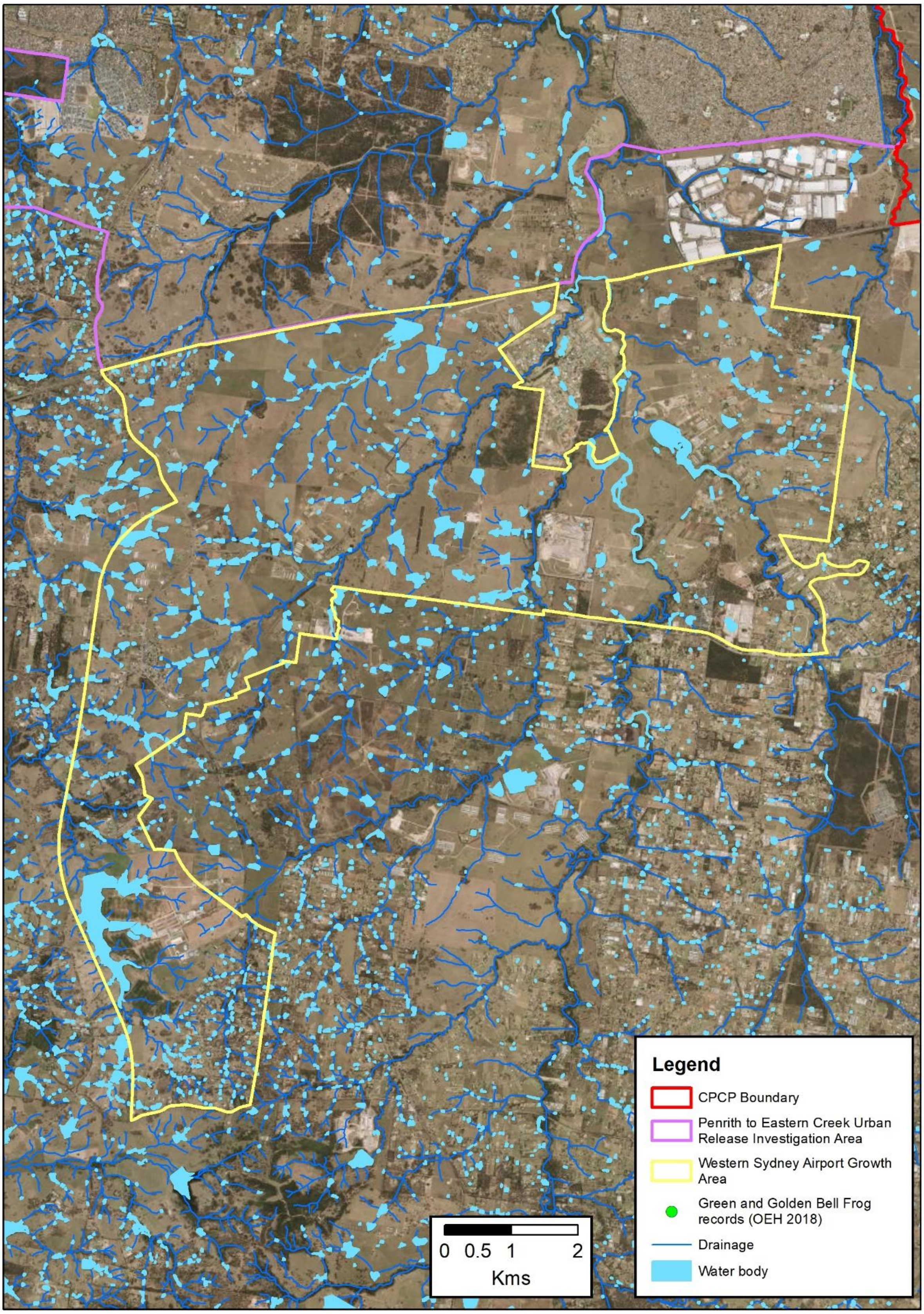


Figure 4. GGBF records from and mapped water bodies for the Aerotropolis Growth Area (Map provided by DoPE)

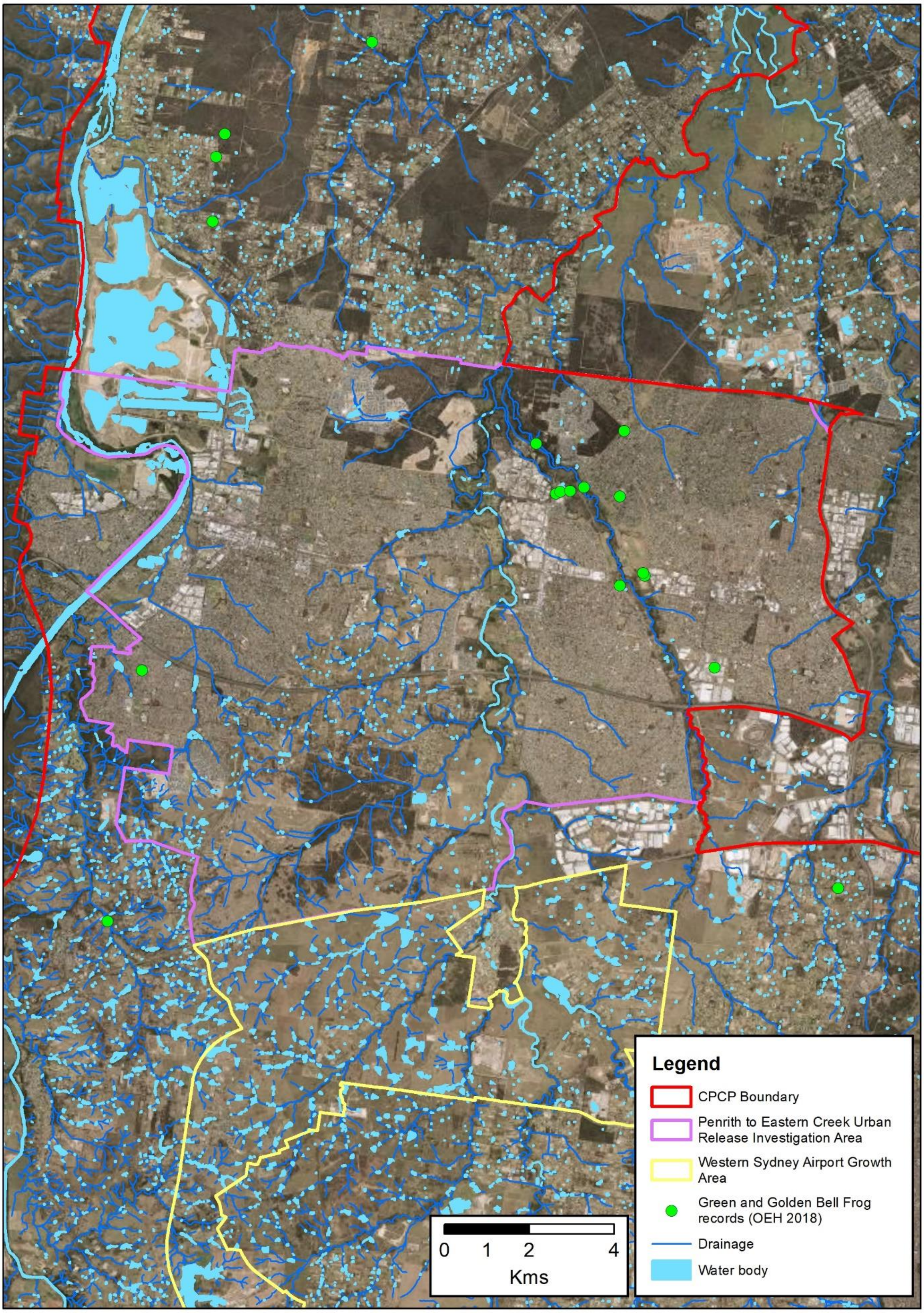


Figure 5. GGBF records from and mapped water bodies for the Greater Penrith to Eastern Creek Growth Area (Map provided by DoPE)

Three points are clearly evident. Firstly, that few actual records have been obtained for the GGBF on the area of the Cumberland Subregion under consideration and it would appear that the species has never been common in this area. Secondly, the majority of records are from prior to 1990, indicating that most populations are likely to now be extinct. This fits in with the pattern of declines noted for the GGBF by Mahony et al. (2013) that noted populations to rarely persist more than 10 kilometres from the coast. The entire study area meets this criterion. Thirdly, the few records that are available tend to be clustered into discrete areas. This is typical of the GGBF that is more likely to be found at sites where there are other nearby records (Hamer and Mahony 2010; Hamer 2018) and is attributed to the metapopulation structure of this species that requires a series of supporting and interacting sub-populations (in this case based around water bodies) in order for the species to have long-term success.

4.2 Surveys completed for the Biocertification

Surveys were completed by Biosis and Ecoplanning on behalf of DPE. The extent of the surveys are provided in the maps listed in Appendix 2.

4.3 Surveys completed for this assessment

No field surveys were specifically completed for this assessment to locate GGBF. As noted before, access to most of the potential breeding habitat is not available and time did not allow for this outcome. Instead, brief and broad habitat assessments were conducted within each of the four priority GAs to provide an understanding of the available habitats and their quality. This looked for features such as the availability and proximity of natural and artificial water bodies and the matrix of vegetation or other habitats between water bodies. These assessments confirmed the initial assessment that the built up areas provide little suitable habitat of any type for the GGBF, but the more rural locations are broadly suitable for GGBF populations to persist and include large numbers of human created water bodies.

4.4 Assessment of species presence

Likelihood of species presence

Studies have demonstrated a strong relationships to exist between the probability of occupancy of a pond by GGBF and the connectivity of wetland sites within the landscape. This relationship is evident in two forms. Firstly, in the spatial arrangement of permanent wetlands, allowing a short enough distance and suitable matrix of intervening habitat for frogs to move between ponds. Secondly, in the total area of wetlands within a 1 km-radius around a pond, which provides multiple interactive breeding sites within an area (Hamer et al. 2002; Hamer & Mahony 2010; Valdez et al. 2015; Hamer 2018). Hence consideration of the presence of the GGBF at a local scale is based on the presence of a high density of water bodies that are well connected by both proximity and suitable habitat to move through.

A second consideration is that at a much larger scale where water bodies greater than 10 kilometres from coast are unlikely to contain the frog, presumably because salinity levels are too low to play any significant role in attenuating chytrid. Sites greater than 10 kilometres from the coast may still be viable where they have an “anti-fungicidal” environment (ie, have chemical properties that inhibit growth). It is not feasible to map such locations based on historic use and it would be unlikely that such site properties would be extensive enough to provide clear guidance that the species would be present. If such did exist, it would seem very likely that the species would already have been recorded there. Hence the best understanding of the suitability of sites is based on previous records of the GGBF.

Justification for determining presence

Wilton

It has been determined that the GGBF is not likely to currently be present within the WGA. Copland (1957) records a specimen from the Picton area and so the GGBF was once present at least immediately adjacent to the WGA. However, there are no available records specific to the WGA and the distance to the coast indicates it is unlikely the GGBF would persist in the WGA.

No species polygon is provided as the species is not considered present within the WGA. The majority of the available habitat (rural lands) is suitable for this species and it could potentially return or colonise the WGA if the impacts of the amphibian chytrid fungus can be overcome.

Greater Macarthur Growth Area

It has been determined that the GGBF is not likely to currently be present within the broad GMGA. The only records of the species within the area are the very recent records of juvenile GGBF from around the Blair Athol area (Figure 3). As noted, these records are believed to be of individuals that escaped from a semi-captive colony and no extant “native” population was likely present. There are also no indications that a population has established as a result of the escape these individuals. Whilst, as for the Wilton area, it would seem likely that the GGBF was once present within the WGA, there is no evidence that it is currently present and the distance to the coast of the GMGA indicates it is unlikely to be able to persist in the current environment without some known source populations.

Figure 7 provides the species polygon of determined habitat area for the GGBF in the GMGA, although I again note that this is based on likely escaped frogs. This covers the locations of known records, the riparian zone joining those records and a buffer of 1000 m around that riparian zone and records that is the area deemed likely for GGBF to use for foraging, shelter, breeding and as migratory habitat as they move between water bodies and riparian areas.

Western Sydney Aerotropolis Growth Area

It has been determined that there is not likely to be a population of the GGBF currently present within the WSAGA. There are no records from within the GA, despite the presence of suitable habitat in rural areas in the form of a high density of water bodies. There is no evidence that it is currently present and the distance to the coast indicates it is unlikely that the GGBF would persist in this area. The two most closely associated records (Figure 4) are single records not closely aligned with other records and so it is unlikely that a larger stable population has been or is present within the WSAGA.

Greater Penrith to Eastern Creek Growth Area

It has been determined that a population of the GGBF may remain present within the GPEC. There are a number relatively recent records from within and immediately adjacent to the GPEC located along the Ropes Creek corridor (Figure 8) and areas of suitable habitat remain along that corridor in the form of a high density of water bodies within undeveloped lands. It is not certain that the population still remains, given the ongoing declines noted for the GGBF, but the survey completed for the Biocertification has not been adequate to establish the current status of the GGBF population.

Figure 8 provides a species polygon for the GGBF within the GPEC. This covers the locations of known records, the riparian zone joining those records and a buffer of 1000 m around that riparian zone and records that is the area deemed likely for GGBF to use for foraging, shelter, breeding and as migratory habitat as they move between water bodies and riparian areas.

4.5 Assessment of suitable habitat

The information in Section 2 demonstrates the ability of the GGBF to use a broad range of habitats and only urbanised areas represent unsuitable habitat, mainly because of the absence of breeding ponds and the high density of roads and buildings that form barriers to movements.

All four GAs contain suitable habitat matrix in the form of rural areas with a numerous water bodies within close proximity (< 500 metres). This should provide both breeding and non-breeding water bodies sufficiently close to allow GGBF to migrate between them and with adjacent vegetation and shelters that they would allow them to successfully do so. These surrounding areas would also provide over-wintering sites and vegetated areas to provide supplies of invertebrates as food for GGBF. The presence of the Plague Minnow would potentially limit the presence of the GGBF in some or most areas, but it is not possible to determine the extent of this effect without visiting the water bodies and the GGBF can still inhabit sites with the Plague Minnow where there is suitable emergent vegetation and where fish free ephemeral sites develop, which could be in most places across the broad landscape.

Habitat only is likely to be unsuitable where there is a matrix of roads of more than single carriageways in both directions. Larger roads represent barriers in both distances that frogs must cover in exposed conditions and carry volumes of traffic that may prohibit the successful crossing by frogs. The more rural areas of the GAs generally do not have many or even any such roads traversing them and so they should provide a suitable environment for the GGBF in at least this respect.

Species polygons

Predicted polygons for the GGBF are provided only for the GMGA (Figure 7) and GPEC (Figure 8). This is because it is considered that only these two areas may contain extant populations of the GGBF with evidence to demonstrate that they have historically been present within the two GAs. The species polygon that indicates the distribution of GGBF populations within the GA, with the polygons being based on the presence of known populations or recent records. The polygon covers the locations of known records, the riparian zone joining those records and a buffer of 1000 m around that riparian zone and records that is the area deemed likely for GGBF to use for foraging, shelter, breeding and as migratory habitat as they move between water bodies and riparian areas. The extent that these overlap with proposed development areas are also indicated.

As noted before, the figures also include highlighted areas that have been designated as potential migratory corridors for GGBF should populations return to the landscape in the future. These represent areas that GGBF would be predicted to use to move around and recolonise the GAs, if this was able to take place. They essentially follow the known riparian strips associated with rivers or where a series of identified water bodies provide the opportunity for GGBF to migrate through a series of stepping stones. These corridors do not represent current habitat that needs consideration under the Biocertification process and they do not constitute polygons of habitat for the GGBF. Rather they have been noted simply for consideration for broader scale conservation planning, should that be of interest, under the premise that the GGBF will ultimately recover from its current declined state (through disease immunity or behavioural changes) that will allow them to recolonise suitable habitats. I note that I have included a broad corridor of non-riparian area as a potential movement corridor on the western side of the WGA, as the loop of the river provides for a broad patch of land that may provide a means of the GGBF migrating across that patch if it were ever to recover.

Estimate of area of habitat

The estimated area of suitable GGBF habitat in each GA (the species polygon) and the area of this habitat expected to be impacted by development (falls within the footprint) is provided in Table 2. The latter is minimal and only exists for the GPEC.

Realistically all of the rural landscape contains suitable habitat with a range of suitable breeding ponds providing habitat for the GGBF. However, it is expected the GGBF will only persist in areas with known populations and that can maintain a metapopulation structure. Sufficient historic survey has been conducted to conclude that additional significant populations are not now present within the GAs.

Table 2. Areas of identified suitable habitat and area of habitat within each Growth Area

Growth Area	**Area of habitat (ha)**	**Area within development footprint (ha)**
Wilton	0	0
Greater Macarthur	238.8	0
Western Sydney Aerotropolis	0	0
Greater Penrith to Eastern Creek	1421.6	13.1

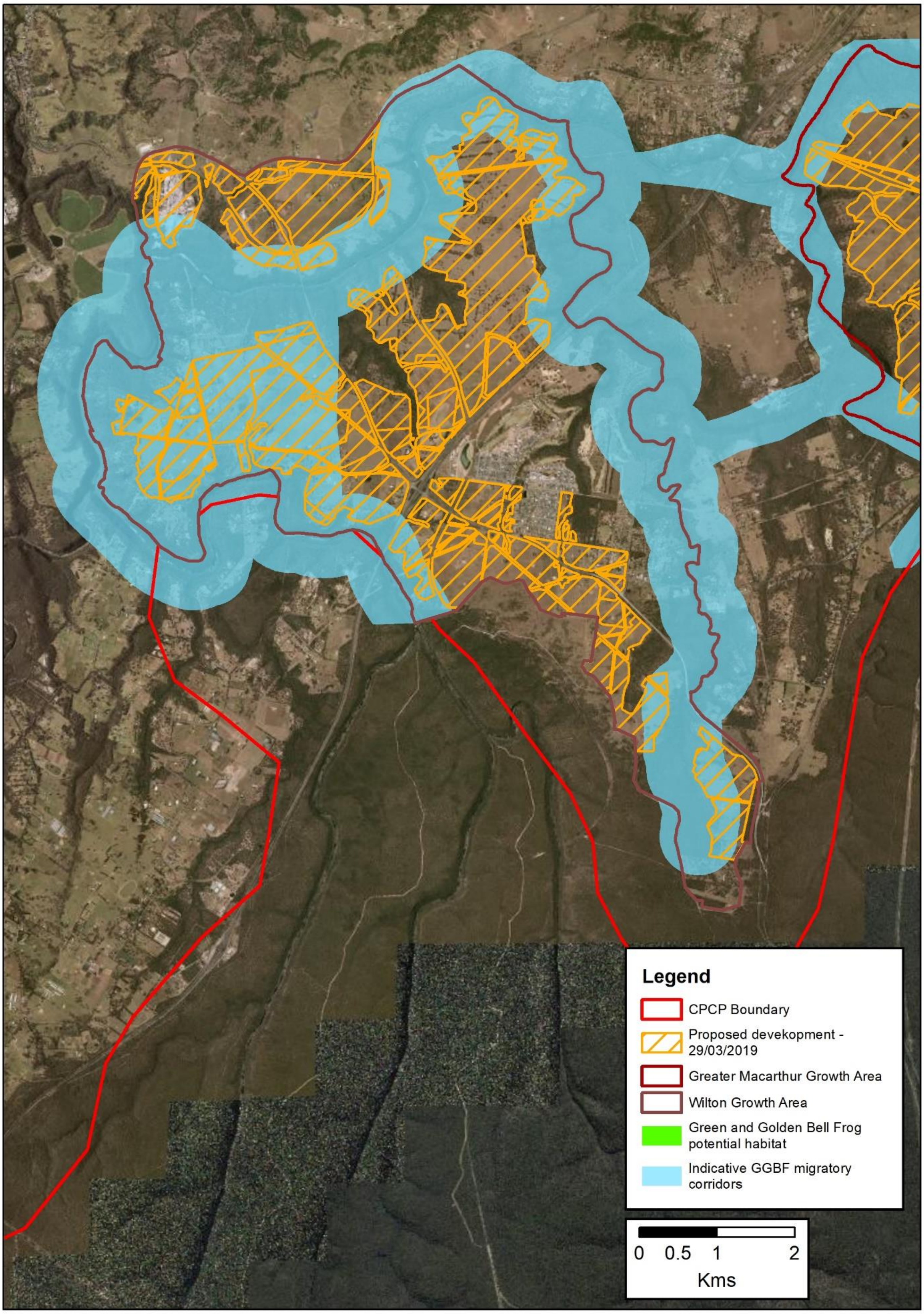


Figure 6. Polygon and potential migratory habitat for the Green and Golden Bell Frog relative to the Wilton Growth Area (Map provided by DPE)

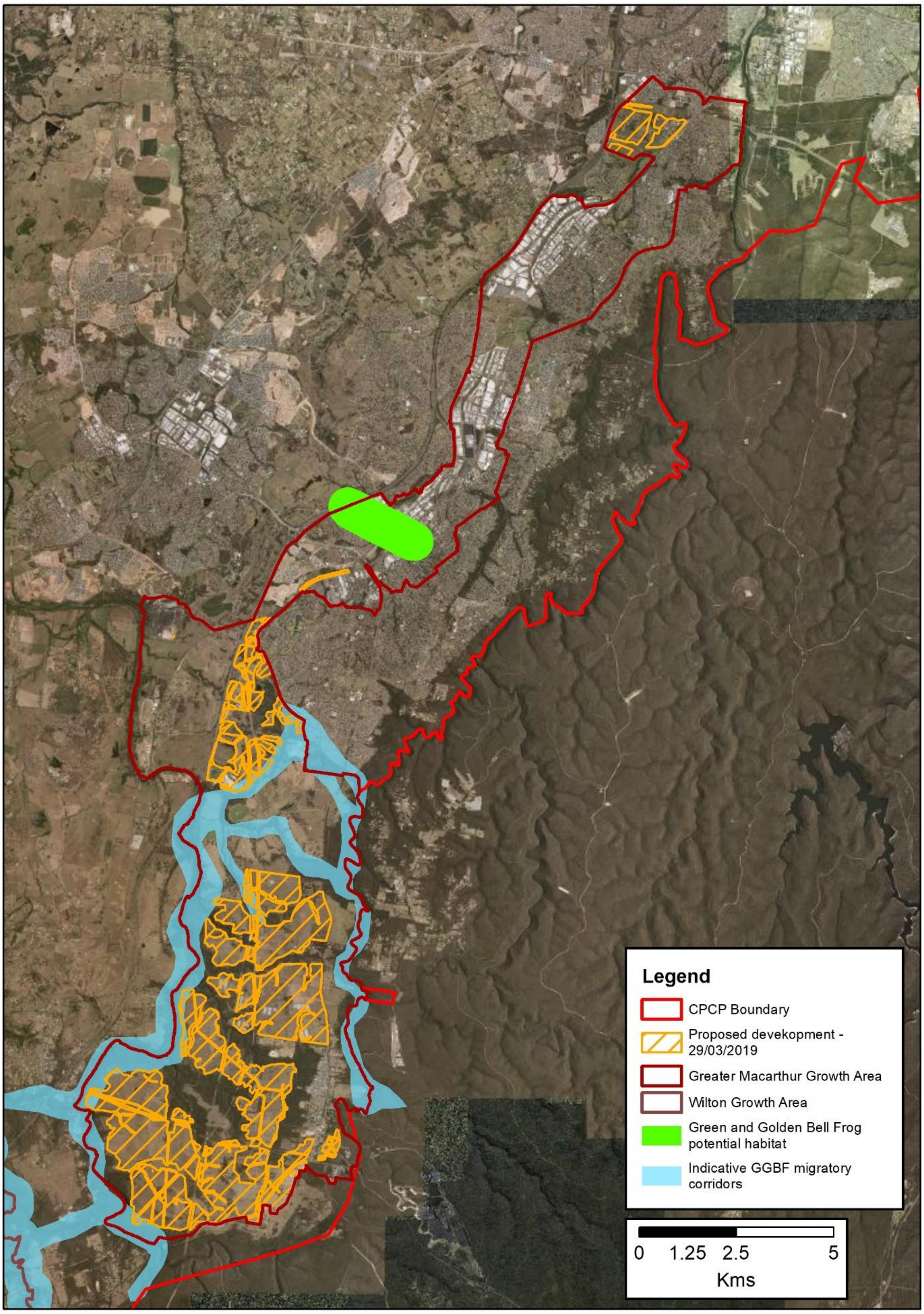


Figure 7. Polygon for Green and Golden Bell Frog habitat within the Greater Macarthur Growth Area (Map provided by DPE)

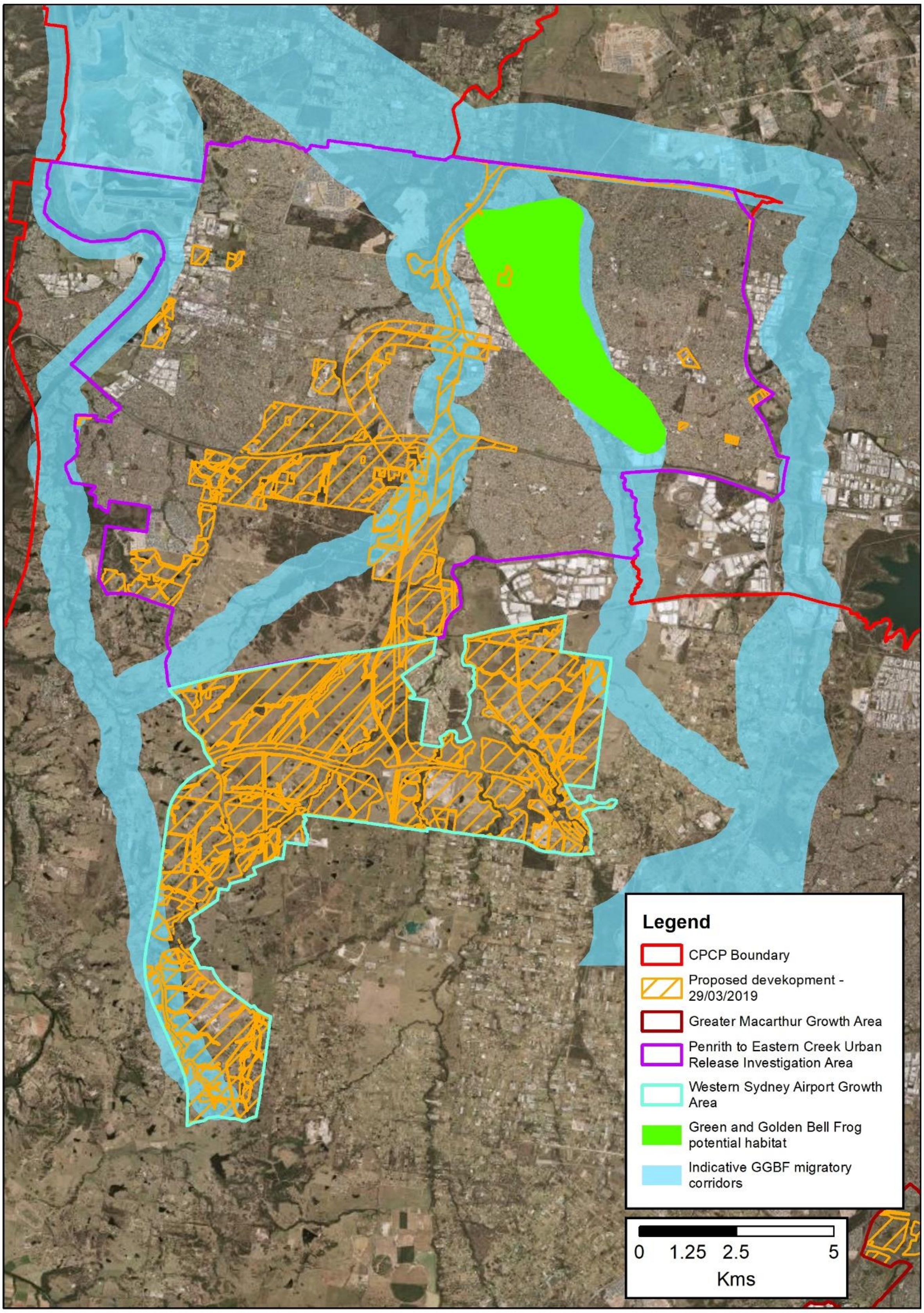


Figure 8. Habitat polygons and identified likely future migration corridors for the Green and Golden Bell Frog relative to the Greater Penrith to Eastern Creek and Western Sydney Aerotropolis Growth Areas (Map provided by DPE)

5 Information used in this assessment

Data, maps and information provided by DPE and project partners are noted through the report

6 References

Alford, R.A. and Richards, S.J. 1999. Global amphibian declines: A problem in applied ecology. Annual Review of Ecology and Systematics 30: 133-165.

Anstis, M. 2013. *Tadpoles and Frogs of Australia*. New Holland Publishers, Sydney.

Barker, J., Grigg, G.C. and Tyler, M.J. 1995. *A Field Guide to Australian Frogs*. Surrey Beatty and Sons, Chipping Norton.

Copland, S.J. 1957. Australian tree frogs of the genus *Hyla*. Proceedings of the Linnean Society of New South Wales 82: 9–108.

Christy, M.T. 2001. *The ecology and conservation biology of the green and golden bell frog Litoria aurea (Lesson 1829) (Anura: Hylidae)*. PhD thesis, University of Sydney.

Christy, M. and Dickman, C. 2002. Effects of salinity on tadpoles of the green and golden bell frog (*Litoria aurea*). Amphibia-Reptilia 23: 1-11.

Cogger, H.G. 2014. *Reptiles and Amphibians of Australia* (seventh edition). CSIRO Publishing, Victoria.

Courtice, G.P. and Grigg, G.C. 1975. A taxonomic revision of the *Litoria area* complex (Anura: Hylidae) in southeastern Australia. Australian Zoologist 18: 149-63.

Darcovich, K. and O'Meara, J. 2008. An Olympic legacy: Green and golden bell frog conservation at Sydney Olympic Park 1993–2006. Australian Zoologist 34: 236–248.

Department of Environment and Conservation (DEC) 2005. *Draft Recovery Plan for the Green and Golden Bell Frog (Litoria aurea)*. DEC NSW, Hurstville, NSW.

Daly, G. 2014. From rags to riches and back again: fluctuations in the green and golden bell frog *Litoria aurea* population at Nowra on the south coast of New South Wales. Australian Zoologist 37: 157-172.

Department of Environment, Climate Change and Water 2010a. Cumberland Plain Recovery Plan. NSW Department of Environment, Climate Change and Water, Sydney.

Department of Environment, Climate Change and Water 2010b. Report on the Methodology for Identifying Priority Conservation Lands on the Cumberland Plain. NSW Department of Environment and Climate Change, Sydney.

Fletcher, J.J. 1889. Observations on the oviposition and habits of certain Australian batrachians. Proceedings of the Linnean Society of New South Wales 4: 357-387.

Freudenberger D., Noble J. and Morton S. 1997. *A Comprehensive, Adequate and Representative Reserve System for the Southern Mallee of NSW: Principles and Benchmarks*. A consultancy report prepared for the NSW Department of Land and Water Conservation and the Southern Mallee Regional Planning Committee.

Gillespie, G.R., Osborne, W.S. and McElhinney, N.A. 1995. *The Conservation Status of Frogs in the Australian Alps: a Review*. A Report to the Australian Alps Liaison Committee.

Gillespie, G.R. 1996. Distribution, habitat and conservation status of the green and golden bell frog *Litoria aurea* (Lesson 1829) (Anura:Hylidae) in Victoria. Australian Zoologist. 30: 199-207.

Goldingay, R.L. 1996. The green and golden bell frog *Litoria aurea* – from riches to ruins: conservation of a formerly common species. Australian Zoologist 30: 248-256.

Goldingay, R.L., Parkyn, J., Newell D.A. 2017. No evidence of protracted population decline across 17 years in an unmanaged population of the green and golden bell frog in north-eastern New South Wales. Australian Journal of Zoology 65: 87-96.

Hamer A.J. 2018. Accessible habitat and wetland structure drive occupancy dynamics of a threatened amphibian across a peri-urban landscape. Landscape and Urban Planning 178: 228-237.

Hamer A.J. and Mahony, M.J. 2007. Life history of an endangered amphibian challenges the declining species paradigm. Australian Journal of Zoology 55: 79-88.

Hamer, A.J., and Mahony, M.J. 2010. Rapid turnover in site occupancy of a pond-breeding frog demonstrates the need for landscape-level management. Wetlands 30: 287-299.

Hamer, A.J., Lane, S.J. and Mahony, M.J. 2002. Management of freshwater wetlands for the endangered green and golden bell frog (*Litoria aurea*): roles of habitat determinants and space. Biological Conservation 106: 413-424.

Hamer, A.J., Lane, S.J. and Mahony, M.J. 2008. Movement patterns of adult green and golden bell frogs *Litoria aurea* and the implications for conservation management. Journal of Herpetology 42: 397– 407.

Kearney, B.D., Byrne, P.G. & Reina, R.D. 2012. Larval tolerance to salinity in three species of Australian Anuran: An indication of saline specialisation in *Litoria aurea*. PLoS One 7(8), e43427.

Lemckert, F.L. 1996. Surveys for the green and golden bell frog, *Litoria aurea*, by the State Forests of New South Wales. *Australian Zoologist* 30: 208-213.

Lemckert, F.L. 2004. Variations in anuran movements and habitat use: implications for conservation. Applied Herpetology 1: 165-181.

Lemckert, F.L. and Mahony, M.J. 2008. Core calling periods of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3: 71-76.

Lemckert, F.L., and Mahony, M.J. 2018. The status of Decline and Conservation of Frogs in Temperate Coastal South-eastern Australia. Pp 59-72 In: *Amphibian Biology Volume 11 - Conservation and Decline of Amphibians: Eastern Hemisphere (Australia, New Zealand and Pacific Islands)*. H. Heatwole and J. Rowley (Eds.). CSIRO Publishing, Melbourne.

Lemckert, F.L. 2017. *Surveys for the Green and Golden Bell Frog at Meroo for the Saving our Species Research Program*. Report to NSW Office of Environment and Heritage, Sydney.

Mahony, M. 1999. Review of the declines and disappearances within the bell frog species group (*Litoria aurea* species group) in Australia. Page(s) 81–93 In: *Declines and disappearances of Australian frogs*. A. Campbell (Ed.). Canberra: Environment Australia.

Mahony, M.J., Hamer, A.J., Pickett, E.J., McKenzie, D.J., Stockwell, M.P. Garnham, J.I., Keely, C.C., Deboo, M., O'Meara, J., Pollard, C.J., Clulow, S., Lemckert, F.L., Bower, D.S., and Clulow, J. 2013. Identifying conservation and research priorities in the face of uncertainty: a review of the threatened bell frog complex in eastern Australia. *Herpetological Conservation and Biology* 8: 519-538.

Moore, J.A. 1961. The frogs of eastern New South Wales. Bulletin of the American Museum of Natural History 121: 149-386.

Muir, G. 2008. Design of a movement corridor for the Green and Golden Bell Frog *Litoria aurea* at Sydney Olympic Park. Australian Zoologist 4: 297-302.

Osborne, W., Patmore, S., Hunter, D. and Pietsch, R. 2008. Preliminary observations on a highly-restricted tableland population of green and golden bell frogs on the Upper Molonglo River, NSW. Australian Zoologist 34: 271–284.

Penman, T.D. and Lemckert F.L. 2008. Monitoring the green and golden bell frog: current problems and an alternative approach. *Australian Zoologist* 34: 373-378.

Puschendorf, R., Hoskin, C.J., Cashins, S.D,, McDonald, K., Skerratt, L.F., Vanderwal, J. and Alford, R.A. 2011. Environmental refuge from disease-driven amphibian extinction. Conservation Biology 25: 956–964.

Pyke, G. and White, A. 2001. A review of the biology of the green and golden bell frog *Litoria aurea*. Australian Zoologist 31: 563–598.

Pyke, G.H., White, A.W., Bishop, P.J. and Waldman, B. 2002. Habitat-use by the green and golden bell Frog *Litoria aurea* in Australia and New Zealand. Australian Zoologist 32: 12-31.

Stockwell, M.P., Clulow, J. and Mahony, M.J. 2012. Sodium chloride inhibits the growth and infective capacity of the amphibian chytrid fungus and increases host survival rates. PloS one: 7, e36942.

Threlfall, C.G., Jolley, D.F., Evershed, N., Goldingay, R.L. and Buttemer, W.A. 2008. Do green and golden bell frogs *Litoria aurea* occupy habitats with fungicidal properties? Australian Zoologist 34: 350-360

Tyler, M.J., and Knight, F. 2009. *Field Guide to the Frogs of Australia*. CSIRO Publishing, Collingwood, Victoria.

Valdez, J.W., Stockwell, M.P., Klop-Toker, K., Clulow, S., Clulow, J., and Mahony, M.J. 2015. Factors driving the distribution of an endangered amphibian toward an industrial landscape in Australia. Biological Conservation 191: 520-528.

van de Mortel, T. and Goldingay, R. 1998. Population assessment of the endangered green and golden bell frog *Litoria aurea* at Port Kembla, New South Wales. Australian Zoologist 30: 398-404.

West Australian Local Government Association 2004. *Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region*. West Australian Local Government Association, Perth.

Wassens, S., Hall, A. and Spencer, J. 2017. The effect of survey method on the detection probabilities of frogs and tadpoles in large wetland complexes. Marine and Freshwater Research 68: 686-696.

West M, Hamer A, McCarthy M. 2017. *Litoria aurea (green and golden bell frog) Occupancy Analysis Report 2016/2017*. The University of Melbourne, Parkville, Victoria.

White, A.W. 1995. Disappearing frogs. Australian Zoologist 30: 48-56.

White, A.W. and Pyke, G.H. 1996. Distribution and conservation status of the green and golden bell frog *Litoria aurea* in New South Wales. Australian Zoologist 30: 177–189.

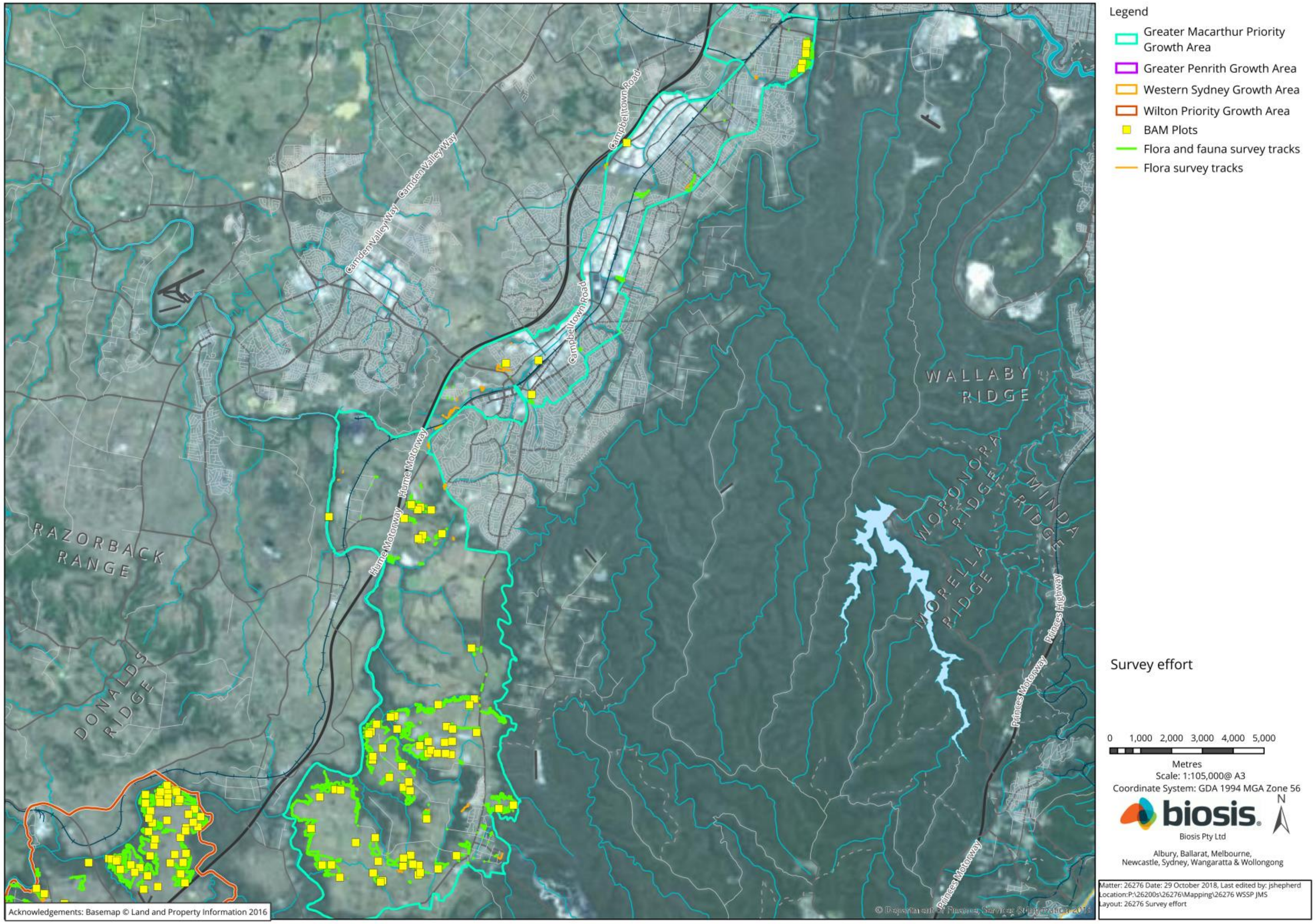
White, A.W. and Pyke, G.H. 1999. Past distribution of *Litoria aurea* and *Litoria castanea* in the Bathurst-Orange Area of New South Wales. Herpetofauna 29: 2-9.

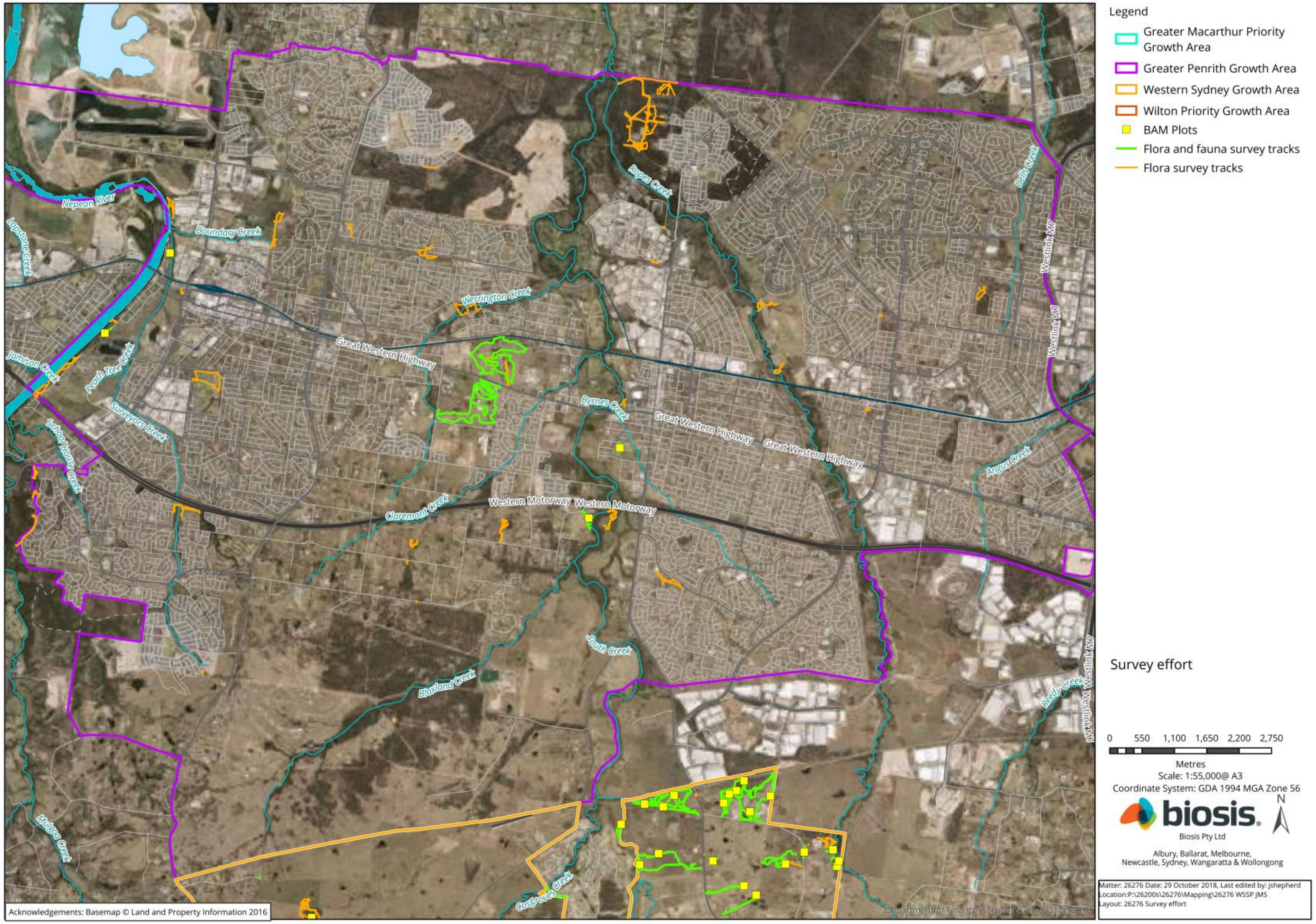
White, A.W. and Pyke, G.H. 2008. Green and golden bell frogs in New South Wales: current status and future prospects. Australian Zoologist 34: 319-333.

7 Appendices

Appendix 1: Curriculum vitae

Appendix 2: Maps showing survey effort

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Greater Penrith Growth Area
Western Sydney Growth Area
Wilton Priority Growth Area
BAM Plots
Flora and fauna survey tracks
Flora survey tracks
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Boundary Creek
Lapstone Creek
Werrington Creek
Ropes Creek
Bells Creek
Westlink M7
Great Western Highway
Jamison Creek
Peach Tree Creek
Surveyors Creek
School House Creek
Byrnes Creek
Angus Creek
Claremont Creek
Western Motorway
South Creek
Blaxland Creek
Reedy Creek
Mulgoa Creek
Cosgroves Creek
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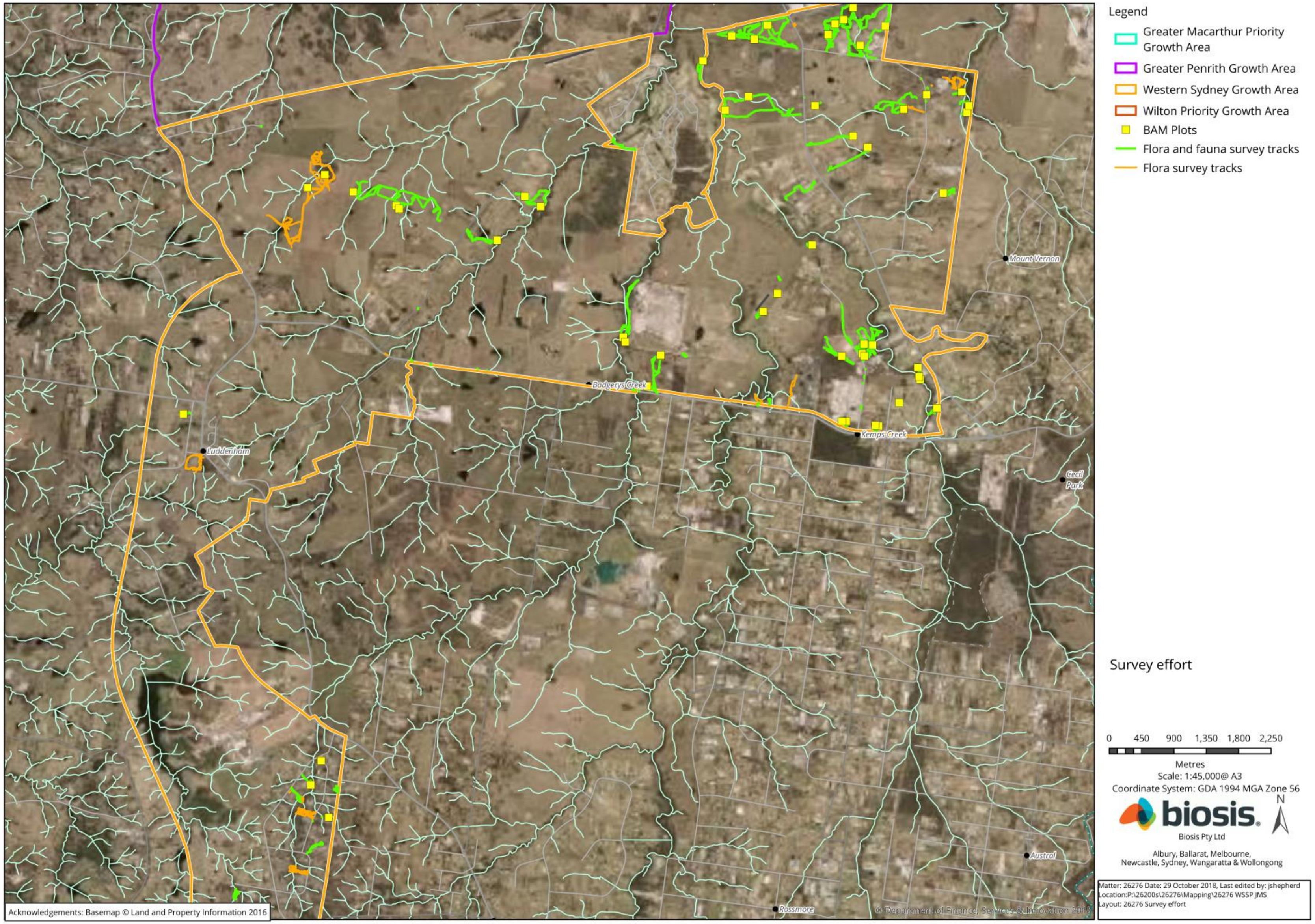

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Badgerys Creek
Kemps Creek
Luddenham
Cecil Park
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Acknowledgements: Basemap © Land and Property Information 2016
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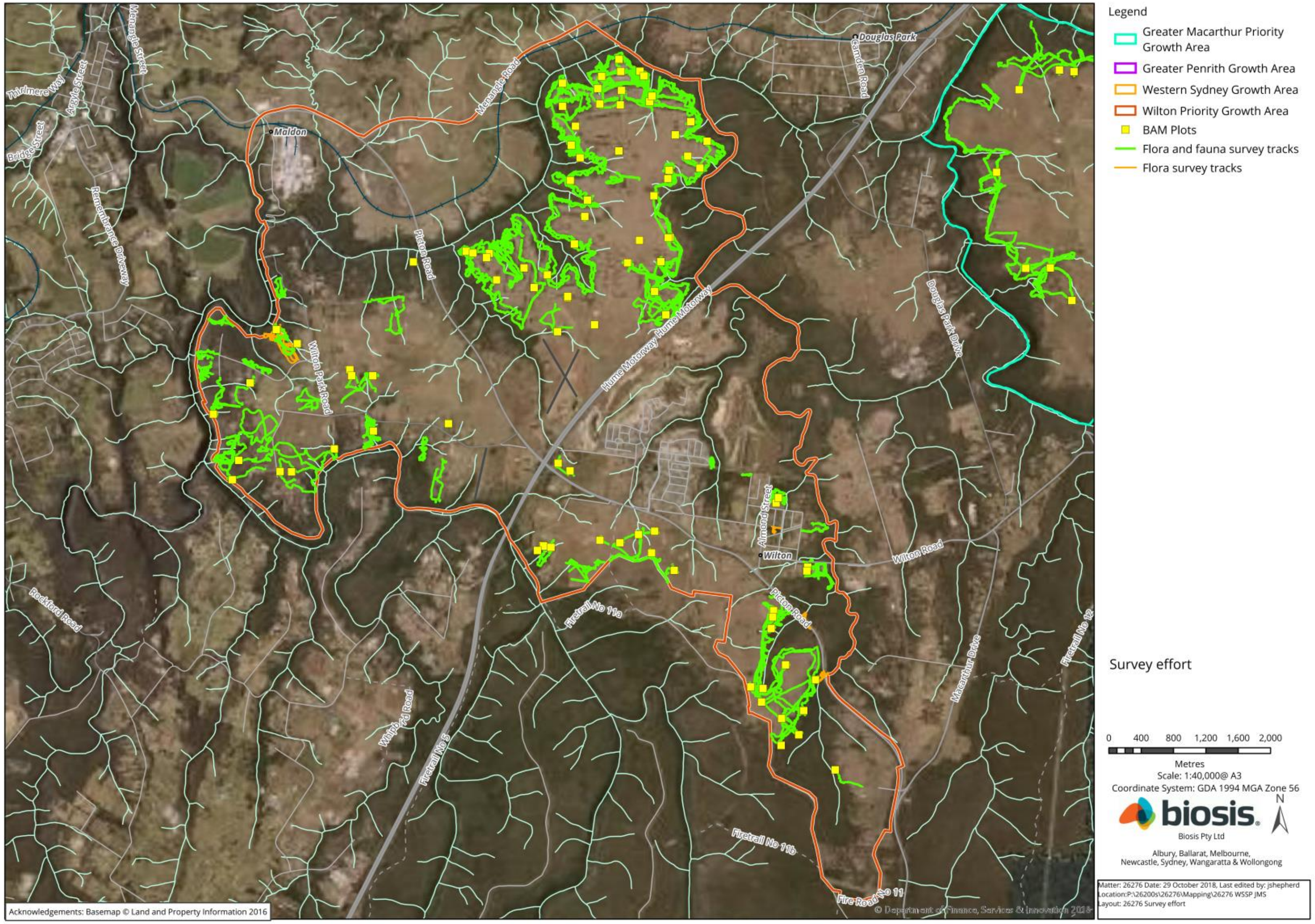
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Douglas Park Drive
Almond Street
Wilton
Wilton Road
Picton Road
Firetrail No 11a
Rockford Road
Firetrail No 5
Macarthur Drive
Firetrail No 11b
Fire Road No 11
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Legend
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Member of the Surbana Jurong Group

Dr Francis Lemckert

Principal Environmental Scientist - Environment

Years of Industry Experience

- 30+ Years

Qualifications, Training and Memberships

- PhD University of Newcastle
- Master of Science, University of Sydney
- Bachelor of Science, University of Sydney
- Australian Society of Herpetologists (Past-President, Vice-President and Secretary)
- NSW Declining Frogs Working Group (Secretary)
- Amphibian Specialist Group of the IUCN
- Conjoint University of Newcastle, Australian Museum

Key Skills and Competencies

- Fauna and flora monitoring
- Fauna survey
- Fauna research
- Expert reporting under the BAM
- Specialist fauna knowledge
- Impact and ecological assessment
- Wildlife survey training
- Government agency consultation
- Herpetology

Professional Overview

Frank has been a professional scientist since 1992, specialising in the ecology and management of threatened vertebrates, particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland) establishing long-term research programs into the management of forest fauna and developing strategies to mitigate the impacts of human disturbances. His specialty is the ecology and management of frogs, but he also has detailed knowledge of threatened reptiles and microbat management, and has conducted hundreds of surveys for all of the vertebrate groups. Frank has worked extensively with the NSW state and federal Governments on varying issues of fauna management and is experienced in the application of NSW and federal legislation regarding the conservation of threatened species and communities. At a technical level he has participated in the preparation of a draft NSW/National recovery plan for *Heleioporus australiacus*, expert advice and review on Impact Assessment Guidelines for the *Litoria aurea*, *Litoria raniformis* and *Litoria olongburensis* and a review of the National Recovery Plan for the stream frogs of SE Queensland. He also assisted in assessing the Vic Forests fauna survey and assessment program for threatened fauna. Frank has also worked extensively with the Australian Biological Resources Study to undertake biodiversity surveys across NSW and into far southern Queensland.

Frank has a long history in fauna monitoring and management having developed broad scale monitoring strategies for vertebrate fauna when at NSW DPI. He completed a review of the methods available to undertake frog monitoring, including linking in with current river monitoring programs and developed a pilot reptile survey program for the Pilliga State Forests. He monitoring works included using both traditional population counts and consideration of more recently developed presence-absence modelling and his works included using mark-recapture techniques. He has published papers on optimal monitoring methods and its analysis and has been an author on more than 90 peer-reviewed national and international scientific publications and has undertaken presentations at more than 50 conferences across the world.

Finally, Frank has had a long history in wildlife management education, having been the lead on the wildlife training school program conducted in NSW continuously since 1993. This program has provided in-depth training on fauna and flora survey, management and identification in all parts of NSW and has been attended by more than 1000 people including government regulators, consultants and NGO staff. The courses have emphasised practical hands-on demonstrations of survey techniques to demonstrate the most effective use of the different traps and monitoring methods and approaches available and included recognised experts on the target groups. Information lessons also included talks on the ecology and management of target threatened species for any given area and course.

Relevant Project Experience

Mona Vale Road Upgrades

In regards to Mona Vale Road, Frank worked as a sub-contractor to Ecosure to provide expert surveys and technical advice on the survey and impact assessment for the Red-crowned Toadlet and Giant Burrowing Frog for both the Mona Vale Road East and Mona Vale Road West upgrade projects. This provided the first records for the Giant Burrowing Frog (*Heleioporus australiacus*) in that area and also recorded several locations for the Red-crowned Toadlet (*Pseudophryne australis*) as well as records of the Eastern Pygmy Possum (*Cercartetus nanus*) as part of nocturnal surveys. He also provided reviews of impact assessments for the Mona Vale Road west report covering all aspects of the surveys and the assessments for all of the threatened fauna. It also considered the impacts of fragmentation of the proposed upgrade and methods to mitigate impacts.

Warringah Council Crown Lands surveys

Between 2011-2013 Frank also completed a detailed reptile and frog survey of the available crown lands in the Warringah Council (now part of Northern Beaches Council) Local Government Area. This included targeted surveys for all reptiles and frogs likely to be present and provided detailed information to the Council to inform planning of development proposals into the future. These surveys provided additional record sites for the Giant Burrowing Frog and Red-crowned Toadlet in the LGA.

Saving our Species targeted surveys – Green and Golden Bell Frog (*Litoria aurea*)

Frank was engaged by the NSW Office of Environment and Heritage to undertake four rounds of targeted surveys for the Green and Golden Bell Frog in the area around Meroo Lake on the south coast of NSW. This required repeat surveys of transects to count the frogs and the collection of site data to be used in a broader analysis of Green and Golden Bell Frog habitat preferences. Frank completed the surveys successfully, locating hundreds of individuals and provided a report on time as required.

Princes Highway upgrade at South Nowra

Frank completed targeted and monitoring surveys and EPBC and EP&A/TSC Act assessments for the Green and Golden Bell Frog and hollow using fauna and was the appointed Project Herpetologist. He also produced two EPBC Referrals for the Green and Golden Bell Frog, guided the development of mitigation works, produced fauna rescue guidelines and advised on the ongoing scientific monitoring program.

Dee Why Town Centre Bat Management

Frank was the technical lead on several projects managing the impacts of drainage culvert upgrades on threatened microbats present in Dee Why. This included the identification of bats present, mapping of bat roosting sites, completion of an SIS and ongoing monitoring of the bats through the works to ensure impacts remained within acceptable limits. The bats present proved to be Eastern Bentwing-bats (*Miniopterus schreibersii oceanensis*) and the works times to minimise impacts at sensitive times for the bats.

Pacific Highway upgrade for Oxley Highway to Kempsey and Frederickton to Eungai

Frank has been involved in a diversity of fauna related work for this project including population and mitigation monitoring surveys for the Giant Barred Frog (*Mixophyes iteratus*) and Green-thighed Frogs (*Litoria brevipalmata*) and provided review and quality assurance for reports on monitoring for Giant Barred Frogs, Green-thighed Frogs, Brush-tailed Phascogales, Squirrel Gliders, Hairy Joint Grass, *Maundia triglochinoides*, Koalas and Glossy Black Cockatoos. He also reviewed works on water quality, underpass use, fauna crossings, nest box use and road-kill.

Expert Witness Somersby land clearing

In 2016 Frank provided expert advice to DoEE on the potential impacts of alleged illegal land-clearing on the Giant Burrowing Frog at Somersby on the NSW Central Coast. This includes a site search to locate the presence of tadpoles (located in the central stream) and an assessment of the value of the cleared habitat to this frog and the likely long-term effects on the local population.

Threatened Frog Monitoring and Modelling – Hornsby Council

In 2015-2016 Frank completed surveys of known record sites for the Red-crowned Toadlet and the Giant Burrowing Frog in the Hornsby Local Government Area to provide data on the location of these two species within areas adjacent to areas of housing and in undeveloped locations. The data provided the basis for an ongoing monitoring program to be carried out by Council and assess if housing was impacting the local water quality and the frogs. Habitat modelling was also produced for the Giant Burrowing Frog, allowing Council to better target assessment requirements for development applications.

Expert review - Pacific Highway threatened frog monitoring program

Frank was commissioned to provide an expert review of the proposed frog monitoring program to assess the impacts and success of mitigation for approximately 130 km of the Pacific Highway in northern NSW. This expert review considered the thoroughness and technical relevance of the proposed program and covered Giant Barred Frogs, Green-thighed Frogs, Wallum Sedge Frogs Brush-tailed Phascogales, Squirrel Gliders, Hairy Joint Grass, *Maundia triglochinoides*, Koalas and Glossy Black Cockatoos. He also reviewed works on water quality, underpass use, fauna crossings, nest box use and road-kill.

Forests NSW fauna monitoring strategy

Between 2008 and 2011 Frank assisted in developing a state-wide fauna monitoring strategy for Forests NSW, concentrating on the herpetological component. This lead to a working paper on options for frog monitoring and undertaking a pilot program for reptile monitoring in the Pilliga Forests of northwest NSW.

Selected Publications

Fitzgerald, M., Shine, R. & Lemckert, F. 2002. Spatial ecology of arboreal snakes (*Hoplocephalus stephensii*, Elapidae) in an eastern Australian forest. Austral Ecology 27: 537-545.

Hamer, R., Lemckert, F. & Banks, P. 2011. Adult frogs are sensitive to the predation risks of olfactory communication. Biology Letters 7: 361-363.

Hero, J-M., Morrison, C., Gillespie, G., Roberts J.D., Newell, D., Meyer, E., McDonald, K., Lemckert, F., Mahony, M., Osborne, W., Hines, H., Richards S., Hoskin, C., Clarke, J., Doak, N. & Shoo, L. 2006. Overview of the conservation status of Australian frogs. Pacific Conservation Biology 12: 313-320.

Lemckert, F. 2004. The biology and conservation status of the heath frog, *Litoria littlejohni*. Herpetofauna 34: 99-104.

Lemckert, F. 2010. Habitat relationships and presence of the threatened heath frog *Litoria littlejohni* (Anura: Hylidae) in central New South Wales, Australia. Endangered Species Research 11: 271-278.

Lemckert, F. & Mahony, M. 2008. Core calling periods of the frogs of temperature New South Wales, Australia. Herpetological Conservation and Biology 3: 71-76.

Lemckert, F. and Penman, T. (2012). Climate change and Australia's frogs: how much do we need to worry? In: Wildlife & Climate Change: Towards Robust Conservation Strategies for Australian Fauna (D. Lunney and P. Hutchings eds.). Pp. 92-97. Royal Zoological Society of New South Wales, Mosman, N.S.W.

Lemckert, F., Haywood, A. & Brassil, T. 2006. Correlations between frogs and pond attributes in central New South Wales, Australia: What makes a good pond? Applied Herpetology 3: 67-82.

Lemckert, F. & Mahony, M. 2008. Core calling seasons of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3: 71-76.

Lemckert, F.L. & Morse, R. 1999. Frogs in the timber production forests of the Dorrigo Escarpment in northern New South Wales: An inventory of species present and the conservation of threatened species. In: Declines and Disappearances of Australian Frogs (A. Campbell ed.). Pp 72-80. Environment Australia, Canberra, Australia.

Lemckert, F., Hecnar, S.J. & Pilliod, D.S. 2012. Loss and modification of habitat. In: Conservation and Decline of Amphibians: Ecological Aspects, Effect of Humans, and Management (H. Heatwole and J.W. Wilkinson eds.) - Amphibian Biology, Volume 10. Pp 3291-3342. Surrey Beatty & Sons, Baulkham Hills, Australia.

Lemckert, F., Penman, T. & Haywood, A. 2011. Adaptive monitoring using the endangered northern corroboree frog (*Pseudophryne pengilleyi*) as a case study. Proceedings of the International Academy of Ecology and Environmental Sciences 1: 87-96.

Lemckert, F., Penman, T. & Mahony, M. J. 2013. Relationship of calling intensity to micrometeorology in pond breeding frogs from central eastern New South Wales. Proceedings of the International Academy of Ecology and Environmental Sciences, 3 (2), 170-180.

Lemckert, F., Brassil, T., Kavanagh, R. & Law, B. 2006. Trapping small mammals for research and management: how many die and why? Australian Mammalogy 28: 201–207.

Mahony, M.J., Hamer, A.J., Pickett, E.J., McKenzie, D.J., Stockwell, M.P., Garnham, J.I., Keely, C.C., Deboo, M., O'Meara, J., Pollard, C.J., Clulow, S., Lemckert, F.L., Bower, D.S.& Clulow, J. 2013. Identifying conservation and research priorities in the face of uncertainty: a review of the threatened bell frog complex in eastern Australia. Herpetological Conservation and Biology 8: 519-538.

Penman, T.D., Lemckert, F.L. & Mahony, M.J. 2008. Spatial ecology of the giant burrowing frog (*Heleioporus australiacus*): implications for conservation prescriptions. Australian Journal of Zoology 56: 179-186.

Penman, T.D., Mahony, M.J., Towerton, A.L. & Lemckert, F. 2005. Bioclimatic analysis of disjunct populations of the giant burrowing frog, *Heleioporus australiacus*. Journal of Biogeography 32: 397-405.

Slatyer, C., Rosauer, D. & Lemckert, F. 2007. An assessment of endemism and species richness patterns in the Australian Anura. Journal of Biogeography, 34: 583–596.

Waters, C.M., Penman, T.D., Hacker R.B., Law, B., Kavanagh, R.P., Lemckert, F. & Alemseged, Y. 2013. Balancing trade-offs between biodiversity and production in the re-design of rangeland landscapes. The Rangeland Journal 35: 143-154.

Expert report – *Grevillea juniperina* subsp. *juniperina*

Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas, Peter H. Weston, June 2018

Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Western Sydney Aerotropolis Growth Area, and Greater Penrith to Eastern Creek Urban Release Area, Peter H. Weston, June 2018

Strategic assessment for Cumberland Plain Conservation Plan

Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas

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1. Introduction

PURPOSE

I was engaged by the Department of Planning and Envionment in early June 2018, to produce an expert report on the distribution and abundance of *Grevillea juniperina* subsp. *juniperina* (Proteaceae) within the proposed Greater Macarthur and Wilton Growth Areas (collectively termed "the study area"). The aim of this exercise was to assess whether *Grevillea juniperina* subsp. *juniperina* (the "focal taxon") is native to either of the Growth Areas and, if so, to assess where suitable habitat is located and to estimate the numbers of plants of *Grevillea juniperina* subsp. *juniperina* that are likely to occur there.

According to Section 6.5.2 of the Biodiversity Assessment Method, an expert report must:

- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- estimate the number of individuals or area of habitat (whichever unit of measurement applies to the species/individual) for the biodiversity certification assessment area, including a description of how the estimate was made
- demonstrate what information was considered, rejected and discounted in relation to the determination made in the expert report, and
- identify the expert and provide evidence of their expert credentials.

PROJECT CONTEXT

The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney, including the two growth areas that define the geographic scope of this report: the Greater Macarthur Growth Area and the Wilton Growth Area. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

STUDY AREA

The Greater Macarthur and Wilton Growth Areas are located in the south western part of the Sydney Metropolitan Area, between latitudes 33°57'29"S and 34°16'44"S and longitudes 150°37'12"E and 150°54'47"E.

CREDENTIALS OF EXPERT

I prepared this report as an independent botanical consultant but I am also currently an Honorary Research Associate at the at the New South Wales state herbarium (the National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust). In 2016, I retired from my role as a Senior Principal Research Scientist at the state herbarium, having worked there since 1982 as a Systematic Botanist and as curator of the herbarium's collections of specimens of Proteaceae (including *Grevillea juniperina*) (see my *Curriculum Vitae*, attached). I now work, part-time at the National Herbarium of New South Wales as an Honorary Research Associate. I have published, either as sole author or as a co-author, 50 papers on the systematics and ecology of the Proteaceae in the peer-reviewed scientific literature, including the most comprehensive phylogenetic analysis of the genus *Grevillea* yet published (Mast *et* al. 2015). As curator of Proteaceae at the state herbarium, I examined all specimens of *Grevillea juniperina* subsp. *juniperina* incorporated into the collection between 1982 and 2016. I was invited to contribute to floristic treatments of the Proteaceae for *Flora of New South Wales*, *Flora of Australia*, *Flora of the Perth Region*, *Flora of China*, *Flora of North America*, and to write the treatments of Proteaceae for *Families and Genera of Vascular Plants* and *Flowering Plant Families of the World* (see my *Curriculum Vitae*, attached). I was also asked to conduct a peer review of the essay on the ecology of the Proteaceae that accompanied the "Ecology of Sydney Plants" (Myerscough *et al.* 2000). Throughout my career I have participated in numerous collecting trips in the field, collecting specimens in all Australian states for the state herbarium. In documenting these specimens I had to describe the habitat at each collecting site, including associated plant species, substrate, aspect, degree and kind of disturbance. On some of those trips, I observed and collected *Grevillea juniperina* growing in the wild.

JUSTIFICATION FOR USE OF EXPERT REPORT

Grevillea juniperina subsp. *juniperina* has never been collected within, nor reported as growing as a native, in the study area. However, The OEH Threatened Species Data Collection indicates that *Grevillea juniperina* subsp. *juniperina* has the potential to occur in the following plant communities within the Wilton and Greater Macarthur Growth Areas:

- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain
- 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain

Moreover, a specimen of *G. juniperina* subsp. *juniperina* held by the state herbarium (B. Towle, NSW999291) was collected in June 2017, in a bushland remnant only 3.6 km west of the study area, raising the possibility that suitable habitat for *G. juniperina* subsp. *juniperina* might exist there. If this were so, *G. juniperina* subsp. *juniperina* might once have lived there, or even still exist in the study area as small, unrecorded populations.

Grevillea juniperina subsp. *juniperina* is a perennial shrub that is readily recognised at any time of year by its distinctive vegetative morphology. Conventional surveying would therefore be the most appropriate way to test for its presence, if unlimited access to the study area were allowed. Surveys were undertaken on all areas of land where landowners granted access. However, the survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH 2016) for field traverse surveys due to limitations imposed by land access.

These limitations and the possibility that *G. juniperina* subsp. *juniperina* might be native to the Greater Macarthur and Wilton Growth Areas triggered the need for an expert report.

SPECIES SURVEYS

An initial 726 letters were sent to landholders within the Growth Areas in late 2017. A second letter was sent in March 2018, and targeted door knocking occurred in May 2018. From this, just under 20% of landholders have responded. Surveys were undertaken on all areas of land where landowners granted access. Of the 14,984 hectares within the Wilton and Macarthur Growth Areas, of which 5,385 ha is potential native vegetation that could be impacted by development, DPE has completed surveys across 3,360 hectares (62% of the total survey area). Surveys for *Grevillea juniperina* subsp. *juniperina* were undertaken from November 2017 to May 2018, resulting in no sightings of the species recorded from the survey areas.

2. Species information

SPECIES DESCRIPTION

The following morphological description was produced by merging information from Makinson's (2000) descriptions of the Linearifolia Group, the Speciosa Subgroup, *Grevillea juniperina*, and *Grevillea juniperina* subsp. *juniperina*:

More or less erect to spreading dense divaricate shrub 0.5–1.5 m tall, to 3 m across; major branches appearing subcolumnar (leaves clustered on short lateral branchlets); foliage dense. Branchlets terete, tomentose to villous. Leaves spreading to ascending, often crowded on short lateral branchlets, usually rigid, often dark green with paler veins, entire, narrowly ovate to subulate or linear, angularly deltoid to trigonous in cross-section, 10–22 mm long, 0.6–0.8 mm wide, pungent, needle-like, with dissimilar upper and lower surfaces; upper surface usually with 3–5 longitudinal veins, the midvein and intramarginal veins usually very prominent, sparsely covered with appressed hairs; margins strongly and angularly revolute; lower surface usually fully enclosed, usually densely sericeous or occasionally openly so, rarely glabrous, or open-tomentose; juvenile leaves scarcely broader than adults. Conflorescence terminal, occasionally also axillary and subterminal, usually simple or occasionally 2 (–4)-branched; unit conflorescence erect or slightly decurved, acropetal, subsecund; floral rachis 1–17 mm long. Flowers zygomorphic; torus slightly oblique. with perianth style similar to perianth or a little paler. Perianth densely to openly subsericeous outside with biramous hairs only, bearded inside between 2.5 and 9 mm above base, red, yellow, pale orange, or rarely greenish; tepals remaining coherent over at least the basal third, independently recoiled above (usually the ventral pair more strongly so). Pistil (13–) 20–25 mm long; style glabrous except for minute scattered erect simple hairs extending from back of style-end down at least 3 mm and sometimes almost to ovary, similar colour to perianth or a little paler; pollen-presenter usually oblique or occasionally lateral. Follicles narrowly ovoid or oblong-ellipsoidal, 10–18 mm long, colliculose to smooth, not ridged. Seeds ellipsoidal; margins revolute, a waxy strip on one side extending into a short apical elaiosome.

LIFE CYCLE

Grevillea juniperina subsp. *juniperina* is a perennial, woody plant that germinates from an ellipsoidal seed (Makinson 2000). Germination is significantly enhanced by fire: in a germination experiment, a treatment of smoke plus heat raised the germination percentage from 5-13% observed in the control treatment to 60% (Morris 2000). Seedlings are readily identifiable because their leaves differ minimally from adult leaves and the characteristic growth pattern with abundant lateral short shoots starts when seedlings are less than 10 cm tall. The duration of the juvenile growth phase and the longevity of plants are unknown (Benson & McDougall 2000). Plants are known to be killed by fire (Olde & Marriott 1995, Makinson 2000) and are not known to spread vegetatively (Benson & McDougall 2000), so this taxon can be classed as an obligate seeder. Flowering occurs mainly from August to September, with sporadic flowers appearing in other months (Makinson 2000).The flowers of all subspecies of *Grevillea juniperina* are visited by nectar-feeding birds (Olde & Marriott 1995), which are presumed to be their pollinators (Benson & McDougall 2000). Fertilized carpels develop into follicular fruits that open at maturity, releasing one or two flat seeds, each of which bears a wing-like terminal elaiosome. The seeds are dispersed by wind and also possibly by ants, which may collect the seeds for their edible elaiosomes.

DISTRIBUTION AND ABUNDANCE

Grevillea juniperina subsp. *juniperina* occurs naturally on the northern Cumberland Plain, in Sydney's Western Suburbs, in an area bounded by Scheyville National Park, Agnes Banks Nature Reserve, Mulgoa, Kemps Creek, and Blacktown (OEH Wildlife Atlas, accessed 2/7/2018, Atlas of Living Australia, accessed 3/7/2018). Within this polygon, it is sporadically distributed but often locally abundant in both intact native vegetation and in highly disturbed habitats such as pastures and road cuttings. Collectors' notes on local abundance usually note multiple plants at collecting sites and vary in their estimates of plant numbers from solitary individuals to populations of over 1000. At my site GJ5 (Appendix 1, figure 3), an embankment of a road cutting that is being recolonised by native vegetation, I estimated a population of 5000 plants (including seedlings) in an area of less than one hectare.

A herbarium specimen collected from Gundungarra Reserve, Spring Farm, 4 km north west of the "waist" in the study area (NSW999291), is a geographic outlier that is unlikely to represent a natural occurrence of *Grevillea juniperina* subsp. *juniperina*. Herbarium records that were classed as naturalised occurrences by their collectors, and by R.O. Makinson in curatorial notes, include one from the Melbourne suburb of Heathmont (NSW 834413) and another from Penrose, 67 km south west of the study area (NSW971120).

HABITAT REQUIREMENTS

Makinson (2000: 210) notes that *Grevillea juniperina* subsp. *juniperina* "grows in open dry sclerophyll (eucalypt-dominated) forest or woodland at altitudes of less than about 50 m, in sandy to clay-loam soils and red pseudolateritic gravels." The substrates on which *Grevillea juniperina* subsp. *juniperina* most frequently occurs are sandy to gravelly Cenozoic alluvia, although it also grows on soils derived from Bringelly Shale (Wianamatta Group) and interfaces between these substrates. It has not been recorded on Ashfield Shale, which has a significantly higher phosphate content than Bringelly Shale (Martyn 2018). The vegetation associations in which it has been recorded include

Cumberland Plain Woodland (e.g. figure 1), Castlereagh Ironbark Woodland, Castlereagh Scribbly Gum Woodland (e.g. figure 2) and Shale/Gravel Transition Forest.

Makinson (2000: 211) also notes that "this subspecies shows some ability to colonise mechanically disturbed areas where open ground surface persists; repeated disturbance appears to eliminate it. Populations are often restricted to infrequently managed road verges [e.g. figure 3] or ungrazed semi-cleared land [e.g. figure 4]." At two such disturbed sites where I observed it to be growing (sites GJ2, GJ5, Appendix 1), *Grevillea juniperina* subsp. *juniperina* had vigorously colonised the habitat, with plants representing all life cycle stages from seedlings less than 7 cm tall (e.g. , figure 5) to large, reproductively mature shrubs .

Figure 1. *Grevillea juniperina* subsp. *juniperina* growing in Cumberland Plain Woodland on Bringelly Shale on the eastern side of Park Road, Marsden Park (site GJ1, Appendix 1).

3. Description of the study area

LAND USE HISTORY

The following account is based largely on information gathered from Liston (1988), except where otherwise stated. The first human inhabitants of the study area were Aborigines who moved there many thousands of years ago. People of the Dharawal group were occupants of the study area when Europeans first started to settle in the Sydney Region in 1788. These hunter-gatherers would have managed the grassy woodlands that grew on Wianamatta Shales of the area using fire-stick farming methods (Benson & Howell 1990). In 1816 a large group of them were massacred by soldiers at Appin and by 1830 their community life in the Campbelltown area had disintegrated.

In 1788, six months after Sydney was founded, two bulls and four cows escaped from Sydney Cove. European exploration of the study area commenced in 1795, when 61 naturalised descendants of

Figure 2. *Grevillea juniperina* subsp. *juniperina* growing in Castlereagh Scribbly Gum Woodland on Tertiary alluvium at The Northern Road, Castlereagh Nature Reserve (site GJ3, Appendix 1).

Figure 3. *Grevillea juniperina* subsp. *juniperina* has colonised about 0.4 km of the north eastern embankment of a road cutting through Bringelly Shale on Richmond Road at Marsden Park (site GJ5, Appendix 1) .

Figure 4. A population of *Grevillea juniperina* subsp. *juniperina* plants growing in semi-cleared land on the western side of Park Road, Marsden Park (site GJ2, Appendix 1).

Figure 5. Two seedlings of *Grevillea juniperina* subsp. *juniperina* plants growing in semi-cleared land on gravelly Tertiary alluvium on the western side of Park Road, Marsden Park (site GJ2, Appendix 1) .

those bulls and cows were discovered near Menangle, in an area that became known as "the Cowpastures". Those cattle had discovered a plentiful source of fodder on the alluvial flats of the Nepean River and adjacent grassy woodlands on Wianamatta Shales, which also proved to offer more fertile farming land than sandy soils derived from Hawkesbury Sandstone. By the end of 1809, 34 settlers had been granted land at Minto and Glenfield for farming. Further land was granted to settlers at Appin in 1811, Macquarie Fields and Airds in 1816 and at Campbelltown in 1820. From then to the 1950s, land use in both growth areas was dominated by agriculture, which necessitated extensive clearing of native vegetation from the more fertile alluvial and clayey soils. Agricultural activities conducted in the areas have included the cultivation of wheat (which was curtailed in 1864 when the whole crop was destroyed by an infestation of rust disease) and other cereal crops, grazing of sheep, cattle and horses, intensive production of pigs and poultry, and the cultivation of fruit and vegetables. Campbelltown grew slowly as an urban centre during the 19th century and first half of the 20th century, but population growth accelerated after 1950 due to the rezoning of agricultural land for housing development in the northern part of the Macarthur Growth Area, electrification of the railway line as far south as Macarthur in 1963, the release of the Three Cities Plan (Campbelltown-Camden-Appin) in 1972 and subsequent construction of a number of large-scale housing commission projects from 1973.

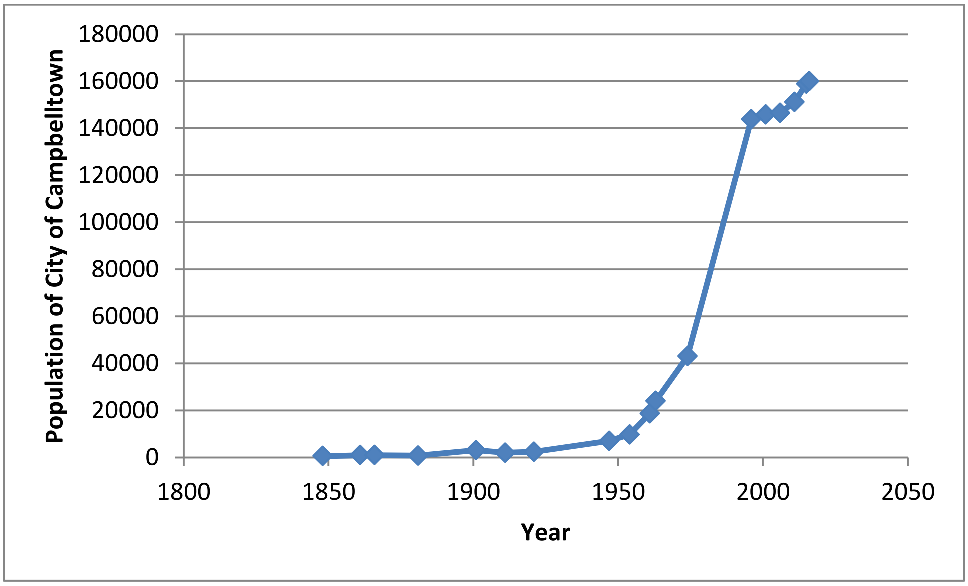

Figure 6. Population growth of Campbelltown, 1848-2016, assembled from data presented at https://www.campbelltown.nsw.gov.au/AboutCampbelltown/History/Campbelltowntimeline

Land use in the northern part of the Macarthur Growth Area is now dominated by residential housing, light industry and transport infrastructure, with only small pockets of pasture and urban bushland remaining intact, albeit weed-infested. In the southern half of the Macarthur Growth Area, south of the "waist" between Mt Annan and Glen Alpine, and in the Wilton Growth Area, land use is still largely rural, with the exception of limited residential and industrial development around Appin and Wilton. Agriculture has been largely restricted to soils derived from Wianamatta Shales and alluvium. Most areas of exposed Hawkesbury Sandstone either still support native vegetation or have been cleared for residential development.

HISTORY OF BOTANICAL EXPLORATION IN THE GROWTH AREAS

The first botanist to collect plant specimens in the same region as the growth areas was Joseph Banks' employee, George Caley, who in 1802 made several expeditions from Prospect through the Cowpastures, reaching Mount Hunter, Menangle and Thirlmere Lakes (Webb 1995). Caley returned to the area in 1803, 1804, 1805 and 1807, once in the company of the great Scottish botanist Robert Brown. Caley mapped a section of Georges River near Ingleburn, following it to Appin, and explored the upper Nepean River system as far as Douglas Park and Appin Falls on the Cataract River (Webb 1995). On these trips, Caley and Brown made extensive botanical collections, from which Brown described numerous species that were new to science, including *Grevillea juniperina*, which they collected near Prospect in 1803. The next botanical collector to visit the area was Franz Sieber, an Austrian who spent six months in the Sydney Region in 1823, during which time he collected specimens of 300 plant species (Ducker 1990), including many that are native to the study area. Botanical exploration of the area then became almost dormant until the late 19th century, when it intensified under the influence of J.H. Maiden, curator of the new Technological Museum, and later director of the Sydney Botanic Gardens. Botanists associated with Maiden, including R.T. Baker, J.L. Boorman, A.A. Hamilton, W.F. Blakely and E. Cheel made several thousand collections in the study area in the late 19th and early 20th centuries (National Herbarium of N.S.W. specimen database), long after much of the native vegetation on Wianamatta Shales and alluvia had been cleared for agriculture. Botanical exploration of the remnant vegetation of the study area has continued to the present day

LANDSCAPE CONTEXT

The Greater Macarthur and Wilton Growth Areas are located on the southern to south eastern rim of the Cumberland Plain, the central part of the saucer-shaped sedimentary Sydney Basin. Here, the uppermost strata of the Sydney Basin, Cenozoic alluvia patchily overlie the Triassic Wianamatta Group, mostly comprising Bringelly and Ashfield Shales, which, in turn overlie Triassic Hawkesbury Sandstone (Martyn 2018). Scattered small volcanic intrusions occasionally pierce the sedimentary strata, such as at Mt Annan, 0.7 km west of the “waist” in the middle of the Greater Macarthur Growth Area.

The most commonly exposed substrate in the northern part of the Greater Macarthur Growth Area is Ashfield Shale, over which patches of Bringelly Shale have been preserved on the western side, while Quaternary alluvia have accumulated in the valleys of Bow Bowing and Bunbury Curran Creeks (NSW Department of Minerals and Energy 1991, NSW Department of Mineral Resources 1985). Here, minor tributaries of the Georges River, such as Redfern, Smiths and McBarrons Creeks have exposed Hawkesbury Sandstone in narrow, shallow but steep-sided valleys.

In the southern half of the Greater Macarthur Growth Area, Bringelly Shale and Quaternary alluvium are restricted to the north west at Menangle Park. Further south, the Nepean and Georges Rivers and their tributaries have cut deep gorges through the Ashfield Shale, exposing large areas of Hawkesbury Sandstone on the steep valley sides and on the adjacent, flat to gently sloping valley borders. Large areas of transitional substrate exist here, where Ashfield Shale colluvium thinly covers Hawkesbury Sandstone or mixes with sandstone-derived soil. The landscape of the Wilton Growth Area resembles that of the southern half of the Greater Macarthur Growth Area but here the predominant substrate is Hawkesbury Sandstone over which an archipelago of thin islands of Ashfield Shale are preserved.

As the Greater Macarthur and Wilton Growth Areas are located on the southern to south eastern rim of the Cumberland Plain, they are gently tilted from south south west to north north east. However, topography also varies locally, with erosion having produced gently rolling landscapes over much of the area but steep-sided valleys contain the major water courses. The lowest point is in the far north east at Glenfield, where the banks of the Georges River are at 15 m altitude, but the land nearby rises to an altitude of 60 m at the junction of Campbelltown Road and Camden Valley Way. In the southern end of the Greater Macarthur Growth Area, just south east of Appin, the altitude reaches 260 m but drops to 230 m on the banks of the Georges River . The Wilton Growth Area varies in altitude from 105 m in the bottom of the Nepean Gorge to 305 m near its southern tip on the Picton Road.

Topographic variation as well as distance from the sea influences climate. The area just west of the Greater Macarthur Growth Area has the lowest average annual rainfall and the highest average January maximum temperature in the Sydney Region (Benson & Howell 1990). Both growth areas are subject to winter frosts.

NATIVE VEGETATION

In terms of the plant community types recognised in the Bionet Vegetation Classification and the vegetation maps that were prepared for this project, the remnant native vegetation of the growth areas consists of:

- 830 Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain;
- 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain;
- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain;
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain;
- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain;
- 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney;
- 1292 Water Gum – Coachwood riparian scrub along sandstone streams;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain.

Plant community types 830, 849 and 850 grow on Wianamatta Shales, 835 on quaternary alluvium, 1081 and 1395 on Hawkesbury Sandstone under a thin layer of Ashfield Shale or shale colluvium and 1181 and 1292 on Hawkesbury Sandstone.

In the course of this project, I visited 23 sites in the field, 19 of which were either in, or adjacent to, the Growth Areas, 20 of which I characterised in detail (Appendix 1).

In the northern half of the Greater Macarthur Growth Area, native vegetation is restricted to small, mostly long, narrow patches of urban bushland, most of which line water courses. A few of these are conserved as council reserves. I visited four bushland remnants either in, or close to the northern part of the Greater Macarthur Growth Area (sites N1, N7, N13, N14, Appendix 1), two of which I characterised in detail (N1, N7). I found all of these to include substantial weed infestation, especially close to water courses. Two species of privet, *Ligustrum sinense* and *L. lucidum*, were the most common woody weeds growing on sandstone, while African Olive (*Olea europea* subsp. *cuspidata*) was common on Wianamatta Shales. Common herbaceous weeds included naturalised grasses, Bridal Creeper (*Asparagus asparagoides*) and, near watercourses, Wandering Jew (*Tradescantia fluminensis*). Dumped household and garden rubbish was common near road access points in most patches of remnant bushland.

In the southern half of the Greater Macarthur Growth Area, and in the Wilton Growth Area, patches of remnant native vegetation become progressively more plentiful, on larger blocks of land, as one moves south but they are still mostly associated with water courses. According to the vegetation maps that were prepared for this project, by far the most abundant plant community type here is 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain. This community type occurs on flat to gently sloping land, on clayey to loamy soils derived from Asfhield shale or shale colluvia over Hawkesbury Sandstone, often adjacent to steep-sided gorges of exposed Hawkesbury Sandstone (e.g. site N8, figure 7).

Figure 7. Plant community type 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, on Ashfield shale colluvium over Hawkesbury Sandstone at Shingle Hill, Wilton (site N10, Appendix 1).

Although almost all of this community type is coded as “intact” in the vegetation maps, I found the condition of these remnants variable, depending on the extent of grazing by stock to which they had been subjected. At one of my sites (site N3, Appendix 1), a shrub stratum was completely absent and all herbaceous plants had been grazed close to the ground (figure 8).

The sides of the gorges of the Nepean and Georges Rivers and their major tributaries are typically covered by plant community type 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney (e.g. site N11, figure 9). In some places this forms a mosaic with plant community type 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain.

Figure 7. Heavily grazed understory vegetation in plant community type 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain at Allen Creek, Wilton (site N3, Appendix 1).

Small, mostly degraded remnants of plant community types 849 and 850 are scattered on Ashfield Shale in the Wilton Growth Area and southern part of the Macarthur Growth Area.

POTENTIAL HABITAT

In its core distribution, *Grevillea juniperina subsp. juniperina* on sandy to gravelly Tertiary alluvia, although it also grows on soils derived from Bringelly Shale (Wianamatta Group) and Quaternary alluvia and interfaces between these substrates. It is recorded from Cumberland Plain Woodland, Castlereagh Ironbark Woodland, Castlereagh Scribbly Gum Woodland and Shale/Gravel Transition Forest.

Figure 8. Plant community type 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney east of Appin (site N11, Appendix 1).

Figure 9. Plant community type 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain east of Appin (site N12, Appendix 1).

The OEH Threatened Species Data Collection indicates that *Grevillea juniperina subsp. juniperina* has the potential to occur in the following plant community types within the Wilton and Greater Macarthur Growth Areas:

- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain;
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain;
- 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain.

Plant community types 849 and 850 are represented in the Growth Areas mostly as small, degraded fragments. Plant community type 883 is absent from the Wilton Growth Area and is represented in the Greater Macarthur Growth Area by a tiny, degraded fragment totalling less than one hectare at Macquarie Fields.

4. Assessment of species presence and suitable habitat

SPECIES RECORDS AND HABITAT ASSESSMENTS

Grevillea juniperina subsp. juniperina has never been recorded in the study area, nor has any formal habitat assessment ever been conducted there. However, on 19 June 2017 the focal taxon was collected adjacent to the study area by Brian Towle at Gundungarra Reserve, Spring Farm, 4 km north west of the "waist" in the Greater Macarthur Growth Area (specimen NSW999291), in a disturbed remnant of Grey Box – Forest Red Gum grassy woodland on Bringelly Shale.

I interviewed two botanists who have published comprehensive taxonomic treatments of *Grevillea*, Robert O. Makinson and Peter M. Olde, to ask for their personal opinions on the likelihood of *Grevillea juniperina subsp. juniperina* being native to the study area. Both are familiar with, and have described the morphology, distribution and ecology of this taxon and Olde has also written on its horticultural attributes. Both consider the core of its distribution to be the area bounded by Scheyville, Richmond, Penrith and Blacktown. Makinson has observed one plant of *Grevillea juniperina subsp. juniperina* growing at Bill Anderson Reserve, Kemps Creek, and thought that this was most probably a wild occurrence, representing the southern limit of distribution of the taxon. Makinson had determined the identity of Towle's collection from Spring Farm as *Grevillea juniperina subsp. juniperina* but was ambivalent about whether this represented a wild record or garden escape. Olde believes that the southern limit of *Grevillea juniperina subsp. juniperina* is north of Luddenham and considers the Kemps Creek and Spring Farm occurrences both to represent garden escapes.

PRIOR SPECIES SURVEYS

Grevillea juniperina subsp. *juniperina* is a perennial shrub that is readily recognised at any time of year by its distinctive vegetative morphology. Conventional surveying would therefore be the most appropriate way to test for its presence, if unlimited access to the study area were allowed. Surveys were undertaken on behalf of DPE on all areas of land where landowners granted access, amounting to 3,360 hectares (62% of the urban development footprint). However, the survey effort for this species did not meet the recommendations in the OEH threatened species guidelines for field traverse surveys due to limitations imposed by land access. No sightings of the species were recorded from the survey areas.

ASSESSMENT OF SPECIES PRESENCE

Grevillea juniperina subsp. *juniperina* is unlikely to be growing wild in either the Greater Macarthur Growth Area or the Wilton Growth Area and has probably never been native to either of these areas.

JUSTIFICATION FOR DETERMINATION

Evidence and arguments supporting the hypothesis that *Grevillea juniperina* subsp. *juniperina* is, or once was native to the study area

There is some evidence that suitable habitat for *Grevillea juniperina subsp. juniperina* exists in the study area. Two of the substrate classes on which *Grevillea juniperina subsp. juniperina* is found growing within its core distribution, Bringelly Shale and Cenozoic alluvia, occur patchily in the Greater Macarthur Growth Area north of Gilead and as a small patch of Bringelly Shale 3 km SW of Appin (NSW Department of Minerals and Energy 1991, NSW Department of Mineral Resources 1985). The focal taxon is therefore adapted to growing on soils that occur in part of the study area. Three of the plant community types in which *Grevillea juniperina subsp. juniperina* grows in its core distribution are also represented in the study area and some of these patches occur on the focal taxon's preferred substrates.

The population of four plants of *Grevillea juniperina subsp. juniperina* that was recently discovered at Gundungarra Reserve, in a patch of degraded remnant Grey Box – Forest Red Gum grassy woodland on Bringelly Shale, just outside the study area, might be native there. This habitat closely resembles small remnant patches of Cumberland Plain woodland that are scattered through the western side of the Greater Macarthur Growth Area north of Gilead and south west of Appin. It is conceivable that small populations of *Grevillea juniperina subsp. juniperina* like the one at Gundungarra Reserve might have survived in patches of remnant bushland on private property that have never been accessible to botanical collectors, including those who have surveyed parts of the growth areas for this project. The presence of *Grevillea juniperina subsp. juniperina* at Gundungarra Reserve also shows that it is capable of growing in the study area.

Most native vegetation originally growing on Bringelly Shale and alluvia in the study area was cleared for agriculture before intensive botanical exploration of the area commenced in the late 19th century, potentially destroying populations of the taxon before they could be discovered. Thus absence of evidence for the presence of the focal taxon in the study area should not be construed as evidence of original absence.

Evidence and arguments against the hypothesis that *Grevillea juniperina* subsp. *juniperina* is, or once was native to the study area

The history of botanical exploration of the study area suggests that if *Grevillea juniperina subsp. juniperina* had originally been native there, then it would probably have been collected or reported there at some time in the last 210 years. George Caley made multiple botanical collecting expeditions through the study area before any land had been granted to settlers and did not collect

Grevillea juniperina subsp. *juniperina* there, although he had earlier collected it near Prospect. One would expect Caley to have collected it if it had been as abundant here as it is in remnant bushland in its core distribution. Franz Sieber collected plant specimens in the study area in 1823, shortly after land started to be cleared there but did not collect *Grevillea juniperina* subsp. *juniperina* either. Intensive botanical exploration of the study area began in the late 19th century, and has continued to the present day and yet none of the numerous botanists who worked there have collected or reported it.

Two of the three plant community types that are potential habitat for *Grevillea juniperina* subsp. *juniperina* in the study area (849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain, 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain) were originally common and widespread between the core distribution of the taxon and the study area 24 km to the south east (Benson 1992). Moreover, two of the substrates on which *Grevillea juniperina* subsp. *juniperina* is known to occur, Bringelly Shale and Cenozoic alluvia, collectively underlie almost the whole area separating the study area from the core distribution of the focal taxon. If *Grevillea juniperina* subsp. *juniperina* had originally been native to the study area, one would expect some evidence of its existence in this intervening area to have accumulated since intensive botanical exploration of the Cumberland Plain commenced in the late 19th century. The only such evidence that I could find from the Wildlife Atlas and herbarium records was one observation of two plants at Bill Anderson Reserve, Kemps Creek and the recent discovery of four plants at Gundungarra Reserve, Spring Farm. The former of these records arguably represents a native occurrence at the margin of the focal taxon's natural distribution but the latter is very dubious as a native occurrence.

I visited Bill Anderson Reserve, Kemps Creek (sites GJ6-GJ8, Appendix 1), and spent a total of 3 hours and 45 minutes searching for *Grevillea juniperina* subsp. *juniperina* and characterising three sites there, including sites at which R.O. Makinson and G. Steenbeeke had told me that they had previously seen individual plants. The whole of this reserve could be classed as suitable habitat for the focal taxon on the basis of substrate (Bringelly Shale) and associated plant species but I could find no plants of it there. This reserve varies in altitude from 50 to 70 m, which is higher than anywhere within the core distributional range of *Grevillea juniperina* subsp. *juniperina*, where it is typically locally abundant in suitable habitats. Its rarity at Kemps Creek is consistent with this locality being at the limit of its ecological tolerance.

Brian Towle reported finding four healthy plants growing in a thicket of *Bursaria spinose* at Gundungarra Reserve, Spring Farm in June 2017 but when I visited this site 12 months later I found all four plants dead (site GJ9, Appendix 1). Their cause of death is most likely to have been water stress caused by drought: in the period May 2017 to June 2018, Campbelltown weather station recorded 317.2 mm of rainfall, less than half the mean annual rainfall of 824 mm (Bureau of Meteorology 2018). The death of these plants calls into question the bioclimatic suitability of this site as a sustainable habitat for *Grevillea juniperina* subsp. *juniperina.* This population was unlike any I had seen in the focal taxon's core distributional range. The plants were all very large, reproductively mature shrubs varying from 1.3 to 2.0 m tall and therefore at least 10 years old if one assumes a rate of growth in height of 13 to 20 cm per year. There was no evidence of seedling recruitment, unlike the populations that I had examined in the Castlereagh –Marsden Park – Shanes Park area, all of which included plants of diverse size classes.

The unusual size distribution and unexpected location of this population seem best explained by an anthropogenic origin. These plants might all be of the same or similar age, having germinated from seeds that escaped here from a local garden after construction of the suburb began in the early 1990s (https://profile.id.com.au/camden/about/?WebID=230, accessed, 21/7/2018). Two collections from naturalised populations of *Grevillea juniperina* subsp. *juniperina* are held by the National Herbarium of NSW – one from Heathmont, a suburb of Melbourne (NSW834413), the other from Penrose, 67 km south west of the study area (NSW971120), demonstrating that garden escapes of this species are likely. A notable feature of both of those collections was the observation of the presence of seedlings, unlike the population at Gundungarra Reserve. Alternatively, the plants at Gundungarra Reserve might have been planted there when the park was established at the same time as the suburb of Spring Farm. Plants used for landscaping purposes are often vegetatively propagated from single, selected clones and this could explain the absence of seedlings, if *Grevillea juniperina* subsp. *juniperina* is reproductively self-incompatible like some other species of *Grevillea* (Smith & Gross 2002). A third plausible scenario is that the plants at Gundungarra Reserve established there from dumped garden waste. The western side of this park, bordering a powerline easement, is an informal garbage dump, with abundant household refuse and garden waste, including discarded plant pots and plant material strewn through this side of the reserve.

The main reason for requiring an expert report on *Grevillea juniperina* subsp. *juniperina* is that three plant community types in which it is typically found in its core range occur in the study area. These were inferred to be potential habitat for the focal species, implying that it might occur, as yet undiscovered, in remnants of those community types within the growth areas. However, the distribution of *Grevillea juniperina* subsp. *juniperina* is also correlated with other environmental variables, such as substrate and altitude. In its core distributional range, it occurs below 50 m altitude (Makinson 2000), but records from Kemps Creek that were unknown to Makinson in 2000, extend its altitudinal range to 70 m. Land under 70 m occurs in two parts of the study area. In the northern half of the Greater Macarthur Growth Area, such low lying land occurs on substrates such as Ashfield Shale and Hawkesbury Sandstone on which *Grevillea juniperina* subsp. *juniperina* has never been recorded and where blocks of intact native vegetation seldom exceed 10 ha in area. Land below 70 m altitude is also found on the banks of the Nepean River between Menangle and Spring Farm but here the land is vegetated with a plant community type in which *Grevillea juniperina* subsp. *juniperina* has not been recorded: 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain. None of the sites that I visited and characterised in or near the study area matched the habitat of the focal species in its core distributional range (Appendix 1). It is reasonable to conclude that no suitable habitat for *Grevillea juniperina* subsp. *juniperina* now occurs within the study area.

Even if suitable habitat did occur in the study area prior to clearance of land for agriculture, this would not be compelling evidence supporting the former presence of *Grevillea juniperina* subsp. *juniperina* there. Other causal factors such as biogeographic history are also important determinants of plant distributions. Absence of the focal taxon from Bringelly Shale and Cenozoic alluvia south of Kemps Creek might reflect a history of incomplete range expansion: it might have originated on the northern Cumberland Plain but not yet dispersed into all of the habitats in which it was capable of growing and competing. Alternatively, it might have once covered a much larger area from which it later contracted as a result of stochastic processes such as high bushfire frequency in the southern Cumberland Plain.

LIKELIHOOD OF SPECIES PRESENCE

Figure 10 shows a frequency histogram of records of *Grevillea juniperina* subsp. *juniperina* from the OEH Wildlife Atlas, with the herbarium specimen from Spring Farm added into the data set, categorised in latitudinal samples 0.05 degrees wide. If the Spring Farm record is rejected as native, as I have recommended, then the frequency distribution resembles a unimodal Gaussian curve, which is typical of many plant species, as well as other kinds of organisms (Brown 1984). If we make the simplifying assumption that surveying and specimen collecting efforts have been unbiased across this range of latitudes within the Cumberland Plain, then this frequency distribution can be treated as a probability distribution. If this argument is accepted, then the whole of the study area lies outside of the curve enclosing all 1488 records. The probability of *Grevillea juniperina* subsp. *juniperina* occurring in the study area can then be conservatively estimated as less than 1/100.

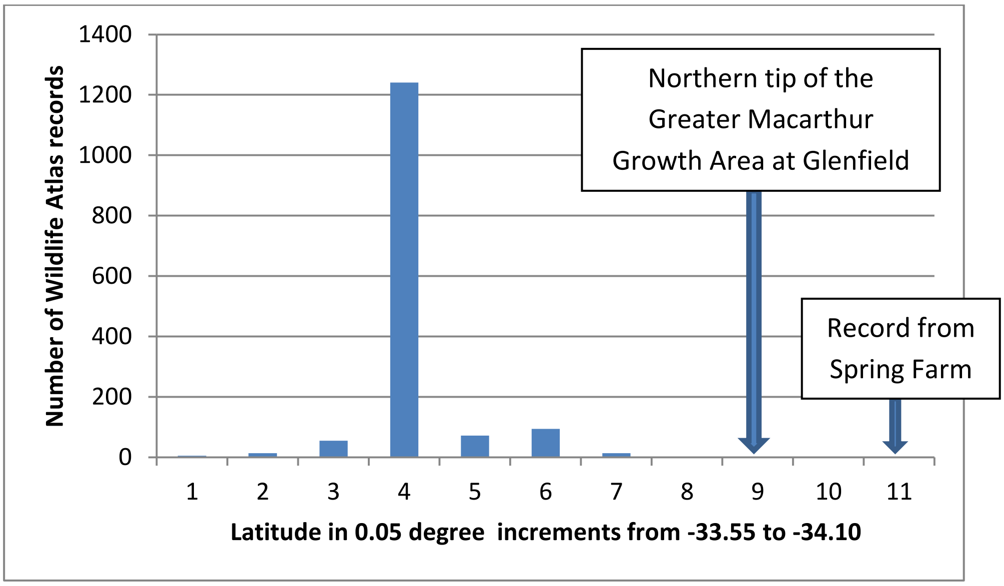

Figure 10. Frequency histogram of records of *Grevillea juniperina* subsp. *juniperina* from the OEH Wildlife Atlas classified according to latitude.

6. Acknowledgements

I am grateful to Teresa James, Bob Makinson, Peter Olde, and Brian Towle for happily being interviewed, and for generously sharing their knowledge about *Grevillea juniperina* subsp. *juniperina*. Alison Butler (Camden Council) kindly provided information about the history of suburban development at Spring Farm and adjacent suburbs.

7. References

Benson D (1992) The natural vegetation of the Penrith 1:100,000 map sheet. *Cunninghamia* 2: 541-596.

Benson D, Howell J (1990) 'Taken for Granted: The Bushland of Sydney and its Suburbs'. Kangaroo Press, Kenthurst, NSW, Australia.

Benson D, McDougall L (2000) Ecology of Sydney plant species Part 7b Dicotyledon families Proteaceae to Rubiaceae. *Cunninghamia* 6: 1016–1202.

Brown JH (1984) On the relationship between abundance and distribution of species. *American Naturalist* 124: 255-279.

Ducker SC (1990) Early Austrian influence on Australian botany. Pp. 297-304 in Short PS (ed) 'History of Systematic Botany in Australasia'. Australian Systematic Botany Society, Melbourne

NSW Department of Minerals and Energy (1991) Penrith 100K Geological Sheet 9035. Sydney, NSW, Australia.

NSW Department of Mineral Resources (1985) Wollongong-Port Hacking 100K Geological Sheet 9029-9129. Sydney, NSW, Australia.

Liston C (1988) 'Campbelltown, the Bicentennial History'. Allen & Unwin, North Sydney, NSW, Australia.

Makinson RO (2000) *Grevillea. Flora of Australia* 17A: 1-524. ABRS/CSIRO, Melbourne, Australia.

Martyn J (2018) 'Rocks and Trees: A Photographic Journey Through the Rich and Varied Geology, Scenery and Flora of the Sydney Region'. STEP Inc, Turramurra, NSW, Australia.

Mast AR, Olde P, Makinson RO, Jones E, Kubes A, Miller E, Weston PH (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646.

Morris EC (2000) Germination response of seven east Austalian *Grevillea* species (Proteaceae) to smoke, heat exposure and scarification. *Australian Journal of Botany* 48: 179–189.

Myerscough PJ, Whelan RJ, Bradstock RA (2000) Ecology of Proteaceae with special reference to the Sydney region. *Cunninghamia* 6: 951–1015.

Olde P, Marriott N (1995) 'The Grevillea Book', vol. 2. Kangaroo Press, Kenthurst, New South Wales, Australia.

Smith JA, Gross CL (2002) The pollination ecology of *Grevillea beadleana* McGillivray (Proteaceae), an endangered shrub from northern New South Wales, Australia. *Annals of Botany* 89: 97-108.

Webb JB (1995) 'George Caley: Nineteenth Century Naturalist: a Biography'. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

8. Appendices

APPENDIX 1: Characterisation of habitat at selected sites

The tables on following pages record data that I collected at sitews both within and outside the study area. Several of these sites received “over the fence” assessments and were not characterised in detail. Each site that was characterised in detail was centred on an arbitrarily selected plant of *Grevillea juniperina* subsp. *juniperina* (sites numbered GJ1-GJ5, GJ9) or at places where the focal taxon had previously been reported (sites GJ6-GJ8) or at an arbitrarily point in the case of sites examined in or near the growth areas (sites N1-N14). At each site the precise latitude and longitude, altitude, substrate, soil description, slope and aspect were also recorded. Also, at each site all woody plant species and a few species of herbaceous plants that could be reliably identified from vegetative characters were recorded within a radius of 30 metres. Attributes of sites at which *Grevillea juniperina* subsp. *juniperina* was found (sites GJ1-GJ5, GJ9) were compared with comparable attributes of sites in or near the growth areas to assess whether any sites in the growth areas closely matched *Grevillea juniperina* subsp. *juniperina* sites.

Site	Location	Latitude	Longitude	Altitude	substrate
GJ1	Southern end of Park Rd, E side, Marsden Park	33°41'22.6"S	150°50'03.1"E	25 m	Bringelly Shale
GJ2	Junction of Walker Pde and Park Rd, Marsden Park	33°40'58.8"S	150°50'06.3"E	25 m	Tertiary alluvium
GJ3	Castlereagh Nature Reserve, Northern Rd, Londonderry	33°40'44.9"S	150°44'37.3"E	52 m	Tertiary alluvium
GJ4	Junction of Palmyra Ave and Stony Creek Rd, Shanes Park	33°43'09.1"S	150°46'52.7"E	25 m	Bringelly Shale-Tertiary alluvium
GJ5	Richmond Rd, Marsden Park	33°41'03.3"S	150°49'12.4"E	25 m	Bringelly Shale
GJ6	Bill Anderson Reserve, Kemps Creek site 1	33°52'55.2"S	150°47'21.4"E	70 m	Bringelly Shale
GJ7	Bill Anderson Reserve, Kemps Creek site 2	33°52'53.2"S	150°47'19.0"E	66 m	Bringelly Shale
GJ8	Bill Anderson Reserve, Kemps Creek site 3	33°52'41.7"S	150°46'53.7"E	50 m	Bringelly Shale
GJ9	Gundungarra Reserve, Spring Farm	34°03'38.9"S	150°44'15.0"E	125 m	Bringelly Shale
N1	Colong Reserve, Smiths Creek, Leumeah	34°03'22.6"S	150°50'24.3"E	87 m	Hawkesbury Sandstone
N2	Douglas Park bridge, Nepean River	34°11'32.5"S	150°42'48.6"E	110 m	Hawkesbury Sandstone
N3	Allens Creek, Wilton site 1	34°12'36.7"S	150°41'15.4"E	157 m	Hawkesbury Sandstone
N4	Allens Creek, Wilton site 2	34°12'25.7"S	150°41'17.9"E	201 m	Hawkesbury Sandstone
N5	Allens Creek, Wilton site 3	34°12'25.2"S	150°41'23.5"E	140 m	Hawkesbury Sandstone
N6	Ouesdale Creek, Appin	34°11'30.1"S	150°46'53.5"E	215 m	Hawkesbury Sandstone
N7	Noorumba Reserve, Rosemeadow	34°06'49.3"S	150°47'27.2"E	139 m	Ashfield Shale
N8	Shingle Hill, site 1	34°12'26.8"S	150°38'50.5"E	145 m	Hawkesbury Sandstone
N9	Shingle Hill, site 2	34°12'26.8"S	150°38'50.5"E	144 m	Hawkesbury Sandstone
N10	Shingle Hill, site 3	34°12'35.3"S	150°38'54.1"E	160 m	Mittagong Formation
N11	Georges River, Appin site 1	34°12'27.4"S	150°47'50.9"E	268 m	Hawkesbury Sandstone
N12	Georges River, Appin site 2	34°12'18.4"S	150°47'50.5"E	260 m	Hawkesbury Sandstone
N13	Bicentennary Reserve, Minto	34°00'49.7"S	150°51'11.5"E	35 m	Ashfield Shale
N14	Bunbury Curran Reserve, Macquarie Fields	33°59'00.2"S	150°53'51.7"E	15 m	Hawkesbury Sandstone

Appendix 1a: Environmental data for sites visited as part of this study (continued on next page)

Site	Soil description	Slope	Aspect	Vegetation structure (canopy)	Vegetation structure (understory)
GJ1	brown sandy loam	<5°	SW	dry sclerophyll forest-woodland	sparse shrubby understory
GJ2	brown gravelly clay-loam	0°		Partially cleared woodland	Shrubby thickets separated by open pasture
GJ3	brown, gravelly clay-loam	0°		dry sclerophyll forest	sparse shrubby understory
GJ4	brown , gravelly clay-loam	<5°	W	dry sclerophyll woodland	dense shrubby understory
GJ5	gravelly brown clay	20°	SW	Regenerating Dry sclerophyll woodland	sparse shrubby understory
GJ6	red-brown sandy loam	0°		Dry sclerophyll woodland	sparse to dense shrubby understory
GJ7	red-brown sandy loam	<5°	N	disturbed dry sclerophyll woodland	moderately dense shrubby understory
GJ8	red-brown sandy loam	<5°	NW	disturbed dry sclerophyll forest	dense shrubby understory
GJ9	brown clay	0°		Highly disturbed, remnant woodland	mosaic of shrubby thickets and weedy grassland
N1	black sand	0°		Disturbed dry sclerophyll forest	moderately dense shrubby understory
N2	black sand	0-20°	SW	Dry sclerophyll forest	sparse shrubby understory
N3	brown sandy loam	0°		Heavily grazed dry sclerophyll forest	no shrub layer
N4	brown sandy loam	0°		Heavily grazed dry sclerophyll forest	mosaic of shrubby thickets and clear ground
N5	pale grey-brown sand	5-30°	SE	Dry sclerophyll forest	moderately dense shrubby understory
N6	brown sandy loam	5-15°	SSW	Dry sclerophyll forest	mosaic of dense to moderately dense shrubby thickets
N7	red-brown clay	0°		Dry sclerophyll forest	moderately dense shrubby understory
N8	dark brown humus-rich sand	<5°	N	Dry sclerophyll woodland	sparse to dense shrubby understory
N9	dark brown humus-rich sand	<5°	W	Dry sclerophyll woodland	sparse to moderately dense shrubby understory
N10	brown loam	<5°	N	Dry sclerophyll forest	dense shrubby understory
N11	dark brown humus-rich sand	0°		Dry sclerophyll forest	sparse to moderately dense shrubby understory
N12	dark brown humus-rich sand	0°		Dry sclerophyll forest	sparse to moderately dense shrubby understory
N13				Dry sclerophyll forest	
N14				Dry sclerophyll forest	

Appendix 1a (continued): Environmental data for sites visited as part of this study

	Sites >																		
Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Acacia binervata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Acacia binervia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Acacia elongata	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia falcata	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1
Acacia longifolia	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia mearnsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Acacia parramattensis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Acacia terminalis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Acrotriche divaricata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Actinotus helianthi	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Allocasuarina glareicola	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	0	1	0	1	1	1	1	0	0	1	0	1	1	1	0	1	1	1	1	1
Allocasuarina torulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Angophora bakeri	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0
Angophora floribunda	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Astrotricha latifolia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
Backhousia myrtifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Banksia serrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Appendix 1b: Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Banksia spinulosa	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	1	0	1	1
Beyeria viscosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Billardiera scandens	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bossiaea obcordata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Bossiaea rhombifolia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bursaria spinosa	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	0	0
Bursaria spinosa	1	0	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	1	0	0
Callistemon linearis	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopetalum gummiferum	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1
Correa reflexa	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0
Corymbia gummifera	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Crowea exalata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cryptandra amara	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptandra spinescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Dampiera stricta	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Dampiera purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Daviesia corymbosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Daviesia ulicifolia	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia acicularis	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dillwynia rudis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia sieberi	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia tenuifolia	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Dodonaea falcata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea triquetra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Elaeocarpus reticulatus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Enchylaena tomentosa	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Eremophila debilis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Eucalyptus crebra	0	0	1	1	0	0	0	1	0	0	1	1	0	0	1	0	0	1	0	0
Eucalyptus eugenioides	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus fibrosa	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Eucalyptus globoidea	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eucalyptus longifolia	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus moluccana	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Eucalyptus paniculata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eucalyptus pilularis	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Eucalyptus piperita	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1
Eucalyptus punctata	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1	0	1
Eucalyptus sclerophylla	0	1	0	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	1	1
Eucalyptus sieberi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eucalyptus sparsifolia	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1
Eucalyptus tereticornis	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Exocarpos cupressiformis	1	0	0	0	1	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0
Exocarpos strictus	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1	1	1	1	1
Goodenia hederacea	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Grevillea arenaria	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Grevillea diffusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
*Grevillea juniperina*subsp. *Juniperina*	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea mucronulata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Grevillea sericea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hakea laevipes	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Hakea sericea	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Hardenbergia violacea	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibbertia aspera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hovea linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hovea purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Indigofera australis	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Isopogon anemonifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Jacksonia scoparia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	1	0	1	0	1	1	0	1	1	0	1	1	1	0	0	1	1	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Lasiopetalum ferrugineum cordatum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lasiopetalum ferrugineum ferrugineum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Leptospermum polygalifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Leptospermum trinervium	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	1	1	1
Leucopogon ericoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Leucopogon juniperinus	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Leucopogon virgatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Lissanthe strigosa	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Lomandra longifolia	0	0	0	0	1	0	1	0	1	0	0	0	1	1	0	0	1	0	1	0
Lomandra obliqua	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Melaleuca decora	1	1	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Melaleuca erubescens	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca linearifolia	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Melaleuca nodosa	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micromyrtus minutiflora	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Myrsine variabilis	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Notelaea longifolia	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	1	1	1	0	0
Olearia viscidula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ozothamnus diosmifolius	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patersonia glabrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Patersonia sericea	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia lanceolata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Persoonia linearis	0	0	0	0	1	1	0	0	1	1	0	1	1	1	0	1	1	1	1	1
Persoonia nutans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia pinifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Petrophile sessilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Phyllanthus hirtellus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pimelea linifolia	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pittosporum revolutum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ6	GJ7	GJ8	GJ9	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Pittosporum undulatum	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Platysace linearifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Podolobium ilicifolium	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0
Polyscias sambucifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Pultenaea parviflora	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Stenocarpus salignus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Stylidium laricifolium	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Stypandra glauca	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Styphelia laeta	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Syncarpia glomulifera	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Westringia longifolia	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Xanthorrhoea media	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Xanthosia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Xylomelum pyriforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

APPENDIX 2: PETER WESTON'S CURRICULUM VITAE

Personal details

Name: Peter Henry Weston.

Address: 18 Lyle Avenue, Lindfield, New South Wales 2070, Australia.

Date and place of birth: 22 October 1956, Lower Hutt, New Zealand.

Immediate family: wife (Susan) and three children (Timothy 33, Caitlin 31, Nicholas 27).

Nationality: Australian.

Interests: soccer, reading, guitar, orchid growing, cross-country skiing, bush walking.

Academic Qualifications

i) **B.Sc.** (first class honours; equal first in order of merit) School of Biological Sciences, University of Sydney; 1975-78, conferred 7 April 1979.
Thesis title: "The evolution and classification of *Boronia* Sm."

ii) **Ph.D.**, School of Biological Sciences, University of Sydney, 1979-83; conferred 18 May 1985.
Thesis title: "Systematics and biogeography of the Persooniinae (Proteaceae)".

Awards, Fellowships and Scholarships

2014	Nancy Burbidge Medal (awarded by the Australasian Systematic Botany Society to a person who has made a longstanding and significant contribution to Australasian systematic botany. It is the foremost award that can be conferred by ASBS).
2014	Australian Biological Resources Study-sponsored Winston Churchill Fellowship for an established career researcher in taxonomy.
2009	Grady L. Webster Structural Botany Publication Award for 2008 and 2009 from the Botanical Society of America. The BSA component of the award (it is awarded in alternate years by the BSA and the American Society of Plant Taxonomists) recognizes the most outstanding paper published in the *American Journal of Botany* in the field of structural and developmental botany (i.e., anatomy and morphology) over a two-year period. It was awarded to Gregory J. Jordan, Peter H. Weston, Raymond J. Carpenter, Rebecca A. Dillon and Timothy J. Brodribb for: "The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae," American Journal of Botany, Volume 95, Issue 5; May 2008.
2006	Carrick Award for Australian University Teaching from the Australian Learning and Teaching Council (one of five members of a teaching

	team from the University of New England cited for Outstanding Contributions to Student Learning).
1992-93	Posting to Royal Botanic Gardens, Kew, as Australian Botanical Liaison Officer.
1982	Charles Gilbert Heydon Travelling Fellowship for the biological sciences (not taken up).
1980-82	University of Sydney Postgraduate Scholarship.
1979-82	Commonwealth Postgraduate Award.
1977	G.S. Caird Scholarship for Third Year Botany, University of Sydney.
1976	Slade Prize for Practical Plant Biology, University of Sydney.

Employment

Present Position: Honorary Research Associate, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney and independent botanical consultant.

Previous positions held:
2008-2016 Senior Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

2000-2008 Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1994-2000 Senior Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1989-1994 Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1982-1989 Scientific Officer, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1979-82 Part-time demonstrator, School of Biological Sciences, University of Sydney.

Adjunct and visiting university appointments

2013-	Adjunct Associate Professor, La Trobe University.
2011-	Adjunct Associate Professor, University of New South Wales.
2006	Visiting Lecturer, Rhodes University, Grahamstown, South Africa.
2004-2009	Adjunct Associate Professor, University of New England.
2000-2004	Adjunct Senior Lecturer, University of New England.

Administrative/management experience

2009	Acting Manager Plant Diversity

2002-2003 Member, Plant Diversity Research Program Leaders Committee
1998-99 Systematics Liaison Officer
1997-98 Member RBGS Market testing working party
1997 Member, RBGS advisory committee for restructuring senior management
1990-91 Systematics Co-ordinator
1996-98 Member, RBGS Joint Consultative Committee

Membership of Learned Societies

1996- Society of Australian Systematic Biologists
1984- Willi Hennig Society (Elected Fellow, 1992-, Council member, 1998-2000)
1979- Society of Systematic Biologists (member, Editorial Board 1993-95)
1978- Australasian Systematic Botany Society (formerly Australian Systematic Botany Society: President, 2009-2012, Vice President, 2008-2009, Chairman, Hansjörg Eichler Research Fund Committee, 1998-2002, Council member, 1996-2002)

Membership of External Committees

2015- Financial Grants Standing Committee (formerly the Grants Policy Standing Committee) of the Australasian Systematic Botany Society
2012-2013 Conference Organising Committee of *Systematics Without Borders*, a joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney (Chairman)
2011- Editorial Board, *Phytotaxa*
2008-2009 Corresponding Member, Editorial Advisory Committee, *Australian Systematic Botany*
2006-2014 Ira Butler Memorial Trophy Committee (a joint committee of the Australasian Native Orchid Society and the Orchid Society of New South Wales) (Chairman)
2004- Editorial Advisory Board, *Kew Bulletin*
2001-2006 Panel of Judges, Eureka Prize for Biodiversity Research
2000-2012 Bushland Management Advisory Committee, Lane Cove Council (Chairman, 2008-2010)
1999-2004 Editorial Advisory Committee, *Australian Systematic Botany*

Spoken presentations at conferences (not including presentations delivered by others)

2015 Building Our Botanical Capital, annual conference of the Australasian Systematic Botany Society: "A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution".
2014 Next Generation Systematics, annual conference of the Australasian Systematic Botany Society: Nancy Burbidge Memorial

Lecture: “Problems and progress in plant systematics since Nancy Burbidge”

2013 Genetics Society of Australasia conference, Sydney *Genetics in the Harbour City*: “Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications”.

2013 Joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, Sydney, *Systematics Without Borders*: “Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications”.

2012 Australasian Systematic Botany Society conference, Perth, *Local knowledge, global delivery*: “Contested, Uncontested and Potentially Controversial Taxonomic Changes in the Proteaceae: How Do They Differ?”

2011 37th annual conference of the South African Association of Botanists, *Plants in a Changing World* and 9th conference of the South African Society of Systematic Biologists, *Biodiversity Matters*; plenary address: “Cenozoic environmental change and the systematics of southern hemisphere plants”

2011 XVIII International Botanical Congress, Melbourne: “Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations”.

2010 VI Southern Connection Congress, Bariloche: “Cladistic biogeography, molecular dating, fossils and the Proteaceae”

2010 VI Southern Connection Congress, Bariloche: “Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests”

2010 Australian Systematic Botany Society conference *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*; Keynote address: “Cenozoic environmental change and the systematics of southern hemisphere plants”

1999 XVI International Botanical Congress, Saint Louis: “Historical biogeography of Proteaceae”.

1997 II Southern Connection Congress, Valdivia: “Cladistic biogeography of a key woody group: Proteaceae”.

1997 First Biennial International Conference of the Systematic Association, Oxford: “Rolf Sattler’s Plant Morphology and Cladistic Analysis”.

1996 *An International Symposium on the Biology of Proteaceae*, Melbourne: “ITS squence variation in the Proteaceae and what it tells us about phylogeny”.

1993 Joint conference of The Systematics Associations and The Linnean Society on *Models in Phylogeny Reconstruction*, London: “Direct methods for polarising character transformation series”.

1990 IXth meeting of the Willi Hennig Society, Canberra: “Transoceanic cladistic patterns in the Proteaceae”.

2003 The Third International Conference on *the Comparative Biology of the Monocotyledons*, Ontario: “Co-evolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators”.
2005 XVII International Botanical Congress, Vienna: “Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae)”.
2006 Australian Systematic Botany Society conference, Cairns, *Plant Diversity in the Tropics*: “A new suprageneric classification of the Proteaceae”.
2007 5th Southern Connection Congress, Adelaide: “‘I’m not dead yet’ – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation)”.
1989 Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney: “Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae”.
1988 Symposium on *Panbiogeography of New Zealand*, Wellington: “Problems with the statistical testing of panbiogeographic hypotheses”.
1985 Australian Flora Foundation Symposium on *Waratahs*, Canberra: “Drifting waratahs or continents?”
1984 Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra: “A reappraisal of Nelson's direct method of character analysis”.

Refereeing manuscripts, grant applications, reports and examining postgraduate theses (last five years)

2016: *Australian Systematic Botany*; *Botanical Journal of the Linnean Society*, *National Research Foundation* (South Africa).
2015: *American Journal of Botany*; Australian Research Council (4); *Australian Systematic Botany*; *Muelleria*; *Nuytsia*; *Phytotaxa*; *PLOS One*; *Telopea* (6).
2014: Australian Research Council (3); *Australian Systematic Botany* (2); *Cunninghamia*; *Journal of Biogeography* (2); *Muelleria*; National Research Foundation (South Africa); *Orchadian*; *Perspectives in Plant Ecology, Evolution and Systematics*; *Plant Systematics and Evolution*; *Telopea* (3).
2013: Australian Research Council; *Australian Systematic Botany*; *Biology Letters*; *Cladistics*; *Diversity and Distributions*; *Evolution*; *Journal of Biogeography*; *New Zealand Journal of Botany*; *Taxon*; *Telopea*.
2012: Australian Research Council (3); *Australian Systematic Botany*; “Darwin, Then and Now” (chapter of book published by University of Chicago Press); *Diversity and Distributions*; *Journal of Biogeography*; National Research Foundation (South Africa); *Phytokeys*.

Research

My research has been in the theoretical and practical aspects of systematic botany, with emphasis on the theory and practice of phylogenetic analysis, and the broader uses to which phylogenetic knowledge may be applied. I have phylogenetically analysed groups in the plant families Proteaceae, Fabaceae, Orchidaceae, Rutaceae, Winteraceae and Lauraceae, contributed to more general analyses of angiosperm phylogeny, and used the results of these analyses to improve biological classification and to test theories of historical biogeography, trait evolution, co-evolution and adaptation. I have earned an international reputation for my contributions to both theoretical and empirical developments in this field.

Herbarium curation and collections

My curatorial responsibilities at the National Herbarium of New South Wales have included the families Rutaceae (1982-1998), Proteaceae (1982-2016), Orchidaceae (1986-2016) and Fabaceae subfamily Faboideae (1986-2016). I have collected plant specimens (mostly angiosperms) in Australia, England, New Zealand, New Caledonia, Chile, South Africa, and Argentina, mostly for the herbarium and living collections of the Royal Botanic Gardens and Domain Trust, Sydney. Duplicates of my collections have been distributed to over 20 herbaria in 8 different countries.

Teaching

I have been actively involved in the preparation and teaching of four third year undergraduate courses in biosystematics:
Western Sydney University (2015-2017): “Principles of Evolution” (unit 300980), “Botany” (unit 300836).
University of New South Wales (2010-2016): “Assembling the Tree of Life” (BIOS3221)
University of New England (2000-2010): Biosystematics (Biosyst 301, Biosyst 302, Evol 301/501).
Botany Department, Rhodes University, Grahamstown, South Africa (February-March 2006): “Plant Biodiversity” course in collaboration with Associate Professor Nigel Barker.

I am currently co-supervising one postgraduate student:
Nanette Thomas (Ph.D., University of New England): Systematics of *Tasmannia* informs Biogeography of Winteraceae.

Postgraduate and honours students I have previously co-supervised include:
Margaret Stimpson (Ph.D., University of New England): Systematics, evolution and ecology of the *Banksia spinulosa* complex (graduated 2017).
Melita Milner (Ph.D., Australian National University): Phylogeography of *Lomatia and Telopea* (Proteaceae) in south eastern Australia (graduated 2015).
Samanta Oon (B.Sc. Honours, University of New South Wales): *Lomatia* likes it both ways: rampant bidirectional introgression of chloroplast genomes between two morphologically distinct species of Lomatia (Proteaceae) (graduated 2015).
Zoe Reynolds (B.Sc. Honours, Australian National University): Phylogenetic, taxonomic and functional turnover in Proteaceae assemblages (graduated 2013).

Emma McIntosh (B.Sc. Honours, University of Sydney): Hybridization and introgression between *Lomatia myricoides* and *L. silaifolia* (Proteaceae) (graduated 2011).
Margaret Stimpson (M.Sc.Stud., University of New England): Review of the *Banksia spinulosa* species complex (Proteaceae) (graduated 2011).
James Indsto (M.Sc., University of Wollongong): Pollination Ecology and Molecular Systematics of *Diuris* (Orchidaceae) of the Sydney Region (graduated 2010).
Nanette Thomas (Grad.Dip.Sci., University of New England): Phylogenetic analysis of Winteraceae (graduated 2009).
David McKenna (Ph.D., University of Wollongong: Demographic and ecological indicators for rarity in obligate-seeding *Persoonia* (Proteaceae) shrubs of the Sydney region, graduated 2007).
Paul Rymer (Ph.D., University of Wollongong: Plant rarity: species distributional patterns, population genetics, pollination biology and seed dispersal in *Persoonia* (Proteaceae), graduated, 2006).
Georgina Lloyd (B.Sc. Honours, University of Sydney: Pseudocopulation in two species of *Cryptostylis*: Implications for maintaining species integrity, graduated 2004)
Andrew Perkins (Ph.D., University of Sydney: Phylogenetic Systematics of the Genus *Calochilus* (Orchidaceae), graduated 2002).
Jim Mant (Ph.D., Australian National University: Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae), graduated 2002).
Siegfried Krauss (Ph.D., University of Wollongong: Systematic pattern and evolutionary process in the complex species *Persoonia mollis* (Proteaceae), graduated 1995).

I have examined 14 honours and postgraduate theses:
Australian National University (Ph.D., 2003, 2007, 2008)
University of Melbourne (Ph.D., 1995, 2011)
University of Newcastle (M.Phil., 2003)
University of Queensland (Ph.D., 2003)
University of Sydney (Ph.D., 1991, 1994, 1997, 2009)
University of Wollongong (B.Sc. Hons., 2001, 2003)
Victoria University (Ph.D., 2007)

Competitive Research and Infrastructure Grants

Peakall, R., Pichersky, E., Linde, C., Weston, P.H. (2015-2019) The biosynthesis and evolution of novel semiochemicals in orchids. $644,800, Australian Research Council Discovery Grant DP150102762.

Hoebee, S.E., Weston, P.H., & Edwards, T.J. (2015-18) Evolution in action or the demise of iconic Australian flora? $217,700, Australian Research Council Discovery Grant DP150100508.

He, T., Lamont, B., Weston, P.H., & Cowling, R. (2012-2014) Origin and evolution of plant functional traits in relation to fire. $310,000, Australian Research Council Discovery Grant DP120103389.

Rossetto, M., Crayn, D.M. & Weston, P.H. (2008-2010) Integrating molecular and morphological data for generic delimitation and species identification in Lauraceae. $73,333, Australian Biological Resources Study.

Cantrill, D., Murphy, D. & Weston, P.H. (2008-10) Understanding the origins of the Australian flora by integrating molecular phylogenies and fossil data in the Proteaceae. $88,900, Hermon Slade Foundation.

Rossetto, M. & Weston, P.H. (2007-2009) Speciation in the Australian flora: testing explanatory hypotheses in waratahs and their allies. $78,000, Hermon Slade Foundation.

Considine, J.A., Krauss, S.L. & Weston, P.H. (2002-2004) A biological basis for the efficient breeding of native plants for export markets: a case study with the Australian Goodeniaceae. $168,126, ARC – Linkage (Krauss and Weston representing industry partners)

Whelan, R.J., Ayre, D.J., England, P., Auld, T.D., & Weston, P.H. (2000-2002) Ecology and genetics of fire-sensitive *Persoonia* species: threatened species recovery and management. $126,480, Australian Research Council (ARC– SPIRT, Auld and Weston representing industry partners).

Trent, R. *et al.* (2000) Enhancement of DNA sequencing equipment for the Sydney University and Prince Alfred Molecular Analysis Centre. $600,000, Australian Research Council (ARC-REIF).

Weston, P.H. (1999-2001) Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae). $75,000, Hermon Slade Foundation.

Weston, P.H. (1997-2000) Taxonomic revision of *Dillwynia* (Fabaceae: Faboideae: Mirbelieae). $62,836, Australian Biological Resources Study.

Weston, P.H. & Thomson, J.A. (1993) A molecular approach to the evolution and biogeography of the Queensland tree waratahs. $4000, Queensland Wet Tropics Management Authority

Weston, P.H. & Thomson, J.A. (1991-92) A molecular approach to the evolution and biogeography of the waratahs. $80,100, Australian Research Council (large grants scheme).

Weston, P.H. (1984) Establishment of a data bank for eucalypt specimens held by NSW. $20,000, Australian Biological Resources Study.

Scientific Publications

[the numbers in square brackets following a reference indicates: 1. the journal's 2016-17 impact factor according to ISI Web of Knowledge, then the number of literature citations for the paper found by Google Scholar, as of 23 May 2018]

H-index = 32, total number of citations = 3831 as of 24 May 2018

1. Craw, R.C. & **Weston, P.H.** (1984) Panbiogeography: a progressive research program? *Systematic Zoology* 33: 1-13. [8.917, 90]

2. **Weston, P.H.**, Carolin, R.C., & Armstrong, J.A. (1984) A cladistic analysis of *Boronia* Sm. and *Boronella* Baill. (Rutaceae). *Australian Journal of Botany* 32: 187-203. [0.793, 48]

3. Morrison, D.A. & **Weston, P.H.** (1985) Analysis of morphological variation in a field sample of *Caladenia catenata* (Smith) Druce (Orchidaceae). *Australian Journal of Botany* 33: 185-195. [0.793, 11]

4. Crisp, M.D. & **Weston, P.H.** (1987a) Waratahs - how many species? Pp. 3-15, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 13]

5. Crisp, M.D. & **Weston, P.H.** (1987b) Cladistics and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae. Pp. 65-130, in C.H. Stirton (ed.) *Advances in Legume Systematics Part 3* (Royal Botanic Gardens: Kew). [-, 126]

6. **Weston, P.H.** (1987) *Persoonia* (Proteaceae). Pp. 348-350, in N.G. Marchant *et al*. (eds.) *Flora of the Perth Region* (Western Australian Herbarium: Perth). [-, 0]

7. **Weston, P.H.** & Crisp, M.D. (1987) Evolution and biogeography of the Waratahs. Pp. 17-34, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 14]

8. **Weston, P.H.**, Wilson, P.G., & Hill, K.D. (1987) Identification of *Cannabis*. *Department of Agriculture New South Wales Miscellaneous Bulletin* 25: 148-150. [-, 0]

9. **Weston, P.H.** (1988a) A revision of *Hicksbeachia* (Proteaceae). *Telopea* 3: 231-239. [0.6, 3]

10. **Weston, P.H.** (1988b) Indirect and direct methods in systematics. Pp. 27-56, in C.J. Humphries (ed.) *Ontogeny and Systematics* (Columbia Univ. Press: New York). [-, 75]

11. **Weston, P.H.** (1989) Problems with the statistical testing of panbiogeographic hypotheses. *New Zealand Journal of Zoology* 16: 511. [0.811, 6]

12. **Weston, P.H.** (1990) Notes on *Boronia* (Rutaceae) in New South Wales, including descriptions of three new species. *Telopea* 4: 121-128. [0.6, 6]

13. **Weston, P.H.** & Johnson, L.A.S. (1991) Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales. *Telopea* 4: 269-306. [0.6, 9]

14. Crisp, M.D. & **Weston, P.H.** (1991) *Almaleea*, a new genus of Fabaceae from south-eastern Australia. *Telopea* 4: 307-311. [0.6, 10]

15. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae), a new genus from New Guinea and eastern Australia. *Telopea* 4: 497-507. [0.6, 12]

16. **Weston, P.H.** (1991) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium*, *Pultenaea* and *Dillwynia* (Fabaceae). Pp. 2-19, 452-455, 456-461, 481-497, 499-504, in G. Harden (ed.) *Flora of New South Wales* vol. 2 (New South Wales Univ. Press: Sydney). [-, 0]

17. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae) and *Almaleea* (Fabaceae). Pp. 29-30, 497-498, in G. Harden (ed.) *op. cit.* [-, 0]

18. **Weston, P.H.** & Porteners, M.F. (1991) *Boronia*, *Eriostemon* and *Phebalium* (Rutaceae). Pp. 227-236, 250-254, 255-263, in G. Harden (ed.) *op. cit.* [-, 0]

19. Porteners, M.F. & **Weston, P.H.** (1991) *Correa* and *Crowea* (Rutaceae). Pp. 247-249, 254-255, in G. Harden (ed.) *op. cit.* [-, 0]

20. Crisp, M.D. & **Weston, P.H.** (1991) *Telopea*. Pp. 30-31, in G. Harden (ed.) *op. cit.* [0.6, 0]

21. Gross, C.L. & **Weston, P.H.** (1992) *Macadamia jansenii* (Proteaceae), a new species from central Queensland. *Australian Systematic Botany* 5: 725-28. [0.75, 7]

22. Crisp, M.D. & **Weston, P.H.** (1993) Geographic and ontogenetic variation in morphology of Australian waratahs (*Telopea*: Proteaceae). *Systematic Biology* 42: 49-76. [14.387, 74]

23. Gilmore, S., **Weston, P.H.**, & Thomson, J.A. (1993) A simple, rapid, inexpensive and widely applicable technique for purifying plant DNA. *Australian Systematic Botany* 6: 139-148. [0.75, 38]

24. **Weston, P.H.** (1993) Key to genera, *Cyrtostylis*, *Cryptostylis*, *Zeuxine*, *Cheirostylis*, *Pseudovanilla*, *Erythrorchis*, *Epipogium*, *Gastrodia*, *Oberonia*, *Liparis*, *Dendrobium*, *Calanthe*, *Phaius*, *Geodorum*, *Dipodium*, *Cymbidium*, *Sarcochilus*, *Rhinerrhiza*, *Peristeranthus*, *Papillilabium*, *Schistotylus*, *Plectorrhiza*, *Taeniophyllum* (Orchidaceae). Pp. 134-138, 218-219, 219-221, 221-233, 236-247, in G. Harden (ed.) *Flora of New South Wales* vol. 4 (New South Wales Univ. Press: Sydney). [-, 0]

25. **Weston, P.H.** & Hill, K.D. (1993) *Bulbophyllum* (Orchidaceae). Pp. 233-236, in G. Harden (ed.) *op. cit.* [-, 0]

26. **Weston, P.H.** & Crisp, M.D. (1994) Cladistic biogeography of Waratahs and their allies (Embothrieae: Proteaceae) across the Pacific. *Australian Systematic Botany* 7: 225-249. [0.75, 72]

27. **Weston, P.H.** (1994) The Western Australian species of subtribe Persooniinae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 6: 51-165. [0.6, 17]

28. **Weston, P.H.** & Johnson, L.A.S. (1994) Three new species of *Persoonia* (Proteaceae) from Queensland. *Telopea* 6: 31-37. [0.6, 1]

29. **Weston, P.H.** (1994) Methods for rooting cladistic trees. Pp. 125-155, in D.J. Siebert, R.W. Scotland and D.M. Williams (eds.) *Models in Phylogeny Reconstruction* (Oxford Univ. Press: Oxford). [-, 36]

30. Crisp, M.D. & **Weston, P.H.** (1995) Mirbelieae. Pp. 245-282, in J.J. Doyle and M.D. Crisp (eds.) *Advances in Legume Systematics Part 7: Phylogeny* (Royal Botanic Gardens: Kew). [-, 36]

31. Crisp, M.D. & **Weston, P.H.** (1995) Subtribe Embothriinae (Proteaceae). *Flora of Australia* 16: 382-390. [-, 0]

32. Crisp, M.D., Linder, H.P. & **Weston, P.H.** (1995) Cladistic biogeography of plants in Australia and New Guinea: congruent pattern reveals two endemic tropical tracks. *Systematic Biology* 44: 457-473. [8.917, 119]

33. Thomson, J.A., **Weston, P.H.** & Tan, M.K. (1995) A molecular approach to tracing the major lineages in *Pteridium*. Pp. 21-28, in R.T. Smith and J.A. Taylor (eds.) *Bracken: an Environmental Issue* (University of Leeds: Leeds). [-, 13]

34. **Weston, P.H.** (1995) Key to the genera of Proteaceae in Australia, Subfamily Persoonioideae, Subfamily Bellendenoideae, Subtribe Gevuininae, Subtribe Hicksbeachiinae. *Flora of Australia* 16: 41-46, 47-125, 125-127, 409-410. [-, 0]

35. Bernhardt, P. & **Weston, P.H.** (1996) The pollination ecology of *Persoonia* (Proteaceae) in eastern Australia. *Telopea* 6: 775-804. [0.6, 46]

36. **Weston, P.H.** & Crisp, M.D. (1996) Trans-Pacific biogeographic patterns in the Proteaceae. Pp. 215-232, in A. Keast & S.E. Miller (eds.) *The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Processes* (SPB Academic Publishing: Amsterdam). [-, 34]

37. **Weston, P.H.** & Johnson, L.A.S. (1997) *Persoonia hindii* (Proteaceae), a new species from the Newnes Plateau, New South Wales. *Telopea* 7: 199-203. [0.6, 5]

38. Jobson, P.C. & **Weston, P.H.** (1998) *Dillwynia glaucula* (Fabaceae: Mirbelieae), a new species from the Southern Tablelands, New South Wales. *Telopea* 8: 1-5. [0.6, 1]

39. **Weston, P.H.** (1999) *Persoonia pauciflora* (Proteaceae), a new species from the Hunter Valley, New South Wales. *Telopea* 8: 159-164. [0.6, 4]

40. Crisp, M.D., Gilmore, S.R. & **Weston, P.H.** (1999) The phylogenetic relationships of two anomalous species of *Pultenaea* (Fabaceae: Mirbelieae) from molecular and morphological data, and description of a new genus. *Taxon* 48: 701-714. [2.447, 19]

41. Jobson, P.C. & **Weston, P.H.** (1999) Two new species of *Dillwynia* (Fabaceae: Mirbelieae), from the Southern Tablelands of New South Wales. *Telopea* 8: 363-369. [0.6, 0]

42. Thomson, J.A., **Weston, P.H.** and Tan, M.K. (1999) A molecular approach to tracing major lineages in *Pteridium*: update and amendment. Pp. 35-36 in J.A. Taylor & R.T. Smith (eds.) *Bracken Fern: Toxicity, Biology and Control* (International Bracken Group: Aberystwyth). [-, 1]

43. **Weston, P.H.** (2000) Process morphology from a cladistic perspective. Pp. 124-144 in R. Scotland & T. Pennington (eds.) *Homology and Systematics: Coding Characters for Phylogenetic Analysis* (Taylor & Francis: Basingstoke). [-, 25]

44. Indsto, J. & **Weston, P.H.** (2000) Near-ultraviolet reflectance in *Dendrobium* (Orchidaceae). Pp. 326-334 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 5]

45. Kores, P.J., **Weston, P.H.**, Molvray, M., & Chase, M.W. (2000) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 449-456 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 60]

46. Savolainen, V., Fay, M.F., Albach, D.C., Backlund, A., van der Bank, M., Cameron, K.M., Johnson, S.A., Lledo, M.D., Pintaud, J.-C., Powell, M., Sheahan, M.C., Soltis, D.E., Soltis, P.S., **Weston, P.H.**, Whitten, W.M., Wurdack, K.J., & Chase, M.W., (2000) Phylogeny of the eudicots: a nearly complete familial analysis based on *rbc*L gene sequences. *Kew Bulletin* 55: 257-309. [0.577, 451]

47. Crisp, M.D. & **Weston, P.H.** (2000) *Telopea* (Proteaceae) Pp. 115-117 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

48. **Weston, P.H.** (2000) *Persoonia* (Proteaceae) Pp. 89-105 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

49. **Weston, P.H.** & Crisp, M.D. (2000) *Alloxylon* (Proteaceae) P. 115 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

50. Hill, R.S. & **Weston, P.H.** (2001) Southern (austral) ecosystems. Pp. 361-370 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* vol. 5 (Academic Press: San Diego). [-, 1]

51. Kores, P.J., Molvray, M., **Weston, P.H.**, Hopper, S.D., Brown, A., Cameron, K.M., and Chase, M.W (2001) A phylogenetic analysis of Diurideae (Orchidaceae) based on plastid DNA sequence data. *American Journal of Botany* 88: 1903-1914. [3.05, 129]

52. Jobson, P.C. & **Weston, P.H.** (2001) *Dillwynia rupestris* (Fabaceae: Mirbelieae), a new species from the New England Tableland of New South Wales. *Telopea* 9: 323-327. [0.6, 0]

53. Barker, N.P., **Weston, P.H.**, Rourke, J.P., & Reeves, G. (2002) The relationships of the southern African Proteaceae as elucidated by internal transcribed spacer (ITS) DNA sequence data. *Kew Bulletin* 57: 867-883. [0.577, 32]

54. Mant, J.G., Schiestl, F.P., Peakall, R., & **Weston, P.H.** (2002) A phylogenetic study of pollinator conservatism among sexually deceptive orchids. *Evolution* 56: 888-898. [4.201, 92]

55. **Weston, P.H.** (2002) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium* (Fabaceae), Pp. 3-20, 622-632 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

56. **Weston, P.H.** & Duretto, M.F. (2002) *Boronia* (Rutaceae). Pp. 265-276 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 3]

57. **Weston, P.H.** & Harden, G.J. (2002) *Correa, Philotheca*, *Eriostemon, Crowea, Phebalium, Nematolepis*, *Leionema* (Rutaceae) Pp. 289-310, in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 4]

58. **Weston, P.H.** & Jobson, P.C. (2002) *Dillwynia* (Fabaceae). Pp. 542-549 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

59. **Weston, P.H.** & de Kok, R. (2002) *Pultenaea* (Fabaceae). Pp. 549-565 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 1]

60. **Weston, P.H.** & Kooyman, R.M. (2002) Systematics of *Eidothea* (Proteaceae), with the description of a new species, *E. hardeniana*, from the Nightcap Range, north-eastern New South Wales. *Telopea* 9: 821-832. [0.6, 15]

61. Bernhardt, P., Sage, T., **Weston, P.H.**, Azuma, H., Lam, M., Thien, L.B., & Bruhl, J. (2003) The pollination of *Trimenia moorei* (Trimeniaceae): floral volatiles, insect/wind pollen vectors, and stigmatic self-incompatibility in a basal angiosperm. *Annals of Botany* 92: 445-458. [4.041, 81]

62. Qiu, H. & **Weston, P.H.** (2003) Proteaceae. *Flora of China* 5: 192-199 (Science Press: Beijing and Missouri Botanical Garden Press: St Louis). [-, 0]

63. Thien, L.B., Sage, T.L., Jaffré, T., Bernhardt, P., Pontieri, V., **Weston, P.H.**, Malloch, D., Azuma, H., Graham, S.W., McPherson, M.A., Rai, H.S., Sage, R.F., & Duprey, J.-L. (2003) The population structure and floral biology of *Amborella trichopoda* Baillon (Amborellaceae). *Annals of the Missouri Botanical Garden* 90: 466-490. [2.838, 71]

64. Mill, R.R. & **Weston, P.** (2004). Proposals to reject the names *Polypodiopsis* and *Polypodiopsis muelleri* (*Plantae vasculares, incertae sedis*). *Taxon* 53: 203-205. [2.447, 2]

65. **Weston, P.H.** (2004) Proteaceae. Pp. 313-316 in N. Smith, S.A. Mori, A. Henderson, D.W. Stevenson & S.V. Heald (eds.) *Flowering Plants of the Neotropics* (The New York Botanical Garden and Princeton University Press: Princeton). [-, 0]

66. **Weston, P.H.** & Turton, M. (2004) *Phebalium bifidum* (Rutaceae), a new species from the Capertee Valley, New South Wales. *Telopea* 19: 787–792. [0.6, 2]

67. Entwisle, T.J. & **Weston, P.H.** (2005) Majority rules, when systematists disagree. *Australian Systematic Botany* 18: 1–6. [0.75, 28]

68. Indsto, J.O., **Weston, P.H.**, Clements, M.A. & Whelan, R.J. (2005) Highly sensitive DNA fingerprinting of orchid pollinia remnants using AFLP. *Australian Systematic Botany* 18: 207–213. [0.75, 9]

69. Jordan, G.J., Dillon, R.A. & **Weston, P.H.** (2005) Solar radiation as a factor in the evolution of scleromorphic leaf anatomy in Proteaceae. *American Journal of Botany* 92: 789–796. [3.05, 92]

70. Kurzweil, H., **Weston, P.H.** & Perkins, A.J. (2005) Morphological and ontogenetic studies on the gynostemium of some Australian members of Diurideae and Cranichideae (Orchidaceae). *Telopea* 11: 11–33. [0.6, 9]

71. Mant, J., Bower, C.C., **Weston, P.H.** & Peakall, R. (2005) Phylogeography of pollinator-specific sexually deceptive *Chiloglottis* taxa (Orchidaceae): evidence for sympatric divergence? *Molecular Ecology* 14: 3067–3076. [6.086, 27]

72. Mant, J., Peakall, R. & **Weston, P.H.** (2005) Specific pollinator attraction and the diversification of sexually deceptive *Chiloglottis* (Orchidaceae). *Plant Systematics and Evolution* 253: 185–200. [1.239, 33]

73. Mant, J., Brown, G.R. & **Weston, P.H.** (2005) Opportunistic pollinator shifts among sexually deceptive orchids indicated by a phylogeny of pollinating and non-pollinating thynnine wasps (Tiphiidae). *Biological Journal of the Linnean Society* 86: 381–395. [2.288, 16]

74. Rymer, P.D., Whelan, R.J., Ayre, D.J. & **Weston, P.H.** (2005) Reproductive success and pollinator effectiveness differ in common and rare *Persoonia* species (Proteaceae). *Biological Conservation* 123: 521–532. [4.022, 50]

75. **Weston, P.H.**, Perkins, A.J., & Entwisle, T.J. (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15. [-, 30]

76. **Weston, P.H.** & Barker, N.P. (2006) A new suprageneric classification of the Proteaceae, with an annotated checklist of genera. *Telopea* 11(3): 314-344. [0.6, 81]

77. Indsto, J.O., **Weston, P.H.**, Clements, M.A., Dyer, A.G., Batley, M. & Whelan, R.J. (2006) Pollination of *Diuris maculata* (Orchidaceae) by male *Trichocolletes venustus* bees. *Australian Journal of Botany* 54: 669-679. [0.793, 35]

78. **Weston, P.H.** (2007) Proteaceae. Pp. 364-404 in K. Kubitzki (ed.) *Families and Genera of Vascular Plants* Volume IX (Springer Verlag: Berlin). [-, 26]

79. **Weston, P.H.** (2007) Proteaceae. Pp. 268-269 in V.H. Heywood, R.K. Brummitt, A. Culham & O. Seberg (eds.) *Flowering Plant Families of the World* (Royal Botanic Gardens, Kew: London). [-, 0]

80. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2007) Floral phyllotaxis and floral architecture in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 168: 285–306. [1.748, 33]

81. Indsto, J.O., **Weston, P.H.**, Clements, M., Dyer, A., Batley, M. & Whelan, R. (2007) Generalised pollination of *Diuris alba* R.Br. (Orchidaceae) by small bees and wasps. *Australian Journal of Botany* 55: 628-634. [0.793, 15]

82. Barker, N.P., **Weston, P.H.**, Rutschmann, F. & Sauquet, H. (2007) Molecular dating of the "Gondwanan" plant family Proteaceae is only partially congruent with the timing of Gondwanan break-up. *Journal of Biogeography* 34: 2012-2027. [4.248, 157]

83. Jordan, G.J., **Weston, P.H.**, Carpenter, R.J., Dillon, R.A. & Brodribb, T.J. (2008) The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae. *American Journal of Botany* 95:521-530. [3.05, 74]

84. Mast, A.R., Willis, C.L., Jones, E.H., Downs, K.M., & **Weston, P.H.** (2008) A smaller *Macadamia* from a more vagile tribe: Inference of phylogenetic relationships and divergence times in *Macadamia* and relatives (tribe Macadamieae; Proteaceae). *American Journal of Botany* 95: 843-870. [3.05, 53]

85. Sauquet, H., **Weston, P.H.**, Anderson, C.L., Barker, N.P. Cantrill, D.J., Mast, A.R., & Savolainen, V. (2009) Contrasted patterns of hyperdiversification in Mediterranean hotspots. *Proceedings of the National Academy of Sciences of the U.S.A.* 106: 221-225. [9.661, 161]

86. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2009) Comparative gynoecium structure and development in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 170: 21-41. [1.748, 21]

87. Sage, T.L., Hristova-Sarkovsi, K., Koehl, V., Lyew, J., Pontieri, V., Bernhardt, P., **Weston, P.**, Bagha, S., & Chiu, G. (2009) Transmitting tissue architecture in relictual-basal angiosperms: implications for transmitting tissue origins. *American Journal of Botany* 96: 183-206. [3.05, 31]

88. Crisp, M.D., Arroyo, M.T.K., Cook, L.G., Gandolfo, M.A., Jordan, G.J., McGlone, M.S., **Weston, P.H.**, Westoby, M., Wilf, P., & Linder, H.P. (2009) Phylogenetic biome conservatism on a global scale. *Nature* 458: 754-758. [40.137, 441]

89. Indsto, J.O., **Weston, P.H.**, & M.A. Clements (2009) A molecular phylogenetic analysis of *Diuris* (Orchidaceae) based on AFLP and ITS reveals three major clades and a basal species. *Australian Systematic Botany* 22: 1-15. [0.75, 6]

90. Sauquet, H., **Weston, P.H.**, Barker, N.P. Anderson, C.L., Cantrill, D.J. & Savolainen, V. (2009) Using fossils and molecular data to reveal the origins of the Cape proteas (subfamily Proteoideae). *Molecular Phylogenetics and Evolution* 51: 31-43. [4.419, 38]

91. Rossetto, M., Thurlby, K.A.G., Offord, C.A., Allen, C.B., & **Weston, P.H.** (2011) The impact of distance and a shifting temperature gradient on genetic connectivity across a heterogeneous landscape. *BMC Evolutionary Biology* 11(126):1-11. [3.221, 17]

92. Byrne, M., Steane, D., Joseph, L., Yeates, D., Jordan, G.J., Crayn, D., Aplin, K., Cantrill D., Cook, L.G., Crisp, M.D., Keogh, J.S., Melville, J., Moritz, C., Porch, N., Sniderman, J.M.K., Sunnucks P., & **Weston, P.H.** (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. *Journal of Biogeography* 38: 1635–1656. [4.590, 187]

93. Mast, A.R., Milton, E.F., Jones, E.H., Barker, R.M., Barker, W.R., & **Weston, P.H.** (2012) Time-calibrated phylogeny of the woody Australian genus *Hakea* (Proteaceae) supports multiple origins of insect-pollination among bird-pollinated ancestors. *American Journal of Botany* 99: 472-487. [3.05, 28]

94. Stimpson, M.L., **Weston, P.H.**, Telford, I.R.H., & Bruhl, J.J. (2012) First instalment in resolution of the *Banksia spinulosa* complex (Proteaceae): *B. neoanglica*; a new species supported by phenetic analysis, ecology and geography. *Phytokeys* 14: 57–80. [0.686, 6]

95. Rossetto, M., Allen, C., Thurlby, K., **Weston, P.H.**, & Milner, M. (2012) Genetic structure and bio-climatic modelling support allopatric over parapatric speciation along a latitudinal gradient. *BMC Evolutionary Biology* 12:149. [3.221, 12]

96. Clark, V.R., Perera, S.J., Stiller, M., Stirton, C.H., **Weston, P.H.**, Stoev, P., Coombs, G., Morris, D., Ratnayake-Perera, D., Barker, N.P., & MacGregor, G.K. (2012) A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation. *SpringerPlus* 1:56 [0.982, 3]

97. Milner, M.L., Rossetto, M., Crisp, M.D., & **Weston, P.H.** (2012) The impact of multiple biogeographic barriers and hybridization on species-level differentiation. *American Journal of Botany* 99: 2045–2057. [3.05, 13]

98. Ford, A.J. & **Weston, P.H.** (2012) A taxonomic revision of *Hollandaea* Anon. (Proteaceae). *Austrobaileya* 8: 670-687. [-, 0]

99. Hidayat, T., **Weston, P.H.**, Yukawa, T., Ito, M., & Rice, R. (2012) Phylogeny of subtribe Aeridinae (Orchidaceae) inferred from DNA sequences data: advanced analyses including Australasian genera. *Jurnal Teknologi (Sciences and Engineering)* 59 (suppl. 1): 87-95. [0.096, 4]

100. **Weston, P.H.** & Hill, R.S. (2013) Southern (austral) ecosystems. Pp. 612-619 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* second edition, vol. 6 (Academic Press: Waltham, MA). [-, 9]

101. Jordan, G.J., Brodribb, T.J., Blackman, C.J., & **Weston, P.H.** (2013) Climate drives vein anatomy in Proteaceae. *American Journal of Botany* 100: 1483-1493.
[3.05, 16]

102. **Weston, P.H.** & Woods, L.A. (2013) Correction of a typographical error in the protologue of *Banksia conferta* A.S.George var. *penicillata* A.S. George. *Telopea* 15: 67–69. [0.6, 0]

103. Milner, M.L., McIntosh, E.J., Crisp, M.D., **Weston, P.H.**, & Rossetto, M. (2013) Microsatellite variation for phylogenetic, phylogeography and population genetic studies in *Lomatia* (Proteaceae). *Australian Systematic Botany* 26: 186-195. [0.75, 2]

104. **Weston, P.H.** (2014) What has molecular systematics contributed to our knowledge of the Proteaceae? Pp. 365-397 in P. Besse (ed.) *Molecular Plant Taxonomy: Methods and Protocols*, *Methods in Molecular Biology*, vol. 1115 (Springer: New York). [-, 11]

105. McIntosh, E., Rossetto, M., **Weston, P.H.**, & Wardle, G. (2014) Maintenance of strong morphological differentiation despite ongoing natural hybridization between sympatric species of *Lomatia* (Proteaceae). *Annals of Botany* 113: 861-872. [4.041, 15]

106. Stimpson, M.L., Bruhl, J.J. & **Weston, P.H.** (2014) Could this be Australia's rarest *Banksia*? *Banksia vincentia* (Proteaceae), a new species known from fourteen plants from south-eastern New South Wales, Australia. *Phytotaxa* 163: 269–286. [1.24, 1]

107. Thomas, N., Bruhl, J.J., Ford, A., & **Weston, P.H.** (2014) Molecular dating of Winteraceae reveals a complex biogeographic history involving both ancient Gondwanan vicariance and long-distance dispersal. *Journal of Biogeography* 41: 894-904. [4.590, 23]

108. **Weston, P.H.**, Perkins, A.J., Indsto, J.O., & Clements, M.A. (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier, R. & P. Bernhardt (eds.) *Darwin's Orchids: Then and Now* (University of Chicago Press: Chicago). [-, 7]

109. Kooyman, R.M., Wilf, P., Barreda, V.D., Carpenter, R.J., Jordan, G.J., Sniderman, J.M.K., Allen, A., Brodribb, T.J., Crayn, D., Feild, T.S., Laffan, S.W., Lusk, C., Rossetto, M., & **Weston, P.H.** (2014) Paleo-Antarctic rainforest into the modern Old World tropics: the rich past and threatened future of the 'southern wet forest survivors'. *American Journal of Botany* 101: 2121 – 2135. [3.05, 33]

110. Lambers, H., Clode, P., Hawkins, H.-J., Laliberté, E., Oliveira, R., Reddell, P., Shane, M.W., Stitt, M., & **Weston, P.H.** (2015) Metabolic adaptations of the non-mycotrophic Proteaceae to soil with a low phosphorus availability. *Annual Plant Reviews* 48: 289–336 (Plaxton, W.C. & Lambers, H. (eds.) *Phosphorus Metabolism in Plants in the Post-genomic Era: From Gene to Ecosystem* (Wiley-Blackwell Publishing: Chichester, UK)). [-,19]

111. Mast, A.R., Olde, P., Makinson, R.O., Jones, E., Kubes, A., Miller, E. & **Weston, P.H.** (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646. [3.05, 12]

112. Thiele, K.R., **Weston, P.H.** & Mast, A.M. (2015) Paraphyly, modern systematics and the transfer of *Dryandra* into *Banksia* (Proteaceae): a response to George. *Australian Systematic Botany* 28: 194–202 [0.75, 1]

113. Milner, M.L., **Weston, P.H.,** Rossetto, M., & Crisp, M.D., (2015) Biogeography of the Gondwanan genus *Lomatia* (Proteaceae): vicariance at continental and intercontinental scales. *Journal of Biogeography* 42: 2440–2451. [4.590, 7]

114. Stimpson, M.L., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (2016) A morphometric analysis of the *Banksia spinulosa* complex (Proteaceae) and its complex taxonomic implications. *Australian Systematic Botany* 29: 55-86. [0.75, 0]

115. Onstein, R.E., Jordan, G.J., Sauquet, H., **Weston, P.H.**, Bouchenak-Khelladi, Y., Carpenter, R.J., & Linder, H.P. (2016) Evolutionary radiations of Proteaceae are triggered by the interaction between traits and climates in open habitats. *Global Ecology and Biogeography* 25: 1239–1251. [6.045, 9].

116. van der Merwe, M., Crayn, D., Ford, A., Rossetto, M., & **Weston, P.H.** (2016) Evolution of Australian *Cryptocarya* (Lauraceae) based on nuclear and plastid phylogenetic trees: evidence of recent landscape-level disjunctions *Australian Systematic Botany* 29: 157–166. [0.75, 2]

117. Citerne, H., Reyes, E., Le Guilloux, M., Delannoy, E., Sannier, J., Simmonet, F., Sauquet, H., Nadot, S., **Weston, P.H.**, & Damerval, C. (2017) Characterisation of CYCLOIDEA-like genes in Proteaceae, a basal eudicot family with multiple shifts in floral symmetry. *Annals of Botany* 119: 367-378. [4.041, 7]

118. **Weston, P.H.**, & Jordan, G.J. (2017) Evolutionary biogeography of the Australian flora in the Cenozoic Era. Pp. 40-62 in D.A. Keith (ed.) *Australian Vegetation*, 3rd edition (Cambridge University Press: Cambridge). [-, 0]

119. Cardillo, M., **Weston, P.H.**, Reynolds, Z., Olde, P.M., Mast, A.R., Lemmon, E., Lemmon, A. & Bromham, L. (2017) The phylogeny and biogeography of *Hakea* (Proteaceae) reveals the role of biome shifts in a continental plant radiation. *Evolution* 71: 1928–1943. [4.201, 1]

120. Holmes, G., **Weston, P.H.**, Murphy, D., Gardner, S., Connelly, C., & Cantrill, D.J. (2018) The genealogy of geebungs: phylogenetic analysis of *Persoonia* (Proteaceae) and related genera in subfamily Persoonioideae. *Australian Systematic Botany* 31: 166–189. [0.75, 0]

121. **Weston, P.H.** (in review) Proteaceae. *Flora of North America North of Mexico* 10-11 (Oxford University Press: New York and Oxford). [-,-]

122. Steenbeeke, G., Dowle, M., Laurence, M.H., Liew, E.C.Y., Newby, Z.-J., Renner, M., Sommerville, K., Weston, P.H., Ward, S. (in review) Phylogeny of selected *Microtis* (Orchidaceae) in south eastern Australia and its implications for taxonomy and conservation priorities. *Telopea* [0.6, -]

Conference Abstracts

1. **Weston, P.H.** (1984) A reappraisal of Nelson's direct method of character analysis. P. 9, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

2. Wilson, P.G. & **Weston, P.H.** (1984) A preliminary cladistic analysis of the *Metrosideros* suballiance (Myrtaceae). P. 19, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

3. **Weston, P.H.** (1984) Drifting waratahs or continents? P. 9, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

4. Crisp, M.D. & **Weston, P.H.** (1984) Waratahs – one species or two? P. 5, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

5. **Weston, P.H.** (1988) Problems with the statistical testing of panbiogeographic hypotheses. Abstracts, Symposium on *Panbiogeography of New Zealand*, Wellington.

6. **Weston, P.H.** (1989) Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae. P. 37, Program and Abstracts, Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney.

7. **Weston, P.H.** & Crisp, M.D. (1990) Transoceanic cladistic patterns in the Proteaceae. P. 51, Abstracts, *Systematics and Biogeography of the Austral Biota*, IXth meeting of the Willi Hennig Society, Canberra.

8. **Weston, P.H.** (1993) Direct methods for polarising character transformation series. P. 13, Programme and Abstracts, *Models in Phylogeny Reconstruction*, a joint conference of The Systematics Association and The Linnean Society, London.

9. Crisp, M.D., Linder, H.P., & **Weston, P.H.** (1994) Cladistic biogeography of Australia: is there more than one endemic tropical track? P. 14, Program and Abstracts, *Origin and Evolution of the Flora of the Monsoon Tropics*, a symposium of the Australian Systematic Botany Society, Kuranda.

10. **Weston, P.H.** (1996) ITS sequence variation in the Proteaceae and what it tells us about phylogeny. P. 49, Abstracts, *An International Symposium on the Biology of Proteaceae*, Melbourne.

11. **Weston, P.H.** (1997) Rolf Sattler's plant morphology and cladistic analysis. P. 54, Abstracts, *First Biennial International Conference of the Systematic Association*, Oxford, U.K..

12. **Weston, P.H.** & Crisp, M.D. (1997) Cladistic biogeography of a key woody group: Proteaceae. P. 5, Abstracts, *II Southern Connection Congress*, Valdivia, Chile.

13. Kores, P.J., Molvray, M., **Weston, P.H.**, & Chase, M.W. (1998) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 33-34, Abstracts. Monocots II Conference, Sydney.

14. **Weston, P.H.** (1999) Historical biogeography of Proteaceae. Abstracts, XVI International Botanical Congress, Saint Louis.

15. **Weston, P.H.** (2002) Proteaceae: Brown and now. P. 16, Abstracts, Robert Brown 200 Conference, Sydney.

16. Mant, J.G., **Weston, P.H.**, Peakall, R., & Schiestl, F.P. (2003) Coevolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators. P. 55, Abstracts, *Monocots III*, The Third International Conference on the Comparative Biology of the Monocotyledons, Ontario, U.S.A..

17. **Weston, P.H.,** Clements, M.A., Indsto, J.O., Mant, J., Peakall, R., & Perkins, A.J. (2005) Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae). XVII International Botanical Congress, Vienna.

18. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2006) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 39 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

19. **Weston, P.H.** (2006) A new suprageneric classification of the Proteaceae. P. 45 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

20. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K.. (2006). Floral architecture and phyllotaxis in Calycanthaceae (Laurales). Abstract 192, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

21. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2006). A phylogenetic approach to the evolution of pollen morphology in Proteaceae (Proteales). Abstract 405, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

2. Milton, E.F., **Weston, P.H.**, Mast, A. (2006) The diversification of ecologically significant traits in the species-rich Australian genus *Hakea* (Proteaceae). Abstract 324, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

23. Mast, A., **Weston, P.H.**, Jones, E., Sauquet, H., Cantrill, D., Jordan, G., & Barker, N. . (2006) The timing of disjunctions in the southern hemisphere family Proteaceae: Sensitivity analysis with 6 genes, multiple calibration points, and 70+ genera. Abstract 327, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

24. Willis, C.L., **Weston, P.H.**, & Mast, A. (2007) Inference of phylogenetic relationships in *Macadamia* and relatives (tribe Macadamieae; Proteaceae) using three chloroplast and three nuclear DNA regions. Abstract 1677, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

25. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K. (2007) Structure and development of the gynoecium in Calycanthaceae (Laurales). Abstract 1121, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

26. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). Abstract 1593, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

27. Milton, E.F., **Weston, P.H.**, Barker, W., Barker, R., & Mast, A. (2007) Inference of phylogenetic relationships in *Hakea* (Proteaceae) using morphology and four chloroplast and three nuclear DNA regions. Abstract 1712, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

28. Kubes, A., **Weston, P.H.**, Makinson, R.O., Olde, P., & Mast, A.R. (2007) Resolving relationships in *Grevillea* (Proteaceae), the third largest Australian plant genus. Abstract 1814, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

29. **Weston, P.H.**, Barker, N.P., Rutschmann, F., & Sauquet, H. (2007) 'I'm not dead yet' – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation). P. 76, Conference Program, 5th International Southern Connection Congress, Adelaide.

30. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 58, Conference Program, 5th International Southern Connection Congress, Adelaide.

31. Mast, A., Jones, E., Barker, R., Barker, W., **Weston, P.H.** (2009) The phylogeny and age of the woody Australian genus *Hakea* (Proteaceae) and the evolution of its leaf and fire persistence features. Abstract 335, Botany & Mycology 2009 (Botanical Society of America conference, Snowbird, Utah)

32. Holmes, G.D., Porter, C., Murphy, D.J., **Weston, P.H.** and Cantrill, D.J. (2009) What are the relationships among Snottygobbles and Geebungs? A preliminary phylogeny of *Persoonia* (Proteaceae). P 45, Conference Booklet, *Systematic Botany: from Science to Society*, a conference of the Australian Systematic Botany Society, Armidale.

33. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests. P. 29, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

34. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Cladistic biogeography, molecular dating, fossils and the Proteaceae. P. 18, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

35. Baum, M., Crisp, M., Rossetto, M. & **Weston, P.** (2010) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 20, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

36. **Weston, P.H.** (2010) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 68, *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*, a conference of the Australian Systematic Botany Society, Lincoln University, New Zealand.

37. **Weston, P.H.** (2011) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 34, Abstracts 2nd Book, *Plants in a Changing World*, (37th annual conference of the South African Association of Botanists, Rhodes University, South Africa).

38. **Weston, P.H.**, Indsto, J.O., Perkins, A.J., Clements, M.A., & Peakall, R. (2011) Total evidence phylogenetic analysis of the orchid tribe Diurideae and what it tells us about the evolution of pollination systems. P. 152, Abstract Book, XVIII International Botanical Congress, Melbourne.

39. **Weston, P.H.**, Wilson, P.G., Conn, B.J., Rymer, P.D. (2011) Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations. P. 266, Abstract Book, XVIII International Botanical Congress, Melbourne.

40. Nguyen, C.H., Beattie, G.A.C., Holford, P., Mabberley, D.J., & **Weston, P.H.** (2011) Determining the origin and diversification of *Murraya paniculata*: one or more species? P. 354, Abstract Book, XVIII International Botanical Congress, Melbourne.

41. Milner, M., Crisp, M.D., Rossetto, M., & **Weston, P.H.** (2011) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 281, Abstract Book, XVIII International Botanical Congress, Melbourne.

42. **Weston, P.H.** (2012) Contested, uncontested and potentially controversial taxonomic changes in the Proteaceae: how do they differ? P. 49, Program and Abstracts, *Local Knowledge, Global Delivery* (Australasian Systematic Botany Society 2012 Perth Conference Committee: Perth).

43. **Weston, P.H.,** Jones, E.H., Olde, P.M., Makinson, R.O., & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 101, *Genetics in the Harbour City* (Program and abstracts of the annual conference of the Genetics Society of Australasia, Sydney).

44. Onstein, R., Jordan, G., Bouchenak-Khelladi, Y., Xing, Y., Wright, I., Sauquet, H., Carpenter, R., **Weston, P.** & Linder, P. (2013) Leaf trait evolution in the Proteaceae. P. 11, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

45. Cantrill, D.J., Lewis, E., Murphy, D.J. & **Weston, P.H.** (2013) Variation in pollen morphology within *Persoonia* (Proteaceae) supports clades revealed by molecular data. P. 19, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

46. **Weston, P.H.**, Jones, E.H., Olde, P.M., Makinson, R.O. & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 20,

Systematics Without Borders (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

47. Schulte, K., Micheneau, C., Simpson, L., **Weston, P.**, Crayn, D. & Clements, M. (2013) The *Dendrobium* alliance revisited: A molecular phylogenetic approach towards reconciling taxonomic concepts in Dendrobiinae (Orchidaceae). P. 32, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

48. Stimpson, M.L., Prychid, C.J., **Weston, P.H.** Whalley, R.D.B. & Bruhl, J.J. (2013) Structure and function of the cotyledonary node in the *Banksia spinulosa* complex (Proteaceae). P. 68, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

49. **Weston, P.H.** (2014) Problems and progress in plant systematics since Nancy Burbidge. P. 17, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

50. Thomas, N., Bruhl, J., Ford, A. & **Weston, P.** (2014) Molecular dating of Winteraceae reveals a complex biogeographical history involving both ancient Gondwanan vicariance and long-distance dispersal. P. 28, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

51. **Weston, P.H.** Reyes, E. & Sauquet, H. (2015) A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution. P. 35, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

52. Schulte, K., Micheneau, C., Field, A., **Weston, P.**, Crayn, D. & Clements, M. (2015) The *Dendrobium* alliance revisited: examining macroevolutionary patterns in Dendrobiinae (Orchidaceae). P. 30, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

53. Thiele, K., Barker, W.R., Crayn, D.M., Waycott, M., Holland, A., Breitwieser, I., Lockhart, P., Bayly, M., **Weston, P.H.**, & Schulte, K. (2015) Progress towards a decadal plan for Australasian biodiversity science – an update. P. 33, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

Articles in Magazines, Newsletters, etc.

1. Weston, P.H. (1988c) Proteaceae. Australian Plants 14: 259.

2. Weston, P.H. (1988d) The flower - part 2. *Australian Plants* 14: 262-263.

3. Weston, P.H. (1992) A special tree [an article about *Idiospermum australiense*]. *Friends of the Royal Botanic Gardens Newsletter* 14: 4.

4. Weston, P.H. & Crisp, M.D. (1995) Phylogenetic analysis. *Australasian Biotechnology* 5(5): 291-293.

5. Weston, P.H. (1998) Lust, lies and fungus flies. *The Gardens* 39: 8-9.

6. Weston, P.H. (2000) Flower wasps and bird orchids. *The Gardens* 44: 5.

7. Weston, P.H. (2000) An intriguing case of snottygobbles. *The Gardens* 44: 11.

8. Weston, P.H. (2001) The Nightcap Oak comes out of the bush and into the spotlight. *The Gardens* 50: 6.

9. Weston, P.H. (2001) New tree species discovered in Australia. *Forest Genetic Resources* 29: 26.

10. Weston, P.H. & Kooyman, R.M. (2002) *Eidothea hardeniana*: botany and ecology of the 'Nightcap Oak'. *Australian Plants* 21: 339-342, 344.

11. Weston, P.H. (2003) Proteaceae subfamily Persoonioideae: botany of the geebungs, snottygobbles and their relatives. *Australian Plants* 22: 62-78, 91.

12. Weston, P.H. (2005) Sex and Death in the Sydney Tropical Centre. *The Gardens* 65: 6-7, republished in re-edited form in *Australian Orchid Review* 70(5): 32-33.

14. Weston, P.H. (2009) From the President. *ASBS Newsletter* 141: 1-3.

15. Weston, P.H. (2010) Madagascar: a world of botanical wonders. *The Gardens* 84: 10-11.

16. Weston, P.H. (2010) From the President. *ASBS Newsletter* 142: 1.

17. Weston, P.H. (2010) From the President. *ASBS Newsletter* 143: 1-3.

18. Weston, P.H. (2010) From the President. *ASBS Newsletter* 144-145: 1.

19. Weston, P.H. (2010) ASBS President's Report 2009–2010. *ASBS Newsletter* 144-145: 4-6.

20. Weston, P.H. (2010) Life Membership awarded to John Clarkson. *ASBS Newsletter* 144-145: 16.

21. Weston, P.H. (2010) ASBS 2010 Conference Report, Lincoln, Canterbury, New Zealand. *ASBS Newsletter* 144-145: 17-21.

22. Weston, P.H. (2011) From the President. *ASBS Newsletter* 146: 1-2.

23. Weston, P.H. (2011) From the President. *ASBS Newsletter* 147-148: 1-3.

24. Weston, P.H. (2011) Award of Nancy T. Burbidge Medals to Professors Pauline Ladiges and Michael Crisp. *ASBS Newsletter* 147-148: 3-8.

25. Weston, P.H. (2011) The ARC-ERA journal ranking project has been aborted. *ASBS Newsletter* 147-148: 11-12.

26. Weston, P.H. (2011) Recent advances and new developments in biogeographical reconstruction methods. *ASBS Newsletter* 147-148: 14.

27. Weston, P.H. (2011) [Book review of] The Flowering of Australia's Rainforests: A Plant and Pollination Miscellany. By Geoff Williams and Paul Adam. *ASBS Newsletter* 147-148: 21-23.

28. Weston, P.H. (2011) From the President. *ASBS Newsletter* 149: 1-2.

29. Weston, P.H. (2011). ASBS President's Report 2010-2011. *ASBS Newsletter* 149: 4-7.

30. Weston, P.H. (2012) From the President. *ASBS Newsletter* 150: 1-2.

31. Weston, P.H. (2012) New proposals to change ASBS rules. *ASBS Newsletter* 150: 4-10.

32. Weston, P.H. (2012) From the President. *ASBS Newsletter* 151: 1-2.

33. Weston, P.H. (2012) A remarkable botanical find: the double discovery of *Danhatchia australis* in Australia. *The Gardens* 94: 27.

34. Weston, P.H. (2012) From the President. *ASBS Newsletter* 152: 1-2.

35. Weston, P.H. (2013) Exploring southern Africa. *The Gardens* 96: 18-19.

36. Weston, P.H. (2013) ASBS President's Report 2011-2012. *ASBS Newsletter* 153: 7-10.

37. Weston, P. (2013) Not an exact science. *Sydney Morning Herald,* 19 June 2013: 19.

38. Weston, P.H. (2015) Funding research. *The Gardens* 103:33.

39. Weston, P.H. (2016) Building a database of floral characters for researching the iconic Australian plant family Proteaceae. Report to the Winston Churchill Memorial Trust (https://www.churchilltrust.com.au/media/fellows/Weston_P_2014_Building_a_database_of_floral_characters_of_Proteaceae.pdf).

Strategic assessment for Cumberland Plain Conservation Plan Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Western Sydney Aerotropolis Growth Area, and Greater Penrith to Eastern Creek Urban Release Investigation Area

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1. Introduction

1.1 Purpose of the expert report

I was engaged by the Department of Planning and Envionment in September 2018, to produce an expert report on the distribution and abundance of *Grevillea juniperina* subsp. *juniperina* (Proteaceae) within the proposed Western Sydney Aerotropolis Growth Area, and Greater Penrith to Eastern Creek Urban Release Investigation Area (collectively termed "the study area"). This immediately followed my submission of a similar report on the same species for the Greater Macarthur and Wilton Growth Areas (Weston unpublished) The aim of this exercise was to assess whether *G. juniperina* subsp. *juniperina* is native to either of the Growth Areas and, if so, to assess where suitable habitat is located and to estimate the area occupied by *G. juniperina* subsp. *juniperina* in the study area and within the development footprint.

According to Section 6.5.2 of the Biodiversity Assessment Method, an expert report must:
- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- estimate the number of individuals or area of habitat (whichever unit of measurement applies to the species/individual) for the biodiversity certification assessment area, including a description of how the estimate was made
- demonstrate what information was considered, rejected and discounted in relation to the determination made in the expert report, and
- identify the expert and provide evidence of their expert credentials.

1.2 Project context

The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney, including the two growth areas that define the geographic scope of this report: the Western Sydney Aerotropolis Growth Area and the Greater Penrith to Eastern Creek Urban Release Investigation Area. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

1.3 Study area

The study area is located in the western to south western part of the Sydney Metropolitan Area, between latitudes 33.712°S and 33.941°S and longitudes 150.654°E and 150.857°E (figure 1).

1.4 Reasons for use of expert report

Grevillea juniperina subsp. *juniperina* is represented by numerous collections and observations within the Greater Penrith to Eastern Creek Urban Release Investigation Area, and from at least one observation in the Western Sydney Aerotropolis Growth Area. *G. juniperina* subsp. *juniperina* is a perennial shrub that is readily recognised at any time of year by its distinctive vegetative morphology. Conventional surveying would therefore be the most appropriate way to test for its presence, if unlimited access to the study area were allowed. Although sizeable blocks of the

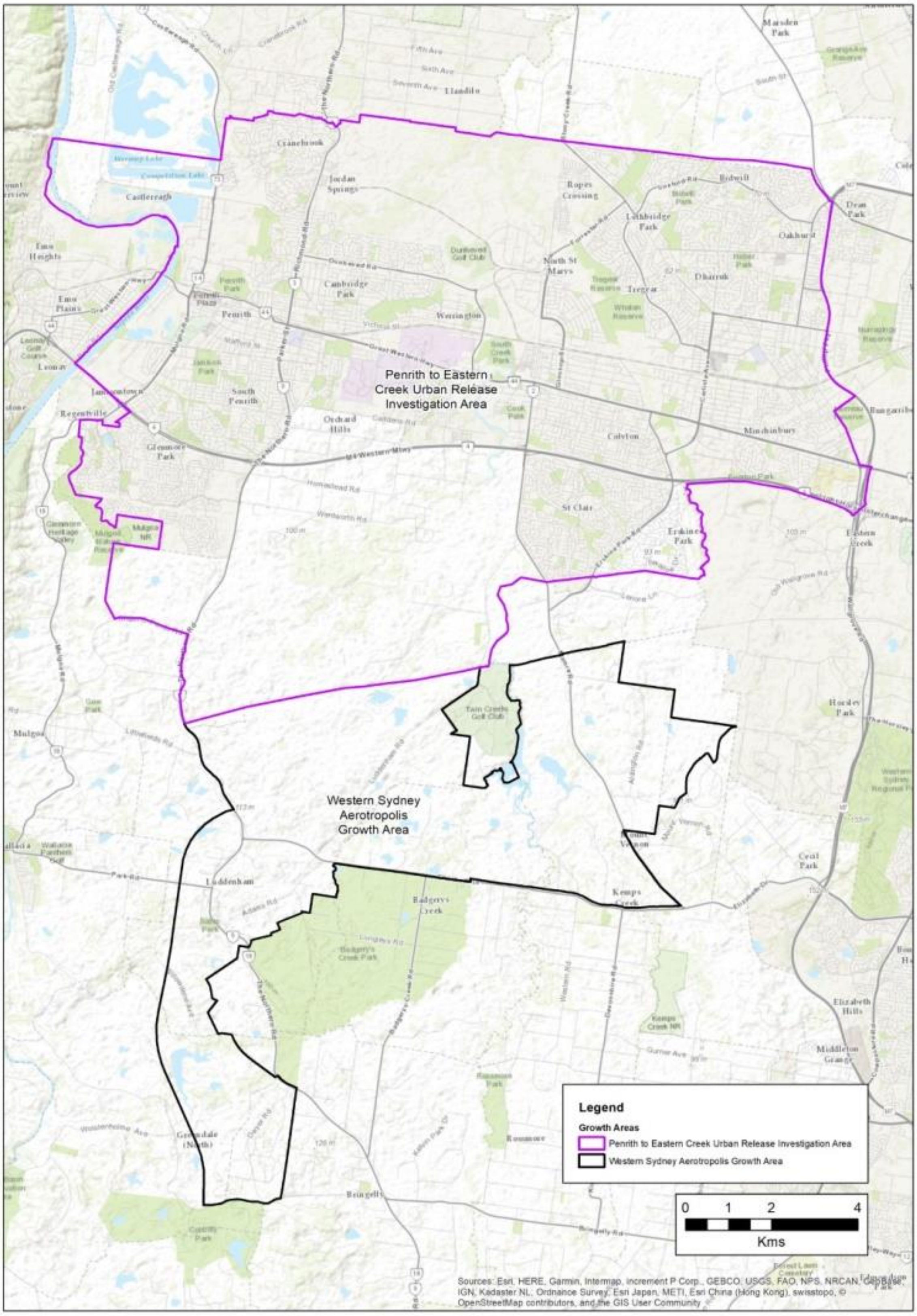

Figure 1. The Greater Penrith to Eastern Creek Urban Release Investigation Area (outlined in purple) and the Western Sydney Aerotropolis Growth Area (outlined in black). © OpenStreetMap contributors.

remnant bushland are found in public reserves, most of the native vegetation occurs on private land or land managed by the Australian Department of Defence. Only 13.5% of landowners granted permission for surveys to be conducted on their land and the Australian Department of Defence was not one of them. An alternative approach involves the construction of a general habitat model for *Grevillea juniperina* subsp. *juniperina*, which can then be used to identify suitable habitat on all land tenures across the two Growth Areas. The limitations of land access necessitated the latter approach. The need for expert knowledge of the ecology of *Grevillea juniperina* subsp. *juniperina* in creating a habitat model triggered the need for an expert report.

1.5 Credentials of expert

I prepared this report as an independent botanical consultant but I am also currently an Honorary Research Associate at the at the New South Wales state herbarium (the National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust). In 2016, I retired from my role as a Senior Principal Research Scientist at the state herbarium, having worked there since 1982 as a Systematic Botanist and as curator of the herbarium's collections of specimens of Proteaceae (including *Grevillea juniperina*) (see my *Curriculum Vitae*, attached). I now work, part-time at the National Herbarium of New South Wales as an Honorary Research Associate.

I have published, either as sole author or as a co-author, 50 papers on the systematics and ecology of the Proteaceae in the peer-reviewed scientific literature, including the most comprehensive phylogenetic analysis of the genus *Grevillea* yet published (Mast *et* al. 2015). As curator of Proteaceae at the state herbarium, I have examined all specimens of *G. juniperina* subsp. *juniperina* in the collection. I was invited to contribute to floristic treatments of the Proteaceae for *Flora of New South Wales*, *Flora of Australia*, *Flora of the Perth Region*, *Flora of China*, *Flora of North America*, and to write the treatments of Proteaceae for *Families and Genera of Vascular Plants* and *Flowering Plant Families of the World* (see my *Curriculum Vitae*, attached). I was also asked to conduct a peer review of the essay on the ecology of the Proteaceae that accompanied the "Ecology of Sydney Plants" (Myerscough *et al.* 2000). Throughout my career I have participated in numerous collecting trips in the field, collecting specimens in all Australian states for the state herbarium. In documenting these specimens I had to describe the habitat at each collecting site, including associated plant species, substrate, aspect, degree and kind of disturbance. On some of those trips, I observed and collected *Grevillea juniperina* growing in the wild.

In June 2018 I was appointed to prepare an expert report on *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas (Weston unpublished), during the preparation of which I characterised in detail the associated plant species and other ecological attributes of five plots, each of 30 metre radius at which I found *G. juniperina subsp. juniperina*. I am personally familiar with this taxon and the habitats in which it lives.

In November 2018 I was approved by the Office of Environment and Heritage as a species expert for *Grevillea juniperina* subsp. *juniperina* under section 6.5.2 of the Biodiversity Assessment Method. This approval is current for a period of six years.

1.6 Species surveys

Letters were sent by the Department of Planning and Environment to all landholders within the development footprint to request access. A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking, resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Urban Release Investigation Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council. Surveys were undertaken on all areas of land where landowners granted access. Access to the Defence Establishment Orchard Hills, which includes large patches of native vegetation, was not provided.

A targeted survey for threatened species was conducted on lands where access was granted. Vegetation transects and random meanders for threatened flora were conducted by the Ecoplanning Pty Ltd and Biosis Pty Ltd in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey included effort through each plant community type and vegetation zone, and extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m). Likely habitat for most flora species comprised areas of lower disturbance. This included areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora. One incidental observation of *Grevillea juniperina* subsp. *juniperina* was made in the study area during this survey, at North St Marys.

The percentages of remnant native vegetation in the growth areas that were sampled in the threatened species survey were 1.0% in Greater Penrith to Eastern Creek and 7.1% in the Western Sydney Aerotropolis. The percentages of sampled remnant native vegetation that were covered by the urban development footprint were 7.9% in Greater Penrith to Eastern Creek and 18.4% in the Western Sydney Aerotropolis. These data include a 20 m buffer from survey tracks.

2. Species information

2.1 Species description

The following morphological description was produced by merging information from Makinson's (2000) descriptions of the Linearifolia Group, the Speciosa Subgroup, *Grevillea juniperina*, and *G. juniperina subsp. juniperina*:

More or less erect to spreading dense divaricate shrub 0.5–1.5 m tall, to 3 m across; major branches appearing subcolumnar (leaves clustered on short lateral branchlets); foliage dense (see figure 2). Branchlets terete, tomentose to villous. Leaves spreading to ascending, often crowded on short lateral branchlets, usually rigid, often dark green with paler veins, entire, narrowly ovate to subulate or linear, angularly deltoid to trigonous in cross-section, 10–22 mm long, 0.6–0.8 mm wide, pungent, needle-like, with dissimilar upper and lower surfaces; upper surface usually with 3–5 longitudinal veins, the midvein and intramarginal veins usually very prominent, sparsely covered with appressed hairs; margins strongly and angularly revolute; lower surface usually fully enclosed, usually densely sericeous or occasionally openly so, rarely glabrous, or open-tomentose; juvenile leaves scarcely broader than adults. Inflorescence terminal, occasionally also axillary and subterminal, usually simple or occasionally 2 (–4)-branched; unit conflorescence erect or slightly decurved, acropetal, subsecund; floral rachis 1–17 mm long (see figure 3). Flowers zygomorphic; torus slightly oblique. with perianth style similar to perianth or a little paler (see figure 3). Perianth densely to openly subsericeous outside with biramous hairs only, bearded inside between 2.5 and 9 mm above base, red, yellow, pale orange, or rarely greenish; tepals remaining coherent over at least the basal third, independently recoiled above (usually the ventral pair more strongly so). Pistil (13–) 20–25 mm long; style glabrous except for minute scattered erect simple hairs extending from back of style-end down at least 3 mm and sometimes almost to ovary, similar colour to perianth or a little paler; pollen-presenter usually oblique or occasionally lateral. Follicles narrowly ovoid or oblong-ellipsoidal, 10–18 mm long, colliculose to smooth, not ridged. Seeds ellipsoidal; margins revolute, a waxy strip on one side extending into a short apical elaiosome.

2.2 Life cycle

Grevillea juniperina subsp. *juniperina* is a perennial, woody plant that germinates from an ellipsoidal seed (Makinson 2000). Germination is significantly enhanced by fire: in a germination experiment, a treatment of smoke plus heat raised the germination percentage from 5-13% observed in the control treatment to 60% (Morris 2000). Seedlings are readily identifiable because their leaves differ minimally from adult leaves and the characteristic growth pattern with abundant lateral short shoots starts when seedlings are less than 10 cm tall. The duration of the juvenile growth phase and the longevity of plants are unknown (Benson & McDougall 2000). Plants are known to be killed by fire (Olde & Marriott 1995, Makinson 2000) and are not known to spread vegetatively (Benson & McDougall 2000), so this taxon can be classed as an obligate seeder. Flowering occurs mainly from August to September, with sporadic flowers appearing in other months (Makinson 2000).The flowers of all subspecies of *Grevillea juniperina* are visited by nectar-feeding birds (Olde & Marriott 1995), which are presumed to be their pollinators (Benson & McDougall 2000). Fertilized carpels develop into follicular fruits that open at maturity, releasing one or two flat seeds, each of which bears a wing-like terminal elaiosome. The seeds are dispersed by wind and also possibly by ants, which may collect the seeds for their edible elaiosomes. A buried soil seed bank accumulates at a site after plants reach reproductive maturity.

2.3 Distribution and abundance

Grevillea juniperina subsp. *juniperina* occurs naturally on the northern part of the Cumberland Subregion of the Sydney Basin IBRA Bioregion, in Sydney's Western Suburbs, in an area bounded by Pitt Town, Agnes Banks, Castlereagh, Mulgoa, Kemps Creek, and Blacktown (OEH Wildlife Atlas, accessed 2/7/2018, Atlas of Living Australia, accessed 3/7/2018). Within this polygon, it is sporadically distributed but often locally abundant in both intact native vegetation (figure 4) and in highly disturbed habitats such as pastures (figure 5), road cuttings, and abandoned railway platforms (figure 6). Collectors' and observers' notes on local abundance usually note multiple plants at recording sites and vary in their estimates of plant numbers from solitary individuals to populations of over 1,000. At some sites its population density is high. For example, between my sites PEC1 and PEC2, in Wianamatta Regional Park, I conducted a survey of reproductively mature plants of *G. juniperina subsp. juniperina* along two transects that were 1 m wide and a total of 1,285 m long (Appendix 1), in which I recorded 246 plants, a density of 1,914 mature plants per hectare.

A herbarium specimen collected from Gundungarra Reserve, Spring Farm, 11 km south south west of the study area (NSW999291), is a geographic outlier. In my earlier expert report on *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas (Weston unpublished a), I argued that this population is unlikely to represent a natural occurrence of *G. juniperina subsp. juniperina*. Herbarium records that were classed as naturalised occurrences by their collectors, and by R.O. Makinson in curatorial notes, include one from the Melbourne suburb of

Figure 2. A large plant of *Grevillea juniperina* subsp. *juniperina* growing on the road verge in front of 327 Luddenham Road, Orchard Hills.

Figure 3. A branchlet of *Grevillea juniperina* subsp. *juniperina* showing lateral short shoots, bearing crowded, needle-like leaves and an inflorescence of greenish-yellow flowers terminating a short shoot.

Heathmont (NSW 834413) and another from Penrose, 94 km south west of the study area (NSW971120).

2.4 Habitat requirements

Makinson (2000: 210) notes that *Grevillea juniperina* subsp. *juniperina* "grows in open dry sclerophyll (eucalypt-dominated) forest or woodland at altitudes of less than about 50 m, in sandy to clay-loam soils and red pseudolateritic gravels." Makinson (2000: 211) also notes that "this subspecies shows some ability to colonise mechanically disturbed areas where open ground surface persists; repeated disturbance appears to eliminate it. Populations are often restricted to infrequently managed road verges or ungrazed semi-cleared land." At two such disturbed sites where I observed it to be growing (sites GJ2, GJ5, Appendix 1), *Grevillea juniperina* subsp. *juniperina* had vigorously colonised the habitat, with plants representing all life cycle stages from seedlings less than 7 cm tall (e.g. , figure 5) to large, reproductively mature shrubs.

The threatened species profile of *Grevillea juniperina* subsp. *juniperina*, published online by OEH (2018) describes its habitat as follows:

- Grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium (often with shale influence), typically containing lateritic gravels.
- Recorded from Cumberland Plain Woodland, Castlereagh Ironbark Woodland, Castlereagh Scribbly Gum Woodland and Shale/Gravel Transition Forest.

Figure 4. A population of *Grevillea juniperina* subsp. *juniperina* growing in intact PCT 849 on Bringelly Shale at Plumpton Park, Plumpton.

Figure 5. A population of *Grevillea juniperina* subsp. *juniperina* that has established in cleared pasture on St Marys Formation alluvium at Marsden Park.

Figure 6. A population of *Grevillea juniperina* subsp. *juniperina* that has established on the platform of the abandoned Dunheved Railway Station, North St Marys.

- Associated canopy species within Cumberland Plain Woodland and Shale/Gravel Transition Forest include *Eucalyptus tereticornis*, *E. moluccana*, *E. crebra*, *E. fibrosa* and *E. eugenioides*. Understorey species include *Bursaria spinosa*, *Dillwynia sieberi*, *Ozothamnus diosmifolius*, *Daviesia ulicifolia*, *Acacia falcata*, *Acacia parramattensis*, *Themeda australis*, *Aristida ramosa*, *Cymbopogon refractus*, *Eragrostis brownii*, *Cheilanthes sieberi*, *Dianella revoluta* and *Goodenia hederacea*.
- In Castlereagh Woodland on more sandy soils the dominant canopy species are *Eucalyptus fibrosa*, *E. sclerophylla*, *Angophora bakeri* and *Melaleuca decora*. Understorey species include *Melaleuca nodosa*, *Hakea sericea*, *Cryptandra spinescens*, *Acacia elongata*, *Gonocarpus teucrioides*, *Lomandra longifolia* and the threatened species *Dillwynia tenuifolia*, *Pultenaea parviflora*, *Micromyrtus minutiflora* and *Allocasuarina glareicola*.

The OEH Threatened Species Data Collection indicates that *Grevillea juniperina* subsp. *juniperina* has the potential to occur in the following plant community types within the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area:

- 724 Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion;
- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion;
- 806 Derived grasslands on shale hills of the Cumberland Plain (50-300m asl);
- 807 Derived grasslands on shale plains of the Cumberland Plain (<100m asl);
- 808 Derived shrubland on Tertiary Gravels of the Cumberland Plain;
- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion;
- 850 Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion;
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion.

3. Description of the study area

3.1 Land use history

This section is based primarily on information from penrithhistory.com, a website maintained by Penrith Library (Penrith Library 2018), except where other sources are explicitly cited. The first human inhabitants of the study area were Aborigines who moved there many thousands of years ago. People of the Darug language group were occupants of the study area when the British first started to settle in the Sydney Region in 1788 (Logan 2011). These hunter-gatherers would have managed the grassy woodlands that grew on Bringelly Shale and Cenozoic alluvia of the area using fire-stick farming methods (Benson & Howell 1990). They used the natural landscape seasonally, taking advantage of different food sources depending on availability, establishing temporary open camps of simple gunyahs on higher ground near water courses. The Nepean River and its tributaries were significant sources of fish, shellfish and useful plants while the wooded plains and gentle hills were sources of game, edible tubers, seeds, fruits and materials for making clothing, tools and shelters (Logan 2011).

In 1789, 18 months after the founding of Sydney, Captain Watkin Tench led a group from Rose Hill to the Nepean River, followed soon by further expeditions from there to Razorback in the south and downstream to the Hawkesbury River in the north (Fitzhardinge 1967). The alluvial flats of the Nepean River and adjacent grassy woodlands on Wianamatta Shales, offered more fertile farming land than sandy soils derived from Hawkesbury Sandstone surrounding the Cumberland Subregion. However, violent clashes between the British and the Darug people led by Pemulwuy delayed settlement west of Prospect until 1802, when Governor King built a headquarters for his government stock reserve at what is now Rooty Hill (NSW Office of Environment and Heritage 2018). King went on to issue land grants at what are now Penrith and Cranebrook in 1804, and Orchard Hills, St Marys and Badgerys Creek in 1806. Further land grants were made in what are now Mulgoa and Greendale in 1810, and Luddenham in 1813. In 1815 the Great Western Road was completed between Parramatta and Bathurst, placing the northern part of the study area on what soon became a major transport artery. Completion of the western railway line from Sydney to Penrith in 1867 and its extension to Bathurst in 1876 significantly enhanced accessibility of the northern part of the study area. From first settlement in the early 19th century to the 1950s, land use in both growth areas was dominated by timber production, agriculture and quarrying, all of which necessitated extensive clearing of native vegetation, especially from the more fertile alluvial and clayey soils. Agricultural activities conducted in the areas have included the cultivation of wheat (which was curtailed in 1861 when the whole crop was destroyed by an infestation of rust disease) and other cereal crops, grazing of sheep, cattle and horses, intensive production of pigs and poultry, and the cultivation of fruit, vegetables, turf and cut-flowers (Wilkinson 2011). Industrial facilities that processed saw logs and agricultural produce, such as timber mills, flour mills, milk processing plants, cattle sale yards, tanneries, canneries and wineries began to be built early in the 19th century and mostly continued operating well into the 20th century. A few manufacturing plants, producing textiles, munitions and bricks were also developed in the 19th and early 20th centuries.

Penrith grew slowly as an urban centre during the 19th century and first half of the 20th century, but population growth accelerated after 1960 due to the establishment of several social housing projects by the N.S.W. Housing Commission. This was followed from the 1970s by the gradual rezoning of much of the agricultural land in the northern part of the Greater Penrith to Eastern Creek Urban Release Investigation Area is for urban development. Land use in this growth area is now dominated by residential housing, retail precincts, light industry and transport infrastructure, but Orchard Hills in the south is still largely rural. Most protected patches of remnant native vegetation are less than 20 Ha in area but the two largest reserves containing intact bushland, Wianamatta Regional Park in the north and The Defence Establishment Orchard Hills in the south, cover approximately 900 Ha and 1370 Ha respectively.

The Western Sydney Aerotropolis Growth Area is still largely rural but includes a staggeringly small area of remnant bushland in public reserves. The largest patch consists of about 3.5 hectares of weed-infested Grey Box – Forest Red Gum grassy woodland in Sales Park, Luddenham.

3.2 Landscape context

The Sydney Basin is a geological entity composed of sedimentary rocks that is shaped a bit like a tilted, triangular, art deco saucer. In the middle of this structure is the Cumberland Subregion, in the northern half of which is located the study area. Here, the uppermost strata of the Sydney Basin, Cenozoic alluvia, patchily overlie the Triassic Wianamatta Group, comprising Bringelly Shale, Minchinbury Sandstone and Ashfield Shale, which, in turn overlie Triassic Hawkesbury Sandstone, the Triassic Narrabeen Group and the Permian Shoalhaven Group (Martyn 2018). Scattered small Jurassic basalt diatremes occasionally pierce the sedimentary strata, such as at Lethbridge Park and Bidwill.

The most commonly exposed substrate in the study area is Bringelly Shale. Over this, the second most commonly exposed substrate, heavy, alluvial Quaternary clay, which has been eroded from Bringelly Shale, has accumulated in a branching pattern across the study area on the floodplains of

South Creek and its tributaries, including Kemps, Badgerys, Cosgrove, Blaxland, Claremont, Werrington and Ropes Creeks (NSW Department of Minerals and Energy 1991).

Other substrates are also exposed over a much smaller area on the northern and western margins of the Greater Penrith to Eastern Creek Urban Release Investigation Area. Two patches of Londonderry Clay, a Paleogene-Neogene alluvium, covering an area of about six square kilometres, have been preserved on the northern edge between St Marys and Shanes Park. On the western margin, between Mulgoa and the north-western corner, gravelly, sandy, silty and clayey Quaternary alluvia of the Cranebrook formation line the eastern bank of the Nepean River and its eastern tributaries, forming an extensive deposit up to four kilometres wide north of Regentville. On the western margin, several square kilometres of Ashfield Shale and a smaller area of Rickabys Creek Gravel, a Paleogene-Neogene alluvium, are exposed from Jamisontown to Glenmore Park.

The whole study area is gently tilted from south to north and all watercourses flow in that general direction. Topography varies subtly in the Greater Penrith to Eastern Creek Urban Release Investigation Area with low, rounded ridges alternating with flat-bottomed flood plains. The lowest point is in the north west corner at Upper Castlereagh, where the bank of the Nepean River is below 10 m altitude, and along the northern margin the altitude is less than 70 metres. The highest point in the Greater Penrith to Eastern Creek Urban Release Investigation Area is 93 metres in altitude at Sovereign, in the south west corner. Along the boundary between the two growth areas, altitude varies from 40 metres in the east to 90 metres in the west.

Topographic relief is still quite gentle, but more noticeable, with steeper slopes, in the Western Sydney Aerotropolis Growth Area. The altitude varies from 40 metres in the north eastern corner to 106 metres just south east of Luddenham village.

Topographic variation, as well as distance from the sea influence climate. The Cumberland Subregion is the driest part of the Sydney Region and also experiences the most extreme temperatures in the region. Key climate statistics for the three weather stations in the study area, for which data are freely available, are shown in table 1. The whole study area is subject to winter frosts.

Weather station	Mean annual rainfall (mm)	Mean maximum temperature (°C)	Mean minimum temperature (°C)
Penrith Lakes AWS (1995-)	718.6	31.0	5.3
Orchard Hills Treatment Works (1970-)	832.7	28.5	5.3
Badgerys Creek McMasters F (1995-)	794.3	28.6	3.8

Table 1. Key climatic statistics for weather stations in the growth areas.

3.3 Native vegetation communities

In terms of the plant community types recognised in the Bionet Vegetation Classification and the vegetation maps that were prepared for this project, the remnant native vegetation of the growth areas consists of:

- 724 Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain (191.3 ha);
- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain (167.4 ha);
- 781 Freshwater wetland (68.9 ha);
- 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion (2.8 ha);

- 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain (989.2 ha);
- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain (2334.1 ha);
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain (88.5 ha);
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain (6.5 ha);
- 1105 River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion (94.2 ha);
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain (2.0 ha).
- 1800 Swamp Oak open forest on river flats of the Cumberland Plain and Hunter valley (228.5 ha).

In the study area, according to the vegetation mapping that was conducted for this project, the following substrates support the following plant community types:

- Quaternary alluvium, including Cranebrook Formation: PCTs 781, 835, 849, 850, 1105, 1800;
- Londonderry Clay: PCTs 724, 725, 835, 849;
- Bringelly Shale: PCTs 724, 725, 835, 849, 883;
- Ashfield Shale: PCTs 830, 835, 849, 1395.
- Rickabys Creek Gravel: 849.

PCT 849 is the most abundant plant community type throughout both growth areas, growing on most of the uncleared land above the zone of floodwater inundation, most commonly on Bringelly Shale. Over 50% of the two largest patches of remnant bushland, Wianamatta Regional Park and the Defence Establishment Orchard Hills is covered in PCT 849 and it covers most of the smaller reserves too. PCT 835 covers the second largest area and also occurs throughout the study area, vegetating the uncleared flood plains of South Creek and its tributaries on Quaternary alluvium, as well as the lowest part of the adjacent slopes. The banks of those creeks as well as some other blocks of low-lying land on Quaternary alluvium, are dominated by PCT 1800. PCTs 724 and 725 are dominant on Londonderry Clay in the northern part of the study area but also occur patchily elsewhere on Bringelly Shale, most notably in the Kemps Creek area and on a rectangular block of regenerating vegetation 0.6-0.8 km west of Luddenham Road, 0.2-0.6 km north of the Warragamba-Prospect water pipeline. PCT 1105 dominates remnant vegetation on the banks of the Nepean River north of Penrith, on Cranebrook Formation alluvium. The remaining plant community types occur only rarely as tiny fragments in the study area. About 6.5 ha of PCT 883 occurs in two patches at the eastern end of Wianamatta Regional Park and about 15 ha remains in a block 0.6 km north of Elizabeth Drive, Kemps Creek. PCT 1395 is represented by a sliver of two hectares on Ashfield Shale at Glenmore Park. PCT 830 is restricted to a fringe of under three hectares in area on the eastern the border of Mulgoa Nature Reserve.

Weed infestation is a problem throughout the study area. This is well illustrated by two sites at Claremont Meadows. The vegetation at a site beyond the eastern end of Caddens Road, on the flood plain of South Creek, which I visited but did not include in my sampling, consisted of a closed forest of *Ligustrum sinense*, *Ligustrum lucidum* (both natives of China, the latter extending to Japan) and *Olea europaea* subsp. *cuspidata* (native of Africa), with scattered emergent trees of *Eucalyptus tereticornis* and *E. amplifoli*a. This would have been a forest of PCT 835 before weed infestation converted it into a novel, derived plant community. Only 0.6 km to the west north west of that site is a superficially pristine block of PCT 724. Even here, however, *Ligustrum sinense* and *Ligustrum lucidum* already dominate the vegetation near South Creek, *Eragrostis curvifolia* is a common component of the ground stratum and seedlings of *Olea europaea* subsp. *cuspidata* are starting to establish throughout the reserve.

4. Assessment of species presence and habitat

4.1 Existing records and surveys

A search of *Grevillea juniperina* subsp. *juniperina* in the Bionet Atlas, conducted on 12 November 2018, returned 1513 observational records. The only targeted survey of this species of which I am aware was conducted by Teresa James in Plumpton Park in October 2007 (Teresa James personal communication). However, patterns in the dates and locations of Bionet records suggest that several intensive surveys of *G. juniperina subsp. juniperina* have been conducted in the 21st century, apparently as part of more general environmental surveys. Most of those were conducted outside the study area but the following are relevant to this report:

- 12 October 2007: 5 records reporting over 700 plants from what is now Wianamatta Regional Park;
- 8-11 September 2008: 4 records reporting approximately 1250 plants from the Defence Establishment Orchard Hills;
- 25 September to 2 November 2009: 118 records from the St Marys Sewage Treatment Plant;
- 6 March to 14 December 2015: 82 records from the Dunheved development site, for the St Marys Central Precinct Project;
- 16 February 2016: 1 record reporting >1000 plants West of Luddenham Rd, north of the Warragamba-Prospect water pipelines;
- 18 October 2016: 22 records reporting 115 plants from Wianamatta Regional Park.

4.2 Surveys completed for the biocertification

Apart from the surveys conducted for this expert report, no targeted surveys for *Grevillea juniperina* subsp. *juniperina* were conducted for biocertification of the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area. Several opportunistic observations were made by other consultants in the course of conducting more general surveys and expert reports on other species.

4.3 Surveys completed for this assessment

4.3.1 Survey Methods

In the course of preparing my expert reports on *Grevillea juniperina* subsp. *juniperina* and *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas (Weston unpublished a, b), I characterised twenty plots of native vegetation in detail, each plot being a circle of radius 30 m (an of area 2827 m^2), centred either on a plant of *G. juniperina subsp. juniperina* or *Pterostylis saxicola* or on an arbitrarily chosen point (at sites where both the *Grevillea* and the *Pterostylis* were absent). I have included data from nine of those plots as samples from outside the study area in my analyses for this report. I have also used the same methods to characterise 33 plots in and adjacent to the study area. I chose the locations with the aim of sampling patches of accessible, remnant bushland representing as broad an ecological range and geographic extent across the two Growth Areas as time would allow, sampling more plots in areas where *G. juniperina subsp. juniperina* had previously been recorded. Some habitats, such as freshwater wetlands, and substrates on which *G. juniperina subsp. juniperina* has never been recorded, such as Cranebrook Formation alluvia, were avoided. At each plot I listed all vascular plant species that could feasibly be identified, taking photographs of plants for later reference in cases where the plant's identity was in question. The latitude and longitude of the centre of each plot was determined using a GPS instrument. The altitude of each site was determined later from 1:25,000 topographic maps. The soil and topography at each site was described and the substrate identified using the Penrith 1:100,000 geological map (NSW Department of Minerals and Energy 1991) and 1:25,000 topographic maps.

I identified the plant community type in each plot using the PCT identification tool in Bionet, and my list of plant species found in each plot.

I conducted statistical analyses of association between presence or absence of *Grevillea juniperina* subsp. *juniperina* in my plots and several other binary variables using the Phi statistic and Fisher's exact test at http://vassarstats.net/tab2x2.html. The other binary variables were plant community types, and substrate Quaternary alluvium present or absent. As multiple tests were conducted, I applied a Bonferroni correction to the significance level s of the tests.

I conducted a census of reproductively mature plants of *Grevillea juniperina* subsp. *juniperina* along a pair of transects, each 1 m wide, oriented in a north-south direction in the eastern part of Wianamatta Regional Park, where multiple plants of the species had previously been recorded, to estimate population density there.

I kept an eye out for plants of *Grevillea juniperina* subsp. *juniperina* as I drove or walked from site to site within the study area. I also conducted a "drive by" survey of inaccessible properties in the southern part of the Western Sydney Aerotropolis, looking over boundary fences of private properties with remnant native vegetation on Willowdene Avenue, Luddenham, and Dwyer and Findley Roads and Francis Street, Greendale.

I developed an improved habitat model for *Grevillea juniperina* subsp. *juniperina*, using data from my own botanical surveys of 38 plots, the published literature, 1513 observers' and collectors' records of *G. juniperina subsp. juniperina* in the Bionet Atlas, vegetation mapping conducted for the Cumberland Plain Conservation Plan (Biosis unpublished), and the geological map of the area (NSW Department of Minerals and Energy 1991).

4.3.2 Results and Conclusions from my Surveys Completed for this Assessment

Site and ecological data for my plots are shown in Appendix 2. I sampled most plant community types and most substrates known in the study area in these plots. According to my identifications of plant community types, I found *Grevillea juniperina* subsp. *juniperina* in the following PCTs in my plots:

- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain (found in 17 plots, 10 of which also hosted *G. juniperina subsp. juniperina*);
- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain (found in 11 plots sampled, 9 of which also hosted *G. juniperina subsp. juniperina*);
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain (found in 2 plots, one of which also hosted *G. juniperina subsp. juniperina*);
- 724 Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain (found in 1 plot, which also hosted *G. juniperina subsp. juniperina*).

Plant community types that I sampled, in which *G. juniperina subsp. juniperina* was absent, were the following.

- 850 Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain (3 plots);
- 1800 Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley (3 plots);
- 1081 Red Bloodwood - grey gum woodland on the edges of the Cumberland Plain (1 plot).

Substrates present in my plots were Londonderry Clay (11 plots, all with *Grevillea juniperina* subsp. *juniperina* present), Bringelly Shale (14 plots, 7 with *G. juniperina subsp. juniperina* present), Londonderry Clay-Bringelly Shale transition (1 plot, with *G. juniperina subsp. juniperina* present), St Marys Formation-Bringelly Shale transition (1 plot, with *G. juniperina subsp. juniperina* present), Quaternary Alluvium (8 plots, *G. juniperina subsp. juniperina* absent from all), Bringelly Shale-Quaternary Alluvium transition (1 plot, *G. juniperina subsp. juniperina* present).

The most striking positive association between habitat variables and presence of *Grevillea juniperina* subsp. *juniperina* was with Londonderry Clay, with all 11 plots on this substrate also hosting the grevillea, a relationship so strong that it did not need statistical testing. In contrast, none of the eight plots on Quaternary Alluvium hosted *G. juniperina subsp. juniperina*. This negative association proved to be statistically significant with a probability due to chance of 0.0013 in the 2-tailed test (significance level adjusted to 0.01 to account for multiple tests). Of the four plant community types in which *G. juniperina subsp. juniperina* was found, none turned out to be significantly associated with presence or absence of the grevillea. It seems reasonable to conclude that substrate type is a more powerful predictor of the presence or absence of *G. juniperina subsp. juniperina* than plant community type.

Comparison of observational records of *Grevillea juniperina* subsp. *juniperina* in the Bionet Atlas with the geological map shows that the association between substrates and plant records can be expressed with greater precision than has been done in the published literature. The substrates on which *G. juniperina subsp. juniperina* most frequently occurs are Londonderry Clay (a Paleogene-Neogene alluvium) and Bringelly Shale (a member of the Triassic Wianamatta Group). Most of the area of exposed Londonderry Clay occurs outside the study area but the density of observational records on this Paleogene-Neogene alluvium, both inside and outside the study area, confirms my conclusion from my plot data that this is a highly favoured substrate of *G. juniperina subsp. juniperina*. The favoured substrate that covers by far the largest area in the study area is Bringelly Shale. *G. juniperina subsp. juniperina* has also been recorded on laterised sand and clay of the St Marys Formation and on Rickabys Creek Gravel (both Paleogene-Neogene alluvia) but these substrates are much less extensive in area than either Londonderry Clay or Bringelly Shale. Rickabys Creek Gravel is very rare in, and St Marys Formation absent, from the study area.

Careful comparison of observational records of *Grevillea juniperina* subsp. *juniperina* with the distribution of Quaternary alluvia, a group of substrates that are mostly associated with the flood plains of existing watercourses in the Cumberland Subregion, supports my earlier conclusion based on my plot data that *G. juniperina subsp. juniperina* rarely, if ever, grows on these substrates. Sporadic inundation of these soils and the higher fertility of many of them, relative to Bringelly Shale and Paleogene-Neogene alluvia, probably explain why *G. juniperina subsp. juniperina* is absent from Quaternary alluvia. *G. juniperina subsp. juniperina* is also conspicuously absent from Ashfield Shale, another member of the Wianamatta Group, small outcrops of which occur on the western margin of the Greater Penrith to Eastern Creek Urban Release Investigation Area. Ashfield Shale has a significantly higher phosphate content than Bringelly Shale (Martyn 2018), which possibly explains the absence of *G. juniperina subsp. juniperina* from soils derived from it. All Proteaceae are highly efficient accumulators of soil phosphate, and moderate levels of this nutrient are toxic to many of them (Lambers *et al.* 2015).

The northern, eastern and western limits of the natural distribution of *Grevillea juniperina* subsp. *juniperina* can be explained simply by the distributions of its favoured substrates. However, its southern limit is much less well defined and I cannot explain it with confidence. The most dense populations of *G. juniperina subsp. juniperina* are found on Paleogene-Neogene alluvia, north of 33° 45' S. South of this latitude, the taxon occurs more patchily, forming sizeable populations at some suitable sites such as Pennard Crescent Luddenham (my plot GJ10), but being absent from other apparently suitable bushland remnants on Bringelly Shale nearby, such as the patch between Cosgrove Creek and Halmstad Boulevard, Luddenham (my plot WSA2). South of 33° 51' S, all known populations are small (fewer than 10 plants), sporadically distributed, and absent from most apparently suitable habitats.

Remnants of plant community type 849 growing on Bringelly Shale are liberally scattered between 33° 53' S and 34° 05' S but only one of these patches of bush is known to support a population of *Grevillea juniperina* subsp. *juniperina*. This is at 34° 03' 38.8'' S 150° 44' 15.5'' E, at Gundungarra Reserve, Spring Farm (my plot GJ9), approximately 14 km south of the southern end of the Western Sydney Aerotropolis Growth Area, where a population of four mature plants of *G. juniperina subsp. juniperina* was discovered in 2017. I have argued elsewhere (Weston unpublished a) that the population at Gundungarra Reserve is probably naturalised, resulting from a garden escape. However, this and other putatively naturalised populations are potentially informative about the limits of the taxon's ecological tolerance, so they should not be dismissed as irrelevant. The Gundungarra Reserve population is at 130 m altitude, which is higher than anywhere in the study area. However, a putatively naturalised population of eight plants from near Penrose grows at 650 m altitude, so altitude seems unlikely to be a limiting factor in the study area. The Penrose population occurs on "residual deposits of unconsolidated clayey coarse- to fine-grained sands to weakly consolidated sandy clay layers" (Triggs & Campbell 2016), analogous to Londonderry Clay, on which *G. juniperina subsp. juniperina* grows within its natural distribution. Whether the gradual thinning of the metapopulation of *G. juniperina subsp. juniperina* from north to south is due to ecological factors or to historical processes is unknown. Nevertheless, the probability of finding this species clearly declines as one moves south of 33° 45' S.

A historical process that may partly explain the patchy distribution of *Grevillea juniperina* subsp. *juniperina* within its distributional range is the potential effect of frequent fires. As plants of *G. juniperina subsp. juniperina* are killed by fire and populations regenerate by germinating from a buried seed bank in response to fire (see section 2.2), this species can be exterminated locally by frequent fires exhausting the soil seed bank. This can happen when a succession of fires occurs with an interval between fires that is less than the average time between germination and reproductive maturity. However, while such a process could explain the contrast mentioned above, between my plots GJ10 and WSA2, it seems unlikely to have affected an area as extensive as the whole southern half of the taxon's distribution.

Another historical process that could have produced the observed distribution is range expansion. If *Grevillea juniperina* subsp. *juniperina* originated in the northern part of the Cumberland Subregion and is still expanding into unfilled niche space in the southern Cumberland Subregion, then we would expect its populations to be smaller and scarcer than those in the north. This hypothesis could be tested using population genetic techniques but such a study is beyond the scope of this project.

4.4 Assessment of species presence

4.4.1 Likelihood of species presence

Grevillea juniperina subsp. *juniperina* is known with confidence in both the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area.

4.4.2 Justification for determining presence

The presence of *Grevillea juniperina* subsp. *juniperina* in the Greater Penrith to Eastern Creek Urban Release Investigation Area is uncontroversial, supported by hundreds of observational and collection records, as well as my observations at 16 of my survey plots there. Its presence in the Western Sydney Aerotropolis Growth Area appears to be marginal but at least one observational record from the western side of Luddenham Road, just south of the northern border of this Growth Area (0.2 km south of my plot PEC25), documents its presence there. The probability of it occurring naturally elsewhere not far inside the northern border of the Western Sydney Aerotropolis Growth Area (the Warragamba to Prospect water pipeline) is high, but most of that border was inaccessible to botanical surveys for this project. The probability of its presence south of Luddenham village seems low, given the evident thinning of its population density towards the south, but it is not zero. Small patches of apparently suitable habitat are scattered through this Growth Area, especially south of Luddenham, but almost all of them were inaccessible for surveying for this project.

4.5 Assessment of suitable habitat

4.5.1 Suitable habitat within the study area

Grevillea juniperina subsp. *juniperina* is known to occur naturally in four plant community types recognised in the Bionet Vegetation Classification. They are:

- 724 Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain;
- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain;
- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain;
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain.

All of these plant community types have been recorded in the study area.

Grevillea juniperina subsp. *juniperina* also occurs on the margins of a fifth plant community type, 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain. This community usually grows on Quaternary alluvium, a substrate on which *G. juniperina subsp. juniperina* does not grow. However, ecological gradients between PCT 835 and adjacent plant community types, particularly PCT 849, are not clear-cut and do not always correspond exactly to transitions between substrate types. PCT 835 growing on Bringelly Shale should be included in the habitat model for *G. juniperina subsp. juniperina* to avoid excluding populations on the margins of alluvial flats.

Most records of *Grevillea juniperina* subsp. *juniperina* report populations living in intact native vegetation but it is also capable of surviving in, and even invading highly disturbed landscapes (see section 2.4)

Grevillea juniperina subsp. *juniperina* is known to occur naturally on four substrate types recognised by the Geological Survey of New South Wales. They are:

- Triassic Bringelly Shale (Wianamatta Group);
- Paleogene-Neogene Londonderry Clay;
- Paleogene-Neogene St Marys Formation;
- Paleogene-Neogene Rickabys Creek Gravel.

The intersection of any of the above plant community types with any of the above substrates indicates suitable habitat for *Grevillea juniperina* subsp. *juniperina*.

4.5.2 Species polygons

My species polygons for *Grevillea juniperina* subsp. *juniperina* (figure 7) include all patches of PCTs 724, 725, 833, 835 and 849 growing on Londonderry Clay, Rickabys Creek Gravel or Bringelly Shale in the study area. They were prepared with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by Biosis Pty Ltd. A shape file for these polygons is held by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment. My arguments justifying these polygons have been set out in sections 2.3, 2.4, 4.1, 4.3, 4.4 and 4.5.1.

4.5.3 Estimate of area of habitat

The areas estimated to represent suitable habitat for *Grevillea juniperina* subsp. *juniperina* in figure 7 are as follows:

- Greater Penrith to Eastern Creek Area Urban Release Investigation Area
  - Habitat mapped – 1989.8 ha
  - Habitat impacted by development footprint – 93.4 ha
- Western Sydney Aerotropolis Growth Area
  - Habitat mapped – 683.5 ha
  - Habitat impacted by development footprint – 310.4 ha

These estimates were calculated with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by Biosis Pty Ltd. My arguments justifying the polygons from which these estimates were calculated have been set out in sections 2.3, 2.4, 4.1, 4.3, 4.4 and 4.5.1.

5. Information used in this assessment

My assessment was based on information obtained from a diversity of sources:

- Databases of observational and vouchered specimen records of *Grevillea juniperina* subsp. *juniperina*:
  - National Herbarium of New South Wales specimen database;
  - Bionet Wildlfie Atlas;
- Interviews with collectors, observers, propagators and scientists of *Grevillea juniperina* subsp. *juniperina* (see section 6, acknowledgements);
- Fieldwork at 42 sites (see Appendix 1):
  - Five sites at which *P. saxicola* had previously been collected;
  - 14 sites in or near the study area that had potentially suitable habitat;
- The scientific and scholarly literature (see section 7, references);
- A GIS map of the study area with layers representing the boundaries, plant community types, development footprint, and the results of flora and fauna surveys, prepared by Biosis Pty Ltd, provided through the Biosis spatial viewer;
- Background information on the study area provided by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment;

- My personal knowledge and experience, gained from 40 years as a professional botanist specialising in the systematics and ecology of the Proteaceae.

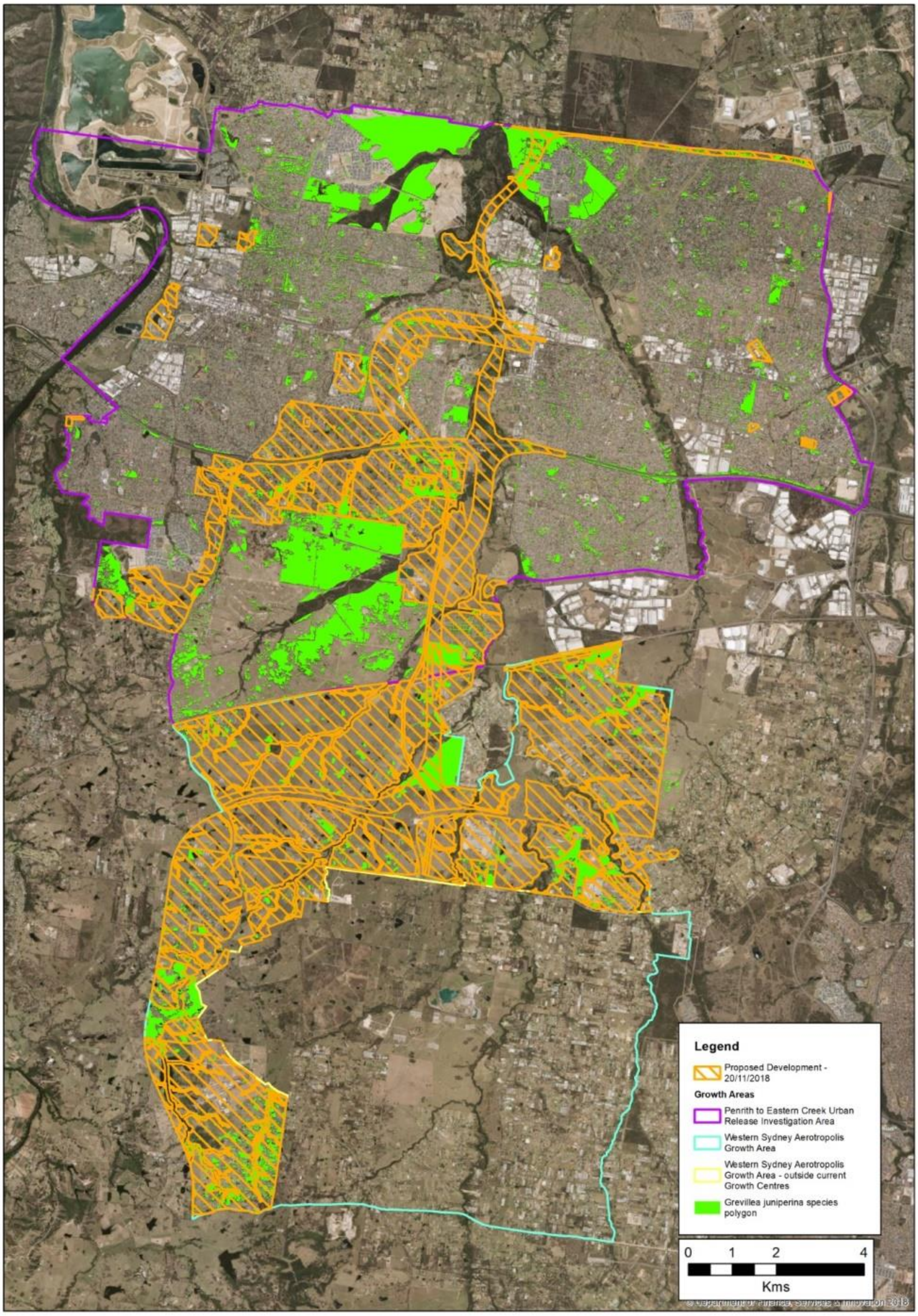

Figure 7. Polygons of suitable habitat for *Grevillea juniperina* subsp. *juniperina* across its whole distribution.

6. Acknowledgements

I am grateful to Teresa James, Bob Makinson, Peter Olde, Brian Towle and Greg Steenbeeke for happily being interviewed, and for generously sharing their knowledge about *Grevillea juniperina* subsp. *juniperina* with me. Darren James (DAJ Environmental) and Phillip Rofe (Biodiversity and Sustainability Branch, NSWDPE) kindly assisted me in producing species polygons and area estimates using the ArcMap software package. I am grateful to Laura Torrible, Dayle Green and Greg Steenbeeke for the provision of support and advice throughout this project.

7. References

Benson D, Howell J (1990) 'Taken for Granted: The Bushland of Sydney and its Suburbs'. Kangaroo Press, Kenthurst, NSW, Australia.

Benson D, McDougall L (2000) Ecology of Sydney plant species Part 7b Dicotyledon families Proteaceae to Rubiaceae. *Cunninghamia* 6: 1016–1202.

Fitzhardinge LF (1967) Watkin Tench (1758-1833). *Australian Dictionary of Biography* 2.

NSW Department of Minerals and Energy (1991) Penrith 100K Geological Sheet 9035. Sydney, NSW, Australia.

Lambers H, Clode P, Hawkins H-J, Laliberté E, Oliveira R, Reddell P, Shane MW, Stitt M, Weston PH (2015) Metabolic adaptations of the non-mycotrophic Proteaceae to soil with a low phosphorus availability. Annual Plant Reviews 48: 289–336 (Plaxton WC , Lambers H (eds) 'Phosphorus Metabolism in Plants in the Post-genomic Era: From Gene to Ecosystem'). Chichester, UK, Wiley-Blackwell Publishing.

Logan GM (2011) 'Wianamatta Regional Park: Conservation Management Plan volume 2 '. NSW Department of Environment, Climate Change and Water, Sydney, NSW, Australia.

Makinson RO (2000) *Grevillea. Flora of Australia* 17A: 1-524. ABRS/CSIRO, Melbourne, Victoria, Australia.

Martyn J (2018) 'Rocks and Trees: A Photographic Journey Through the Rich and Varied Geology, Scenery and Flora of the Sydney Region'. STEP Inc, Turramurra, NSW, Australia.

Mast AR, Olde P, Makinson RO, Jones E, Kubes A, Miller E, Weston PH (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646.

Morris EC (2000) Germination response of seven east Austalian *Grevillea* species (Proteaceae) to smoke, heat exposure and scarification. *Australian Journal of Botany* 48: 179–189.

Myerscough PJ, Whelan RJ, Bradstock RA (2000) Ecology of Proteaceae with special reference to the Sydney region. *Cunninghamia* 6: 951–1015.

NSW Office of Environment and Heritage (2018) The Rooty Hill. https://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=5054842, Accessed 9/11/2018.

Olde P, Marriott N (1995) 'The Grevillea Book', vol. 2. Kangaroo Press, Kenthurst, NSW, Australia.

Penrith Library (2018) Penrith City Local History. penrithhistory.com (accessed 6/11/2018).

Weston PH (unpublished a) Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas. Report to Department of Planning and Environment for the Strategic assessment for Cumberland Plain Conservation Plan.

Weston PH (unpublished b) Expert report on the Sydney Plains Greenhood, *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas. Report to Department of Planning and Environment for the Strategic assessment for Cumberland Plain Conservation Plan.

Wilkinson J (2011). Agriculture in the Sydney region: historical and current perspectives. NSW Parliamentary Library Research Service E-brief 2/2011: 1-13. https://www.parliament.nsw.gov.au/researchpapers/Documents/agriculture-in-the-sydney-region-historical-and-/Agriculture%20in%20the%20Sydney%20region%202.pdf (accessed 9/11/2018).

8. Appendices

8.1 Appendix 1: Characterisation of habitat at selected sites

The tables on following pages record data that I collected at sites both within and outside the study area. Each site was centred on an arbitrarily selected plant of *Grevillea juniperina* subsp. *juniperina*, or at an arbitrarily chosen point where the focal taxon was absent from the site. At each site the precise latitude and longitude, altitude, substrate, soil description, slope and aspect were also recorded. Also, at each site all plant species that could be reliably identified were recorded within a radius of 30 metres.

Site	Gjj present?	Location	Latitude	Longitude	Altitude (m)	substrate
GJ1	y	Southern end of Park Rd, E side, Marsden Park	33°41'22.6"S	150°50'03.1"E	25	St Marys Formation
GJ3	y	Castlereagh Nature Reserve, Northern Rd, Londonderry	33°40'44.9"S	150°44'37.3"E	45	Londonderry Clay
GJ4	y	Junction of Palmyra Ave and Stony Creek Rd, Shanes Park	33°43'09.1"S	150°46'52.7"E	25	Londonderry Clay
GJ5	y	Richmond Road, Marsden Park	33°41'03.3"S	150°49'12.4"E	25	Londonderry Clay
GJ7	n	Bill Anderson Reserve, Kemps Creek site 2	33°52'53.2"S	150°47'19.0"E	65	Bringelly Shale
GJ9	y	Gundungarra Reserve, Spring Farm	34°03'38.8"S	150°44'15.5"E	130	Bringelly Shale
GJ10	y	Pennard Crescent, Luddenham	33°50'37.1"S	150°45'41.9"E	50	Bringelly Shale
PEC1	y	Wianamtta Regional Park, 50 m S of Palmyra Ave, Ropes Crossing	33°43'10.7"S	150°46'34.6"E	30	Londonderry Clay
PEC2	y	Wianamtta Regional Park, S boundary, Ropes Crossing	33°43'52.6"S	150°46'27.5"E	30	Londonderry Clay
PEC3	n	Tregear Reserve, Tregear	33°44'45.0"S	150°47'15.0"E	25	Quarternary alluvium
PEC4	n	Ropes Crossing Boulevard 60 m N of Ropes Creek, Ropes Crossing	33°44'22.3"S	150°46'43.2"E	20	Quarternary alluvium
PEC5	y	Ropes Crossing Boulevard 350 m N of Ropes Creek, Ropes Crossing	33°44'13.0"S	150°46'43.8"E	30	Londonderry Clay
PEC6	y	Links Road, St Marys	33°44'15.7"S	150°45'57.0"E	20	Londonderry Clay
PEC7	y	Embankment, east of entrance to Dunheved Golf Course, St Marys	33°44'44.1"S	150°45'52.5"E	25	Londonderry Clay
PEC8	y	Embankment, south of abandoned railway line, St Marys	33°44'46.8"S	150°46'03.1"E	25	Londonderry Clay
PEC9	y	Bushland between Christie St and abandoned railway line, St Marys	33°44'48.9"S	150°46'08.4"E	25	Londonderry Clay
PEC10	y	Abandoned railway land N of 73A Christie St, St Marys	33°44'46.3"S	150°45'59.4"E	25	Londonderry Clay
PEC11	y	Southern side of abandoned railway station, St Marys	33°44'48.4"S	150°46'14.2"E	30	Londonderry Clay
PEC12	n	Between Dunheved Rd and John Oxley Avenue, Werrington County	33°45'09.1"S	150°44'59.4"E	20	Quarternary alluvium
PEC13	n	Between Dunheved Rd and Dunheved Golf Course, Werrington County	33°44'49.2"S	150°45'08.4"E	30	Quarternary alluvium
PEC14	y	Sinclair Parade, Jordans Springs	33°42'53.3"S	150°43'44.6"E	50	Bringelly Shale

Appendix 1a: Environmental data for sites visited as part of this study (continued on next page)

Site	soil description	Vegetation structure (canopy)	Vegetation structure (understorey)	PCT (my identification)
GJ1	brown sandy loam	dry sclerophyll forest-woodland	sparse shrubby understorey	849
GJ3	brown, gravelly clay-loam	dry sclerophyll forest	sparse shrubby understorey	883
GJ4	brown , gravelly clay-loam	dry sclerophyll woodland	dense shrubby understorey	725
GJ5	gravelly brown clay	Regenerating Dry sclerophyll woodland	sparse shrubby understorey	725
GJ7	red-brown sandy loam	disturbed dry sclerophyll woodland to forest	moderately dense shrubby understorey	883
GJ9	red-brown loam	remnant dry sclerophyll woodland	Grassy, sparsely to densely shrubby understorey	unidentifiable
GJ10	red-brown gravelly loam	dry sclerophyll woodland	sparse shrubby understorey	724
PEC1	brown , gravelly clay-loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC2	brown , gravelly clay-loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC3	brown clay loam	dry sclerophyll woodland	grassy understory with scattered shrubs	1800
PEC4	brown clay loam	dry sclerophyll forest	dense shrubby understorey	1800
PEC5	red-brown gravelly loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC6	red-brown gravelly clay	remnant dry sclerophyll woodland	grassy understorey with scattered shrubs	849
PEC7	red-brown gravelly clay	dry sclerophyll forest	grassy, moderately dense shrubby understorey	725
PEC8	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	725
PEC9	red-brown gravelly clay	dry sclerophyll woodland	grassy, shrubby understorey	849
PEC10	red-brown gravelly clay	dry sclerophyll woodland	grassy, shrubby understorey	725
PEC11	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	849
PEC12	ochre brown clay	dry sclerophyll forest	grassy, shrubby understorey	849
PEC13	ochre brown clay	dry sclerophyll forest	grassy, shrubby understorey	850
PEC14	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	725

Appendix 1a (continued): Environmental data for sites visited as part of this study

Site	Gjj present?	Location	Latitude	Longitude	Altitude (m)	substrate
PEC15	n	Putland Street, Claremont Meadows	33°46'12.8"S	150°45'21.9"E	30	Bringelly Shale
PEC16	n	Corner of Caulfield Road and Equestrian Circuit, Claremont Meadows	33°46'42.3"S	150°45'16.8"E	40	Bringelly Shale
PEC17	n	Caddens Road east, Claremont Meadows	33°46'48.9"S	150°45'36.6"E	25	Quarternary alluvium
PEC18	n	Heaton Avenue, Claremont Meadows	33°46'49.0"S	150°44'28.7"E	35	Quarternary alluvium
PEC19	y	Pandorea Street, Claremont Meadows	33°46'55.1"S	150°44'35.4"E	40	Bringelly Shale
PEC20	y	Pandorea Street, Claremont Meadows	33°46'57.1"S	150°44'35.4"E	40	Bringelly Shale
PEC21	n	Flinders Lane, Orchard Hills	33°47'21.7"S	150°45'28.7"E	25	Quarternary alluvium
PEC22	n	Samuel Marsden Reserve, Orchard Hills	33°47'08.5"S	150°45'40.5"E	25	Quarternary alluvium
PEC23	n	34-64 Wentworth Rd, Orchard Hills	33°47'56.9"S	150°44'17.1"E	50	Bringelly Shale
PEC24	n	Opposite 121 Wentworth Rd, Orchard Hills	33°47'52.7"S	150°43'45.5"E	60	Bringelly Shale
PEC25	y	327 Luddenham Rd, Orchard Hills	33°49'43.2"S	150°45'30.7"E	40	Bringelly Shale
PEC26	y	Plumpton Park, Plumpton	33°45'10.3"S	150°50'05.9"E	50	Bringelly Shale
PEC27	y	Dr Charles Mackay Reserve, Mt Druitt	33°46'29.8"S	150°49'39.1"E	70	Bringelly Shale
PEC28	y	Kestrel Crescent Reserve, Erskine Park	33°47'34.6"S	150°48'34.5"E	45	Bringelly Shale
PEC29	n	Apple Gum Reserve, Glenmore Park	33°47'00.9"S	150°39'51.0"E	40	Ashfield Shale
PEC30	n	Forest Redgum Reserve, Glenmore Park	33°46'43.5"S	150°39'44.7"E	50	Rickabys Creek Gravel
WSA1	n	Sales Park, Luddenham	33°52'55.5"S	150°41'26.3"E	90	Bringelly Shale
WSA2	n	Between Cosgrove Creek and Halmstad Boulevard, Luddenham	33°50'58.9"S	150°44'52.6"E	55	Bringelly Shale

Appendix 1a (continued): Environmental data for sites visited as part of this study

Site	soil description	Vegetation structure (canopy)	Vegetation structure (understorey)	PCT (my identification)
PEC15	dark brown loam	dry sclerophyll forest	grassy, moderately dense shrubby understorey	849
PEC16	gravelly dark brown loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC17	brown clay	dry sclerophyll forest	moderately dense shrubby understorey	1800
PEC18	brown clay	dry sclerophyll forest	moderately dense shrubby understorey	849
PEC19	dark brown loam	dry sclerophyll forest	moderately dense shrubby understorey	849
PEC20	dark brown loam	dry sclerophyll woodland	dense shrubby understorey	849
PEC21	grey-brown loam	dry sclerophyll forest	dense shrubby understorey	849
PEC22	pale brown loam	dry sclerophyll forest	sparse shrubby understorey	849
PEC23	Red-brown clay with lateritic pebbles	dry sclerophyll forest	dense shrubby understorey	849
PEC24	mid-brown clay	dry sclerophyll forest	dense shrubby understorey	850
PEC25	mid-brown clay	dry sclerophyll forest	dense shrubby understorey	849
PEC26	grey-brown loam	dry sclerophyll woodland	grassy understory with scattered shrubs	849
PEC27	grey-brown loam	dry sclerophyll woodland to forest	grassy understorey with sparse to dense shrub stratum	849
PEC28	mid-brown loam	dry sclerophyll woodland	grassy understorey with sparse to dense shrub stratum	849
PEC29	mid-brown loam	dry sclerophyll forest	shrubby, grassy understorey	849
PEC30	ochre brown grevelly loam with abundant, large rounded stones	dry sclerophyll forest	Grassy, sparsely to densely shrubby understorey	849
WSA1	mid-brown loam	dry sclerophyll forest	grassy, shrubby understorey	849
WSA2	red-brown gravelly loam	dry sclerophyll woodland	shrubby grassland	725

Appendix 1a (continued): Environmental data for sites visited as part of this study

	Sites >														
Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Acacia binervia	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Acacia brownii	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Acacia decurrens	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0
Acacia elongata	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Acacia falcata	1	1	0	1	0	0	0	1	1	0	0	0	0	1	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia floribunda	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Acacia implexa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia longifolia	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Acacia parramattensis	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0
Acacia parvipinnula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ajuga australis	?	?	?	?	?	0	0	0	0	0	0	0	0	0	0
Allocasuarina glareicola	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	0	1	0	1	1	0	0	1	1	0	0	0	0	0	1
Angophora bakeri	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora floribunda	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1
Angophora subvelutina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aristida ramosa	?	?	?	?	?	0	0	?	?	?	?	?	?	?	?
Aristida vagans	?	?	?	?	?	0	0	?	?	?	?	?	?	?	?
Arthropodium milleflorum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b: Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >													
Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Asperula conferta	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Astroloma humifusum	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Austrostipa verticillata	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Banksia spinulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0
Bossiaea obcordata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea rhombifolia	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brunoniella australis	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Bursaria spinosa subsp. *spinosa*	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1
Caesia vittata	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Callistemon salignus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calotis cuneifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Carex inversa	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?
Casuarina glauca	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Cheilanthes sieberi	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
Chrysocephalum apiculatum	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Clematis aristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis glycinoides	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
Commelina ensifolia	?	?	?	?	?	0	0	0	0	0	0	0	0	0	0
Cryptandra amara	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >															
Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Cryptandra spinescens	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Daviesia ulicifolia subsp. *ulicifolia*	0	1	1	1	1	0	1	0	0	0	0	1	0	1	1
Desmodium brachypodum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium varians	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dianella caerulea var. *producta*	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *longifolia*	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *stenophylla*	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dianella revoluta var. *revoluta*	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dichondra repens	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Dichopogon fimbriatus	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Dillwynia sieberi	1	0	0	0	0	0	0	0	1	0	0	1	0	0	1
Dillwynia tenuifolia	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0
Dipodium punctatum	?	?	?	?	?	?	?	0	0	0	0	0	0	0	0
Dodonaea falcata	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?
Einadia hastata	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Enchylaena tomentosa	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Entolasia stricta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eremophila debilis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalypts amplifolia	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Eucalyptus baueriana	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >														
Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Eucalyptus crebra	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
Eucalyptus eugenioides	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus fibrosa	1	0	0	0	0	0	1	1	1	0	0	1	0	0	0
Eucalyptus globoidea	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Eucalyptus moluccana	1	0	0	0	0	1	0	0	1	1	0	1	1	0	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sclerophylla	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Eucalyptus tereticornis	1	0	1	1	0	1	0	0	1	1	0	1	1	0	1
Exocarpos cupressiformis	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Exocarpos strictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geitonoplesium cymosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine tabacina	?	?	?	?	?	?	1	0	0	0	0	0	0	0	0
Glycine clandestina	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Goodenia hederacea	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Grevillea juniperina subsp. *juniperina*	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1
Grevillea mucronulata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea laevipes	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea sericea	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0
Hardenbergia violacea	0	1	0	1	0	0	0	0	0	1	1	0	1	1	0
Hibbertia diffusa	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Hypoxis hygrometrica	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Indigofera australis	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Isopogon anemonifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jacksonia scoparia	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0
Lagenifera stipitata	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laxmannia gracilis	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Lepidosperma laterale	0	0	0	1	0	0	0	1	1	0	0	1	1	0	0
Leptospermum parvifolium	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linum marginale	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Lissanthe strigosa	0	0	1	0	1	0	1	1	0	0	0	1	0	0	1
Lobelia purpurascens	?	?	?	?	?	?	1	0	0	0	0	0	0	0	0
Lomandra filiformis	?	?	?	?	?	?	1	0	0	0	0	0	0	0	0
Lomandra longifolia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lomandra multiflora	?	?	?	?	?	?	1	0	0	0	0	0	0	0	1
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lotus australis	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Melaleuca decora	1	1	1	0	1	0	1	1	1	1	0	0	1	0	1
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Melaleuca nodosa	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0
Melaleuca styphelioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melia azedarach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Microlaena stipoides	?	?	?	?	?	?	0	?	?	?	?	?	?	?	?
Micromyrtus minutiflora	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Murdannia graminea	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Opercularia aspera	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Opercularia diphylla	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Oxalis perennans	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Ozothamnus diosmifolius	0	0	1	0	0	0	0	1	1	0	0	0	0	0	1
Patersonia sericea	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia linearis	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Persoonia nutans	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus hirtellus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus virgatus	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Pimelea glauca	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Pimelea linifolia	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Plantago debilis	?	?	?	?	?	?	?	0	0	0	0	0	0	0	0
Plantago gaudichaudii	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala japonica	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Pterostylis saxicola	?	?	?	?	?	?	?	0	0	0	0	0	0	0	0
Pultenaea microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea parviflora	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >															
Associated species	GJ1	GJ3	GJ4	GJ5	GJ7	GJ9	GJ10	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8
Ranunculus lappaceus	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Styphelia laeta	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Themeda triandra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tricoryne elatior	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Viola hederacea	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Wahlenbergia communis	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Wahlenbergia gracilis	?	?	?	?	?	?	0	0	0	0	0	0	0	0	0
Xanthorrhoea media	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea minor	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Acacia binervia	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	0	0	0	0	0	1	1	1	0	1	1	0	0
Acacia elongata	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Acacia falcata	1	0	1	0	0	0	0	0	0	0	1	1	0	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia floribunda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia implexa	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia parramattensis	1	0	1	1	0	1	1	0	1	1	1	0	0	0
Acacia parvipinnula	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ajuga australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Allocasuarina glareicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	1	1	1	0	0	0	0	0	0	0	0	0	1	0
Angophora bakeri	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora floribunda	1	1	1	1	1	0	0	0	1	0	0	1	0	0
Angophora subvelutina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aristida ramosa	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Aristida vagans	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Arthropodium milleflorum	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Asperula conferta	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Astroloma humifusum	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Austrostipa verticillata	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Banksia spinulosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea obcordata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea rhombifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Brunoniella australis	1	0	1	1	0	0	1	1	0	0	1	1	1	1
Bursaria spinosa subsp. *spinosa*	1	1	0	1	1	1	1	1	1	1	1	1	1	1
Caesia vittata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Callistemon salignus	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Calotis cuneifolia	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Carex inversa	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Casuarina glauca	0	0	0	1	0	0	0	0	1	0	1	0	0	0
Cheilanthes sieberi	0	0	0	0	1	0	1	1	0	0	1	1	1	1
Chrysocephalum apiculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis aristata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis glycinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina ensifolia	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Cryptandra amara	0	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Cryptandra spinescens	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Daviesia ulicifolia subsp. *ulicifolia*	0	1	1	0	0	0	1	1	0	0	0	0	0	0
Desmodium brachypodum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium varians	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella caerulea var. *producta*	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Dianella longifolia var. *longifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *stenophylla*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella revoluta var. *revoluta*	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dichondra repens	1	0	1	1	0	0	1	0	0	0	1	1	1	1
Dichopogon fimbriatus	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Sites >

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Dillwynia sieberi	0	1	1	0	0	1	0	0	0	0	0	0	0	0
Dillwynia tenuifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dipodium punctatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea falcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Echinopogon caespitosus	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Einadia hastata	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Enchylaena tomentosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Entolasia stricta	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Eremophila debilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalypts amplifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus baueriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >													
Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Eucalyptus crebra	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Eucalyptus eugenioides	0	0	0	0	1	0	0	1	0	0	1	0	0	0
Eucalyptus fibrosa	1	0	1	0	0	1	1	1	0	0	0	0	0	0
Eucalyptus globoidea	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Eucalyptus moluccana	1	0	0	1	1	1	1	1	0	1	1	1	1	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus tereticornis	1	0	1	1	1	0	1	1	1	1	1	1	1	1
Exocarpos cupressiformis	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Exocarpos strictus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geitonoplesium cymosum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine tabacina	0	0	0	0	0	0	0	0	0	1	0	0	1	1
Glycine clandestina	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Goodenia hederacea	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Grevillea juniperina subsp. *juniperina*	1	1	1	0	0	1	0	0	0	0	1	1	0	0
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea laevipes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea sericea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardenbergia violacea	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hibbertia diffusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypoxis hygrometrica	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Indigofera australis	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Isopogon anemonifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jacksonia scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagenifera stipitata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laxmannia gracilis	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Lepidosperma laterale	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum parvifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Linum marginale	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lissanthe strigosa	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Lobelia purpurascens	0	0	0	0	0	0	1	0	0	0	1	0	1	0
Lomandra filiformis	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Lomandra longifolia	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Lomandra multiflora	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lotus australis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca decora	0	0	0	1	0	0	1	0	0	0	1	0	0	0
Melaleuca linariifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Melaleuca nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca styphelioides	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Melia azedarach	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Microlaena stipoides	?	?	?	?	?	?	?	?	?	?	?	?	0	0
Micromyrtus minutiflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Murdannia graminea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia aspera	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia diphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis perennans	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Ozothamnus diosmifolius	0	0	0	0	0	1	1	1	1	0	0	0	0	1
Patersonia sericea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia nutans	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus hirtellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus virgatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pimelea glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pimelea linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago debilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago gaudichaudii	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala japonica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterostylis saxicola	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC9	PEC10	PEC11	PEC12	PEC13	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22
Ranunculus lappaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Styphelia laeta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Themeda triandra	0	0	0	0	1	0	0	0	0	1	0	0	0	0
Tricoryne elatior	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola hederacea	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Wahlenbergia communis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wahlenbergia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea media	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea minor	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >									
Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Acacia binervia	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	0	1	1	0	0	0	0	0	0
Acacia elongata	0	0	0	0	0	0	0	0	0	0
Acacia falcata	0	0	0	0	1	0	1	1	0	0
Acacia fimbriata	0	0	0	1	0	0	0	0	0	0
Acacia floribunda	0	0	0	0	0	0	0	0	0	0
Acacia implexa	0	0	0	0	1	0	0	1	1	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0
Acacia longifolia	0	0	0	0	0	0	0	0	0	0
Acacia parramattensis	0	0	0	0	0	0	1	1	0	0
Acacia parvipinnula	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	0	0	0	0	0	0	0	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0
Ajuga australis	0	1	0	0	0	0	0	0	0	0
Allocasuarina glareicola	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	0	0	0	0	0	0	1	1	0	1
Angophora bakeri	0	0	0	0	0	0	0	0	0	0
Angophora floribunda	0	0	0	0	0	0	0	0	0	0
Angophora subvelutina	0	0	0	0	0	0	1	0	0	0
Aristida ramosa	0	0	0	0	0	0	1	1	0	0
Aristida vagans	0	0	0	1	1	0	1	1	1	0
Arthropodium milleflorum	1	0	0	1	0	0	0	0	1	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Asperula conferta	0	1	0	0	1	0	0	0	1	0
Astroloma humifusum	0	0	0	0	0	0	0	0	0	1
Austrostipa verticillata	0	0	0	0	0	1	0	0	0	0
Banksia spinulosa	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	0	0	0	0	0	0	0	0	0	0
Bossiaea obcordata	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	0	0	0	0	1	0	0	0	0	0
Bossiaea rhombifolia	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	0	0	0	0	1	0	0
Brunoniella australis	1	0	1	1	1	1	1	1	1	0
Bursaria spinosa subsp. *spinosa*	1	1	1	1	1	1	1	1	1	1
Caesia vittata	0	1	0	0	0	0	1	0	1	0
Callistemon salignus	0	0	0	0	0	0	0	0	0	0
Calotis cuneifolia	0	0	0	1	0	0	0	0	0	0
Carex inversa	0	0	0	0	0	0	1	0	1	0
Casuarina glauca	0	0	0	0	0	0	0	0	0	0
Cheilanthes sieberi	1	0	1	0	1	0	1	1	1	0
Chrysocephalum apiculatum	0	0	0	0	0	0	1	0	0	0
Clematis aristata	0	0	0	0	0	1	0	0	0	0
Clematis glycinoides	0	0	0	0	0	0	0	1	0	0
Commelina ensifolia	0	0	0	1	0	1	1	1	0	0
Cryptandra amara	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Cryptandra spinescens	0	0	0	0	0	0	0	0	0	0
Daviesia ulicifolia subsp. *ulicifolia*	0	0	1	0	0	0	1	0	0	0
Desmodium brachypodum	0	0	0	0	1	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0
Desmodium varians	1	0	0	0	0	0	0	0	0	0
Dianella caerulea var. *producta*	0	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *longifolia*	0	0	0	0	0	0	0	0	1	0
Dianella longifolia var. *stenophylla*	1	0	0	1	1	0	1	1	0	0
Dianella revoluta var. *revoluta*	0	0	0	1	0	0	0	0	0	0
Dichondra repens	1	0	0	1	1	1	1	0	1	0
Dichopogon fimbriatus	0	0	0	1	0	0	0	0	0	0
Dillwynia sieberi	0	0	1	1	1	0	0	0	0	0
Dillwynia tenuifolia	0	0	0	0	0	0	0	0	0	0
Dipodium punctatum	0	0	0	0	0	0	0	1	0	0
Dodonaea falcata	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	0	0	0	0	0	0	0	1	0	0
Einadia hastata	0	0	1	0	0	1	1	0	0	0
Enchylaena tomentosa	0	0	0	0	0	0	0	0	0	0
Entolasia stricta	0	0	0	0	0	0	0	0	0	0
Eremophila debilis	0	0	0	0	1	0	0	0	0	0
Eucalypts amplifolia	0	0	0	0	0	0	0	0	0	0
Eucalyptus baueriana	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Eucalyptus crebra	0	0	0	0	1	0	0	1	1	0
Eucalyptus eugenioides	0	0	0	0	0	0	0	0	0	0
Eucalyptus fibrosa	0	0	0	1	1	1	0	1	0	0
Eucalyptus globoidea	0	0	0	0	0	0	0	1	0	0
Eucalyptus moluccana	1	1	0	1	0	1	1	0	1	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	0	0
Eucalyptus sclerophylla	0	0	0	0	0	0	0	0	0	0
Eucalyptus tereticornis	1	1	1	1	1	1	1	1	1	0
Exocarpos cupressiformis	0	0	0	0	0	0	0	0	0	0
Exocarpos strictus	0	0	0	0	0	0	1	0	0	0
Geitonoplesium cymosum	0	0	0	0	0	0	0	0	1	0
Glycine tabacina	1	0	1	1	1	1	1	1	1	0
Glycine clandestina	0	0	0	0	1	0	1	1	0	0
Goodenia hederacea	0	0	0	0	1	0	1	1	0	0
Grevillea juniperina subsp. *juniperina*	0	0	1	1	1	1	0	0	0	0
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	0	0	0
Hakea laevipes	0	0	0	0	0	0	0	0	0	0
Hakea sericea	0	0	0	0	0	0	0	0	0	1
Hardenbergia violacea	0	0	0	0	1	0	1	0	0	0
Hibbertia diffusa	0	0	0	0	0	0	1	1	0	0
Hypoxis hygrometrica	1	0	0	1	1	0	0	0	0	0
Indigofera australis	0	1	0	0	0	0	0	0	1	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Isopogon anemonifolius	0	0	0	0	0	0	0	0	0	0
Jacksonia scoparia	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	0	0	0	0	0	0	0	0	1
Lagenifera stipitata	0	0	0	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0
Laxmannia gracilis	0	0	0	0	1	0	0	0	0	0
Lepidosperma laterale	0	0	0	0	0	0	0	0	0	0
Leptospermum parvifolium	0	0	0	0	0	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0
Linum marginale	1	0	0	0	0	0	0	0	0	0
Lissanthe strigosa	0	0	0	0	0	0	0	0	0	0
Lobelia purpurascens	0	0	0	0	0	1	0	1	1	0
Lomandra filiformis	0	0	1	0	1	0	0	0	0	0
Lomandra longifolia	0	0	0	0	0	0	1	0	0	0
Lomandra multiflora	0	0	0	0	1	0	0	0	0	0
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0
Lotus australis	0	1	0	0	0	0	0	0	0	0
Melaleuca decora	0	0	1	0	0	1	0	0	0	1
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0
Melaleuca nodosa	0	0	0	0	0	0	0	0	0	0
Melaleuca styphelioides	0	0	0	1	0	0	0	0	0	0
Melia azedarach	0	1	0	0	0	0	1	1	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >								
Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Microlaena stipoides	0	0	0	1	0	0	1	1	0	0
Micromyrtus minutiflora	0	0	0	0	0	0	0	0	0	0
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0
Murdannia graminea	0	0	0	1	0	0	0	0	0	0
Opercularia aspera	0	0	0	0	0	0	0	0	1	0
Opercularia diphylla	0	0	0	1	1	0	1	1	0	0
Oxalis perennans	0	0	0	0	0	0	0	1	1	0
Ozothamnus diosmifolius	0	0	0	0	0	0	0	1	0	0
Patersonia sericea	0	0	0	0	0	0	0	0	0	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0
Persoonia linearis	0	0	0	0	0	0	0	0	0	0
Persoonia nutans	0	0	0	0	0	0	0	0	0	0
Phyllanthus hirtellus	0	0	0	0	0	0	0	0	0	0
Phyllanthus virgatus	0	0	0	1	0	0	0	0	0	0
Pimelea glauca	0	0	0	0	0	0	0	0	0	0
Pimelea linifolia	0	0	0	0	0	0	0	0	0	0
Plantago debilis	0	0	0	0	0	0	0	0	0	0
Plantago gaudichaudii	1	0	0	0	0	0	0	0	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0
Polygala japonica	0	0	0	0	0	0	0	0	1	0
Pterostylis saxicola	0	0	0	0	0	0	0	0	0	0
Pultenaea microphylla	0	0	0	1	1	0	0	0	0	0
Pultenaea parviflora	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC23	PEC24	PEC25	PEC26	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2
Ranunculus lappaceus	0	1	0	0	0	0	0	0	0	0
Solanum prinophyllum	0	0	0	0	0	1	0	0	1	0
Styphelia laeta	0	0	0	0	0	0	0	0	0	0
Themeda triandra	1	0	0	1	0	0	1	1	1	0
Tricoryne elatior	0	0	0	0	1	1	1	1	1	1
Viola hederacea	0	0	0	0	0	0	0	0	0	0
Wahlenbergia communis	0	1	0	0	1	0	0	0	0	0
Wahlenbergia gracilis	0	0	0	0	0	1	0	0	0	0
Xanthorrhoea media	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea minor	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

8.2 Appendix 2: Peter Weston's curriculum vitae

Personal details

Name: Peter Henry Weston.

Address: 18 Lyle Avenue, Lindfield, New South Wales 2070, Australia.

Date and place of birth: 22 October 1956, Lower Hutt, New Zealand.

Immediate family: wife (Susan) and three children (Timothy 34, Caitlin 32, Nicholas 29).

Nationality: Australian.

Interests: soccer, reading, guitar, orchid growing, cross-country skiing, bush walking.

Academic Qualifications

i) **B.Sc.** (first class honours; equal first in order of merit) School of Biological Sciences, University of Sydney; 1975-78, conferred 7 April 1979.
Thesis title: "The evolution and classification of *Boronia* Sm."

ii) **Ph.D.**, School of Biological Sciences, University of Sydney, 1979-83; conferred 18 May 1985.
Thesis title: "Systematics and biogeography of the Persooniinae (Proteaceae)".

Awards, Fellowships and Scholarships

2014	Nancy Burbidge Medal (awarded by the Australasian Systematic Botany Society to a person who has made a longstanding and significant contribution to Australasian systematic botany. It is the foremost award that can be conferred by ASBS).
2014	Australian Biological Resources Study-sponsored Winston Churchill Fellowship for an established career researcher in taxonomy.
2009	Grady L. Webster Structural Botany Publication Award for 2008 and 2009 from the Botanical Society of America. The BSA component of the award (it is awarded in alternate years by the BSA and the American Society of Plant Taxonomists) recognizes the most outstanding paper published in the *American Journal of Botany* in the field of structural and developmental botany (i.e., anatomy and morphology) over a two-year period. It was awarded to Gregory J. Jordan, Peter H. Weston, Raymond J. Carpenter, Rebecca A. Dillon and Timothy J. Brodribb for: "The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae," American Journal of Botany, Volume 95, Issue 5; May 2008.
2006	Carrick Award for Australian University Teaching from the Australian Learning and Teaching Council (one of five members of a teaching team from the University of New England cited for Outstanding Contributions to Student Learning).
1992-93	Posting to Royal Botanic Gardens, Kew, as Australian Botanical Liaison Officer.
1982	Charles Gilbert Heydon Travelling Fellowship for the biological sciences (not taken up).
1980-82	University of Sydney Postgraduate Scholarship.

1979-82	Commonwealth Postgraduate Award.
1977	G.S. Caird Scholarship for Third Year Botany, University of Sydney.
1976	Slade Prize for Practical Plant Biology, University of Sydney.

Employment

Present Position: Honorary Research Associate, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney and independent botanical consultant.

Previous positions held:
2008-2016 Senior Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

2000-2008 Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1994-2000 Senior Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1989-1994 Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1982-1989 Scientific Officer, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1979-82 Part-time demonstrator, School of Biological Sciences, University of Sydney.

Adjunct and visiting university appointments

2013-	Adjunct Associate Professor, La Trobe University.
2011-2016	Adjunct Associate Professor, University of New South Wales.
2006	Visiting Lecturer, Rhodes University, Grahamstown, South Africa.
2004-2009	Adjunct Associate Professor, University of New England.
2000-2004	Adjunct Senior Lecturer, University of New England.

Administrative/management experience

2009	Acting Manager Plant Diversity
2002-2003	Member, Plant Diversity Research Program Leaders Committee
1998-99	Systematics Liaison Officer
1997-98	Member RBGS Market testing working party
1997	Member, RBGS advisory committee for restructuring senior management
1990-91	Systematics Co-ordinator
1996-98	Member, RBGS Joint Consultative Committee

Membership of Learned Societies

1996-	Society of Australian Systematic Biologists
1984-	Willi Hennig Society (Elected Fellow, 1992-, Council member, 1998-2000)
1979-	Society of Systematic Biologists (member, Editorial Board 1993-95)

1978- Australasian Systematic Botany Society (formerly Australian Systematic Botany Society: President, 2009-2012, Vice President, 2008-2009, Chairman, Hansjörg Eichler Research Fund Committee, 1998-2002, Council member, 1996-2002)

Membership of External Committees

2015- Financial Grants Standing Committee (formerly the Grants Policy Standing Committee) of the Australasian Systematic Botany Society

2012-2013 Conference Organising Committee of *Systematics Without Borders*, a joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney (Chairman)

2011- Editorial Board, *Phytotaxa*

2008-2009 Corresponding Member, Editorial Advisory Committee, *Australian Systematic Botany*

2006-2014 Ira Butler Memorial Trophy Committee (a joint committee of the Australasian Native Orchid Society and the Orchid Society of New South Wales) (Chairman)

2004- Editorial Advisory Board, *Kew Bulletin*

2001-2006 Panel of Judges, Eureka Prize for Biodiversity Research

2000-2012 Bushland Management Advisory Committee, Lane Cove Council (Chairman, 2008-2010)

1999-2004 Editorial Advisory Committee, *Australian Systematic Botany*

Spoken presentations at conferences (not including presentations delivered by others)

2015 Building Our Botanical Capital, annual conference of the Australasian Systematic Botany Society: "A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution".

2014 Next Generation Systematics, annual conference of the Australasian Systematic Botany Society: Nancy Burbidge Memorial Lecture: "Problems and progress in plant systematics since Nancy Burbidge"

2013 Genetics Society of Australasia conference, Sydney *Genetics in the Harbour City*: "Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2013 Joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, Sydney, *Systematics Without Borders*: "Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2012 Australasian Systematic Botany Society conference, Perth, *Local knowledge, global delivery*: "Contested, Uncontested and Potentially Controversial Taxonomic Changes in the Proteaceae: How Do They Differ?"

2011 37th annual conference of the South African Association of Botanists, *Plants in a Changing World* and 9th conference of the South African Society of Systematic Biologists, *Biodiversity Matters*; plenary address: "Cenozoic environmental change and the systematics of southern hemisphere plants"

2011 XVIII International Botanical Congress, Melbourne: "Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations".

2010 VI Southern Connection Congress, Bariloche: "Cladistic biogeography, molecular dating, fossils and the Proteaceae"

2010 VI Southern Connection Congress, Bariloche: "Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests"

2010 Australian Systematic Botany Society conference *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*; Keynote address: "Cenozoic environmental change and the systematics of southern hemisphere plants"
1999 XVI International Botanical Congress, Saint Louis: "Historical biogeography of Proteaceae".
1997 II Southern Connection Congress, Valdivia: "Cladistic biogeography of a key woody group: Proteaceae".
1997 First Biennial International Conference of the Systematic Association, Oxford: "Rolf Sattler's Plant Morphology and Cladistic Analysis".
1996 *An International Symposium on the Biology of Proteaceae*, Melbourne: "ITS squence variation in the Proteaceae and what it tells us about phylogeny".
1993 Joint conference of The Systematics Associations and The Linnean Society on *Models in Phylogeny Reconstruction*, London: "Direct methods for polarising character transformation series".
1990 IXth meeting of the Willi Hennig Society, Canberra: "Transoceanic cladistic patterns in the Proteaceae".
2003 The Third International Conference on *the Comparative Biology of the Monocotyledons*, Ontario: "Co-evolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators".
2005 XVII International Botanical Congress, Vienna: "Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae)".
2006 Australian Systematic Botany Society conference, Cairns, *Plant Diversity in the Tropics*: "A new suprageneric classification of the Proteaceae".
2007 5th Southern Connection Congress, Adelaide: "'I'm not dead yet' – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation)".
1989 Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney: "Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae".
1988 Symposium on *Panbiogeography of New Zealand*, Wellington: "Problems with the statistical testing of panbiogeographic hypotheses".
1985 Australian Flora Foundation Symposium on *Waratahs*, Canberra: "Drifting waratahs or continents?"
1984 Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra: "A reappraisal of Nelson's direct method of character analysis".

Refereeing manuscripts, grant applications, reports and examining postgraduate theses (last five years)

2018: *Candollea*; *Flora of the Hunter Region*; *Journal of Biogeography.*
2017: *Australian Systematic Botany*; *Evolution*; *New Zealand Journal of Botany*; *Nuytsia*; *South African Journal of Botany.*
2016: *Australian Systematic Botany*; *Botanical Journal of the Linnean Society*, *National Research Foundation* (South Africa).
2015: *American Journal of Botany*; Australian Research Council (4); *Australian Systematic Botany*; *Muelleria*; *Nuytsia*; *Phytotaxa*; *PLOS One*; *Telopea* (6).
2014: Australian Research Council (3); *Australian Systematic Botany* (2); *Cunninghamia*; *Journal of Biogeography* (2); *Muelleria*; National Research Foundation (South Africa); *Orchadian*; *Perspectives in Plant Ecology, Evolution and Systematics*; *Plant Systematics and Evolution*; *Telopea* (3).

Research

My research has been in the theoretical and practical aspects of systematic botany, with emphasis on the theory and practice of phylogenetic analysis, and the broader uses to which phylogenetic knowledge may be applied. I have phylogenetically analysed groups in the plant families Proteaceae, Fabaceae, Orchidaceae, Rutaceae, Winteraceae and Lauraceae, contributed to more general analyses of angiosperm phylogeny, and used the results of these analyses to improve biological classification and to test theories of historical biogeography, trait evolution, co-evolution and adaptation. I have earned an international reputation for my contributions to both theoretical and empirical developments in this field.

Herbarium curation and collections

My curatorial responsibilities at the National Herbarium of New South Wales have included the families Rutaceae (1982-1998), Proteaceae (1982-2016), Orchidaceae (1986-2016) and Fabaceae subfamily Faboideae (1986-2016). I have collected plant specimens (mostly angiosperms) in Australia, England, New Zealand, New Caledonia, Chile, South Africa, and Argentina, mostly for the herbarium and living collections of the Royal Botanic Gardens and Domain Trust, Sydney. Duplicates of my collections have been distributed to over 20 herbaria in 8 different countries.

Teaching

I have been actively involved in the preparation and teaching of four third year undergraduate courses in biosystematics:
Western Sydney University (2015-2018): “Principles of Evolution” (unit 300980), “Botany” (unit 300836).
University of New South Wales (2010-2016): “Assembling the Tree of Life” (BIOS3221)
University of New England (2000-2010): Biosystematics (Biosyst 301, Biosyst 302, Evol 301/501).
Botany Department, Rhodes University, Grahamstown, South Africa (February-March 2006): “Plant Biodiversity” course in collaboration with Associate Professor Nigel Barker.

I am currently co-supervising one postgraduate student:
Nanette Thomas (Ph.D., University of New England): Systematics of *Tasmannia* informs Biogeography of Winteraceae.

Postgraduate and honours students I have previously co-supervised include:
Margaret Stimpson (Ph.D., University of New England): Systematics, evolution and ecology of the *Banksia spinulosa* complex (graduated 2017).
Melita Milner (Ph.D., Australian National University): Phylogeography of *Lomatia and Telopea* (Proteaceae) in south eastern Australia (graduated 2015).
Samanta Oon (B.Sc. Honours, University of New South Wales): *Lomatia* likes it both ways: rampant bidirectional introgression of chloroplast genomes between two morphologically distinct species of Lomatia (Proteaceae) (graduated 2015).
Zoe Reynolds (B.Sc. Honours, Australian National University): Phylogenetic, taxonomic and functional turnover in Proteaceae assemblages (graduated 2013).
Emma McIntosh (B.Sc. Honours, University of Sydney): Hybridization and introgression between *Lomatia myricoides* and *L. silaifolia* (Proteaceae) (graduated 2011).
Margaret Stimpson (M.Sc.Stud., University of New England): Review of the *Banksia spinulosa* species complex (Proteaceae) (graduated 2011).
James Indsto (M.Sc., University of Wollongong): Pollination Ecology and Molecular Systematics of *Diuris* (Orchidaceae) of the Sydney Region (graduated 2010).
Nanette Thomas (Grad.Dip.Sci., University of New England): Phylogenetic analysis of Winteraceae (graduated 2009).

David McKenna (Ph.D., University of Wollongong: Demographic and ecological indicators for rarity in obligate-seeding *Persoonia* (Proteaceae) shrubs of the Sydney region, graduated 2007).
Paul Rymer (Ph.D., University of Wollongong: Plant rarity: species distributional patterns, population genetics, pollination biology and seed dispersal in *Persoonia* (Proteaceae), graduated, 2006).
Georgina Lloyd (B.Sc. Honours, University of Sydney: Pseudocopulation in two species of *Cryptostylis*: Implications for maintaining species integrity, graduated 2004)
Andrew Perkins (Ph.D., University of Sydney: Phylogenetic Systematics of the Genus *Calochilus* (Orchidaceae), graduated 2002).
Jim Mant (Ph.D., Australian National University: Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae), graduated 2002).
Siegfried Krauss (Ph.D., University of Wollongong: Systematic pattern and evolutionary process in the complex species *Persoonia mollis* (Proteaceae), graduated 1995).

I have examined 14 honours and postgraduate theses:
Australian National University (Ph.D., 2003, 2007, 2008)
University of Melbourne (Ph.D., 1995, 2011)
University of Newcastle (M.Phil., 2003)
University of Queensland (Ph.D., 2003)
University of Sydney (Ph.D., 1991, 1994, 1997, 2009)
University of Wollongong (B.Sc. Hons., 2001, 2003)
Victoria University (Ph.D., 2007)

Competitive Research and Infrastructure Grants

Peakall, R., Pichersky, E., Linde, C., Weston, P.H. (2015-2019) The biosynthesis and evolution of novel semiochemicals in orchids. $644,800, Australian Research Council Discovery Grant DP150102762.

Hoebee, S.E., Weston, P.H., & Edwards, T.J. (2015-18) Evolution in action or the demise of iconic Australian flora? $217,700, Australian Research Council Discovery Grant DP150100508.

He, T., Lamont, B., Weston, P.H., & Cowling, R. (2012-2014) Origin and evolution of plant functional traits in relation to fire. $310,000, Australian Research Council Discovery Grant DP120103389.

Rossetto, M., Crayn, D.M. & Weston, P.H. (2008-2010) Integrating molecular and morphological data for generic delimitation and species identification in Lauraceae. $73,333, Australian Biological Resources Study.

Cantrill, D., Murphy, D. & Weston, P.H. (2008-10) Understanding the origins of the Australian flora by integrating molecular phylogenies and fossil data in the Proteaceae. $88,900, Hermon Slade Foundation.

Rossetto, M. & Weston, P.H. (2007-2009) Speciation in the Australian flora: testing explanatory hypotheses in waratahs and their allies. $78,000, Hermon Slade Foundation.

Considine, J.A., Krauss, S.L. & Weston, P.H. (2002-2004) A biological basis for the efficient breeding of native plants for export markets: a case study with the Australian Goodeniaceae. $168,126, ARC – Linkage (Krauss and Weston representing industry partners)

Whelan, R.J., Ayre, D.J., England, P., Auld, T.D., & Weston, P.H. (2000-2002) Ecology and genetics of fire-sensitive *Persoonia* species: threatened species recovery and management. $126,480, Australian Research Council (ARC– SPIRT, Auld and Weston representing industry partners).

Trent, R. *et al.* (2000) Enhancement of DNA sequencing equipment for the Sydney University and Prince Alfred Molecular Analysis Centre. $600,000, Australian Research Council (ARC-REIF).

Weston, P.H. (1999-2001) Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae). $75,000, Hermon Slade Foundation.

Weston, P.H. (1997-2000) Taxonomic revision of *Dillwynia* (Fabaceae: Faboideae: Mirbelieae). $62,836, Australian Biological Resources Study.

Weston, P.H. & Thomson, J.A. (1993) A molecular approach to the evolution and biogeography of the Queensland tree waratahs. $4000, Queensland Wet Tropics Management Authority

Weston, P.H. & Thomson, J.A. (1991-92) A molecular approach to the evolution and biogeography of the waratahs. $80,100, Australian Research Council (large grants scheme).

Weston, P.H. (1984) Establishment of a data bank for eucalypt specimens held by NSW. $20,000, Australian Biological Resources Study.

Scientific Publications

[the numbers in square brackets following a reference indicate: 1. the journal's 2016-17 impact factor according to ISI Web of Knowledge, then the number of literature citations for the paper found by Google Scholar, as of 13 Feb 2019]

H-index = 34, total number of citations = 4081 as of 13 Feb 2019

1. Craw, R.C. & **Weston, P.H.** (1984) Panbiogeography: a progressive research program? *Systematic Zoology* 33: 1-13. [8.917, 90]

2. **Weston, P.H.**, Carolin, R.C., & Armstrong, J.A. (1984) A cladistic analysis of *Boronia* Sm. and *Boronella* Baill. (Rutaceae). *Australian Journal of Botany* 32: 187-203. [0.793, 49]

3. Morrison, D.A. & **Weston, P.H.** (1985) Analysis of morphological variation in a field sample of *Caladenia catenata* (Smith) Druce (Orchidaceae). *Australian Journal of Botany* 33: 185-195. [0.793, 11]

4. Crisp, M.D. & **Weston, P.H.** (1987a) Waratahs - how many species? Pp. 3-15, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 13]

5. Crisp, M.D. & **Weston, P.H.** (1987b) Cladistics and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae. Pp. 65-130, in C.H. Stirton (ed.) *Advances in Legume Systematics Part 3* (Royal Botanic Gardens: Kew). [-, 131]

6. **Weston, P.H.** (1987) *Persoonia* (Proteaceae). Pp. 348-350, in N.G. Marchant *et al*. (eds.) *Flora of the Perth Region* (Western Australian Herbarium: Perth). [-, 0]

7. **Weston, P.H.** & Crisp, M.D. (1987) Evolution and biogeography of the Waratahs. Pp. 17-34, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 14]

8. **Weston, P.H.**, Wilson, P.G., & Hill, K.D. (1987) Identification of *Cannabis*. *Department of Agriculture New South Wales Miscellaneous Bulletin* 25: 148-150. [-, 0]

9. **Weston, P.H.** (1988a) A revision of *Hicksbeachia* (Proteaceae). *Telopea* 3: 231-239. [0.6, 3]

10. **Weston, P.H.** (1988b) Indirect and direct methods in systematics. Pp. 27-56, in C.J. Humphries (ed.) *Ontogeny and Systematics* (Columbia Univ. Press: New York). [-, 76]

11. **Weston, P.H.** (1989) Problems with the statistical testing of panbiogeographic hypotheses. *New Zealand Journal of Zoology* 16: 511. [0.811, 7]

12. **Weston, P.H.** (1990) Notes on *Boronia* (Rutaceae) in New South Wales, including descriptions of three new species. *Telopea* 4: 121-128. [0.6, 6]

13. **Weston, P.H.** & Johnson, L.A.S. (1991) Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales. *Telopea* 4: 269-306. [0.6, 9]

14. Crisp, M.D. & **Weston, P.H.** (1991) *Almaleea*, a new genus of Fabaceae from south-eastern Australia. *Telopea* 4: 307-311. [0.6, 10]

15. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae), a new genus from New Guinea and eastern Australia. *Telopea* 4: 497-507. [0.6, 12]

16. **Weston, P.H.** (1991) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium*, *Pultenaea* and *Dillwynia* (Fabaceae). Pp. 2-19, 452-455, 456-461, 481-497, 499-504, in G. Harden (ed.) *Flora of New South Wales* vol. 2 (New South Wales Univ. Press: Sydney). [-, 0]

17. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae) and *Almaleea* (Fabaceae). Pp. 29-30, 497-498, in G. Harden (ed.) *op. cit.* [-, 0]

18. **Weston, P.H.** & Porteners, M.F. (1991) *Boronia*, *Eriostemon* and *Phebalium* (Rutaceae). Pp. 227-236, 250-254, 255-263, in G. Harden (ed.) *op. cit.* [-, 0]

19. Porteners, M.F. & **Weston, P.H.** (1991) *Correa* and *Crowea* (Rutaceae). Pp. 247-249, 254-255, in G. Harden (ed.) *op. cit.* [-, 0]

20. Crisp, M.D. & **Weston, P.H.** (1991) *Telopea*. Pp. 30-31, in G. Harden (ed.) *op. cit.* [0.6, 0]

21. Gross, C.L. & **Weston, P.H.** (1992) *Macadamia jansenii* (Proteaceae), a new species from central Queensland. *Australian Systematic Botany* 5: 725-28. [0.75, 8]

22. Crisp, M.D. & **Weston, P.H.** (1993) Geographic and ontogenetic variation in morphology of Australian waratahs (*Telopea*: Proteaceae). *Systematic Biology* 42: 49-76. [14.387, 76]

23. Gilmore, S., **Weston, P.H.**, & Thomson, J.A. (1993) A simple, rapid, inexpensive and widely applicable technique for purifying plant DNA. *Australian Systematic Botany* 6: 139-148. [0.75, 41]

24. **Weston, P.H.** (1993) Key to genera, *Cyrtostylis*, *Cryptostylis*, *Zeuxine*, *Cheirostylis*, *Pseudovanilla*, *Erythrorchis*, *Epipogium*, *Gastrodia*, *Oberonia*, *Liparis*, *Dendrobium*, *Calanthe*, *Phaius*, *Geodorum*, *Dipodium*, *Cymbidium*, *Sarcochilus*, *Rhinerrhiza*, *Peristeranthus*, *Papillilabium*, *Schistotylus*, *Plectorrhiza*, *Taeniophyllum* (Orchidaceae). Pp. 134-138, 218-219, 219-221, 221-233, 236-247, in G. Harden (ed.) *Flora of New South Wales* vol. 4 (New South Wales Univ. Press: Sydney). [-, 0]

25. **Weston, P.H.** & Hill, K.D. (1993) *Bulbophyllum* (Orchidaceae). Pp. 233-236, in G. Harden (ed.) *op. cit.* [-, 0]

26. **Weston, P.H.** & Crisp, M.D. (1994) Cladistic biogeography of Waratahs and their allies (Embothrieae: Proteaceae) across the Pacific. *Australian Systematic Botany* 7: 225-249. [0.75, 73]

27. **Weston, P.H.** (1994) The Western Australian species of subtribe Persooniinae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 6: 51-165. [0.6, 19]

28. **Weston, P.H.** & Johnson, L.A.S. (1994) Three new species of *Persoonia* (Proteaceae) from Queensland. *Telopea* 6: 31-37. [0.6, 1]

29. **Weston, P.H.** (1994) Methods for rooting cladistic trees. Pp. 125-155, in D.J. Siebert, R.W. Scotland and D.M. Williams (eds.) *Models in Phylogeny Reconstruction* (Oxford Univ. Press: Oxford). [-, 38]

30. Crisp, M.D. & **Weston, P.H.** (1995) Mirbelieae. Pp. 245-282, in J.J. Doyle and M.D. Crisp (eds.) *Advances in Legume Systematics Part 7: Phylogeny* (Royal Botanic Gardens: Kew). [-, 37]

31. Crisp, M.D. & **Weston, P.H.** (1995) Subtribe Embothriinae (Proteaceae). *Flora of Australia* 16: 382-390. [-, 0]

32. Crisp, M.D., Linder, H.P. & **Weston, P.H.** (1995) Cladistic biogeography of plants in Australia and New Guinea: congruent pattern reveals two endemic tropical tracks. *Systematic Biology* 44: 457-473. [8.917, 121]

33. Thomson, J.A., **Weston, P.H.** & Tan, M.K. (1995) A molecular approach to tracing the major lineages in *Pteridium*. Pp. 21-28, in R.T. Smith and J.A. Taylor (eds.) *Bracken: an Environmental Issue* (University of Leeds: Leeds). [-, 13]

34. **Weston, P.H.** (1995) Key to the genera of Proteaceae in Australia, Subfamily Persoonioideae, Subfamily Bellendenoideae, Subtribe Gevuininae, Subtribe Hicksbeachiinae. *Flora of Australia* 16: 41-46, 47-125, 125-127, 409-410. [-, 0]

35. Bernhardt, P. & **Weston, P.H.** (1996) The pollination ecology of *Persoonia* (Proteaceae) in eastern Australia. *Telopea* 6: 775-804. [0.6, 48]

36. **Weston, P.H.** & Crisp, M.D. (1996) Trans-Pacific biogeographic patterns in the Proteaceae. Pp. 215-232, in A. Keast & S.E. Miller (eds.) *The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Processes* (SPB Academic Publishing: Amsterdam). [-, 34]

37. **Weston, P.H.** & Johnson, L.A.S. (1997) *Persoonia hindii* (Proteaceae), a new species from the Newnes Plateau, New South Wales. *Telopea* 7: 199-203. [0.6, 6]

38. Jobson, P.C. & **Weston, P.H.** (1998) *Dillwynia glaucula* (Fabaceae: Mirbelieae), a new species from the Southern Tablelands, New South Wales. *Telopea* 8: 1-5. [0.6, 1]

39. **Weston, P.H.** (1999) *Persoonia pauciflora* (Proteaceae), a new species from the Hunter Valley, New South Wales. *Telopea* 8: 159-164. [0.6, 5]

40. Crisp, M.D., Gilmore, S.R. & **Weston, P.H.** (1999) The phylogenetic relationships of two anomalous species of *Pultenaea* (Fabaceae: Mirbelieae) from molecular and morphological data, and description of a new genus. *Taxon* 48: 701-714. [2.447, 21]

41. Jobson, P.C. & **Weston, P.H.** (1999) Two new species of *Dillwynia* (Fabaceae: Mirbelieae), from the Southern Tablelands of New South Wales. *Telopea* 8: 363-369. [0.6, 0]

42. Thomson, J.A., **Weston, P.H.** and Tan, M.K. (1999) A molecular approach to tracing major lineages in *Pteridium*: update and amendment. Pp. 35-36 in J.A. Taylor & R.T. Smith (eds.) *Bracken Fern: Toxicity, Biology and Control* (International Bracken Group: Aberystwyth). [-, 1]

43. **Weston, P.H.** (2000) Process morphology from a cladistic perspective. Pp. 124-144 in R. Scotland & T. Pennington (eds.) *Homology and Systematics: Coding Characters for Phylogenetic Analysis* (Taylor & Francis: Basingstoke). [-, 24]

44. Indsto, J. & **Weston, P.H.** (2000) Near-ultraviolet reflectance in *Dendrobium* (Orchidaceae). Pp. 326-334 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 5]

45. Kores, P.J., **Weston, P.H.**, Molvray, M., & Chase, M.W. (2000) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 449-456 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 60]

46. Savolainen, V., Fay, M.F., Albach, D.C., Backlund, A., van der Bank, M., Cameron, K.M., Johnson, S.A., Lledo, M.D., Pintaud, J.-C., Powell, M., Sheahan, M.C., Soltis, D.E., Soltis, P.S., **Weston, P.H.**, Whitten, W.M., Wurdack, K.J., & Chase, M.W., (2000) Phylogeny of the eudicots: a nearly complete familial analysis based on *rbc*L gene sequences. *Kew Bulletin* 55: 257-309. [0.577, 467]

47. Crisp, M.D. & **Weston, P.H.** (2000) *Telopea* (Proteaceae) Pp. 115-117 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

48. **Weston, P.H.** (2000) *Persoonia* (Proteaceae) Pp. 89-105 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

49. **Weston, P.H.** & Crisp, M.D. (2000) *Alloxylon* (Proteaceae) P. 115 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

50. Hill, R.S. & **Weston, P.H.** (2001) Southern (austral) ecosystems. Pp. 361-370 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* vol. 5 (Academic Press: San Diego). [-, 1]

51. Kores, P.J., Molvray, M., **Weston, P.H.**, Hopper, S.D., Brown, A., Cameron, K.M., and Chase, M.W (2001) A phylogenetic analysis of Diurideae (Orchidaceae) based on plastid DNA sequence data. *American Journal of Botany* 88: 1903-1914. [3.05, 135]

52. Jobson, P.C. & **Weston, P.H.** (2001) *Dillwynia rupestris* (Fabaceae: Mirbelieae), a new species from the New England Tableland of New South Wales. *Telopea* 9: 323-327. [0.6, 0]

53. Barker, N.P., **Weston, P.H.**, Rourke, J.P., & Reeves, G. (2002) The relationships of the southern African Proteaceae as elucidated by internal transcribed spacer (ITS) DNA sequence data. *Kew Bulletin* 57: 867-883. [0.577, 33]

54. Mant, J.G., Schiestl, F.P., Peakall, R., & **Weston, P.H.** (2002) A phylogenetic study of pollinator conservatism among sexually deceptive orchids. *Evolution* 56: 888-898. [4.201, 96]

55. **Weston, P.H.** (2002) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium* (Fabaceae), Pp. 3-20, 622-632 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

56. **Weston, P.H.** & Duretto, M.F. (2002) *Boronia* (Rutaceae). Pp. 265-276 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 3]

57. **Weston, P.H.** & Harden, G.J. (2002) *Correa, Philotheca*, *Eriostemon, Crowea, Phebalium, Nematolepis*, *Leionema* (Rutaceae) Pp. 289-310, in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 4]

58. **Weston, P.H.** & Jobson, P.C. (2002) *Dillwynia* (Fabaceae). Pp. 542-549 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

59. **Weston, P.H.** & de Kok, R. (2002) *Pultenaea* (Fabaceae). Pp. 549-565 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 1]

60. **Weston, P.H.** & Kooyman, R.M. (2002) Systematics of *Eidothea* (Proteaceae), with the description of a new species, *E. hardeniana*, from the Nightcap Range, north-eastern New South Wales. *Telopea* 9: 821-832. [0.6, 15]

61. Bernhardt, P., Sage, T., **Weston, P.H.**, Azuma, H., Lam, M., Thien, L.B., & Bruhl, J. (2003) The pollination of *Trimenia moorei* (Trimeniaceae): floral volatiles, insect/wind pollen vectors, and stigmatic self-incompatibility in a basal angiosperm. *Annals of Botany* 92: 445-458. [4.041, 87]

62. Qiu, H. & **Weston, P.H.** (2003) Proteaceae. *Flora of China* 5: 192-199 (Science Press: Beijing and Missouri Botanical Garden Press: St Louis). [-, 0]

63. Thien, L.B., Sage, T.L., Jaffré, T., Bernhardt, P., Pontieri, V., **Weston, P.H.**, Malloch, D., Azuma, H., Graham, S.W., McPherson, M.A., Rai, H.S., Sage, R.F., & Duprey, J.-L. (2003) The population structure and floral biology of *Amborella trichopoda* Baillon (Amborellaceae). *Annals of the Missouri Botanical Garden* 90: 466-490. [2.838, 72]

64. Mill, R.R. & **Weston, P.** (2004). Proposals to reject the names *Polypodiopsis* and *Polypodiopsis muelleri* (*Plantae vasculares, incertae sedis*). *Taxon* 53: 203-205. [2.447, 2]

65. **Weston, P.H.** (2004) Proteaceae. Pp. 313-316 in N. Smith, S.A. Mori, A. Henderson, D.W. Stevenson & S.V. Heald (eds.) *Flowering Plants of the Neotropics* (The New York Botanical Garden and Princeton University Press: Princeton). [-, 0]

66. **Weston, P.H.** & Turton, M. (2004) *Phebalium bifidum* (Rutaceae), a new species from the Capertee Valley, New South Wales. *Telopea* 19: 787–792. [0.6, 2]

67. Entwisle, T.J. & **Weston, P.H.** (2005) Majority rules, when systematists disagree. *Australian Systematic Botany* 18: 1–6. [0.75, 29]

68. Indsto, J.O., **Weston, P.H.**, Clements, M.A. & Whelan, R.J. (2005) Highly sensitive DNA fingerprinting of orchid pollinia remnants using AFLP. *Australian Systematic Botany* 18: 207–213. [0.75, 9]

69. Jordan, G.J., Dillon, R.A. & **Weston, P.H.** (2005) Solar radiation as a factor in the evolution of scleromorphic leaf anatomy in Proteaceae. *American Journal of Botany* 92: 789–796. [3.05, 96]

70. Kurzweil, H., **Weston, P.H.** & Perkins, A.J. (2005) Morphological and ontogenetic studies on the gynostemium of some Australian members of Diurideae and Cranichideae (Orchidaceae). *Telopea* 11: 11–33. [0.6, 9]

71. Mant, J., Bower, C.C., **Weston, P.H.** & Peakall, R. (2005) Phylogeography of pollinator-specific sexually deceptive *Chiloglottis* taxa (Orchidaceae): evidence for sympatric divergence? *Molecular Ecology* 14: 3067–3076. [6.086, 26]

72. Mant, J., Peakall, R. & **Weston, P.H.** (2005) Specific pollinator attraction and the diversification of sexually deceptive *Chiloglottis* (Orchidaceae). *Plant Systematics and Evolution* 253: 185–200. [1.239, 33]

73. Mant, J., Brown, G.R. & **Weston, P.H.** (2005) Opportunistic pollinator shifts among sexually deceptive orchids indicated by a phylogeny of pollinating and non-pollinating thynnine wasps (Tiphiidae). *Biological Journal of the Linnean Society* 86: 381–395. [2.288, 16]

74. Rymer, P.D., Whelan, R.J., Ayre, D.J. & **Weston, P.H.** (2005) Reproductive success and pollinator effectiveness differ in common and rare *Persoonia* species (Proteaceae). *Biological Conservation* 123: 521–532. [4.022, 57]

75. **Weston, P.H.**, Perkins, A.J., & Entwisle, T.J. (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15. [-, 34]

76. **Weston, P.H.** & Barker, N.P. (2006) A new suprageneric classification of the Proteaceae, with an annotated checklist of genera. *Telopea* 11(3): 314-344. [0.6, 86]

77. Indsto, J.O., **Weston, P.H.**, Clements, M.A., Dyer, A.G., Batley, M. & Whelan, R.J. (2006) Pollination of *Diuris maculata* (Orchidaceae) by male *Trichocolletes venustus* bees. *Australian Journal of Botany* 54: 669-679. [0.793, 37]

78. **Weston, P.H.** (2007) Proteaceae. Pp. 364-404 in K. Kubitzki (ed.) *Families and Genera of Vascular Plants* Volume IX (Springer Verlag: Berlin). [-, 26]

79. **Weston, P.H.** (2007) Proteaceae. Pp. 268-269 in V.H. Heywood, R.K. Brummitt, A. Culham & O. Seberg (eds.) *Flowering Plant Families of the World* (Royal Botanic Gardens, Kew: London). [-, 0]

80. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2007) Floral phyllotaxis and floral architecture in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 168: 285–306. [1.748, 36]

81. Indsto, J.O., **Weston, P.H.**, Clements, M., Dyer, A., Batley, M. & Whelan, R. (2007) Generalised pollination of *Diuris alba* R.Br. (Orchidaceae) by small bees and wasps. *Australian Journal of Botany* 55: 628-634. [0.793, 17]

82. Barker, N.P., **Weston, P.H.**, Rutschmann, F. & Sauquet, H. (2007) Molecular dating of the "Gondwanan" plant family Proteaceae is only partially congruent with the timing of Gondwanan break-up. *Journal of Biogeography* 34: 2012-2027. [4.248, 166]

83. Jordan, G.J., **Weston, P.H.**, Carpenter, R.J., Dillon, R.A. & Brodribb, T.J. (2008) The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae. *American Journal of Botany* 95:521-530. [3.05, 82]

84. Mast, A.R., Willis, C.L., Jones, E.H., Downs, K.M., & **Weston, P.H.** (2008) A smaller *Macadamia* from a more vagile tribe: Inference of phylogenetic relationships and divergence times in *Macadamia* and relatives (tribe Macadamieae; Proteaceae). *American Journal of Botany* 95: 843-870. [3.05, 55]

85. Sauquet, H., **Weston, P.H.**, Anderson, C.L., Barker, N.P. Cantrill, D.J., Mast, A.R., & Savolainen, V. (2009) Contrasted patterns of hyperdiversification in Mediterranean hotspots. *Proceedings of the National Academy of Sciences of the U.S.A.* 106: 221-225. [9.661, 169]

86. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2009) Comparative gynoecium structure and development in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 170: 21-41. [1.748, 25]

87. Sage, T.L., Hristova-Sarkovsi, K., Koehl, V., Lyew, J., Pontieri, V., Bernhardt, P., **Weston, P.**, Bagha, S., & Chiu, G. (2009) Transmitting tissue architecture in relictual-basal angiosperms: implications for transmitting tissue origins. *American Journal of Botany* 96: 183-206. [3.05, 34]

88. Crisp, M.D., Arroyo, M.T.K., Cook, L.G., Gandolfo, M.A., Jordan, G.J., McGlone, M.S., **Weston, P.H.**, Westoby, M., Wilf, P., & Linder, H.P. (2009) Phylogenetic biome conservatism on a global scale. *Nature* 458: 754-758. [40.137, 465]

89. Indsto, J.O., **Weston, P.H.**, & M.A. Clements (2009) A molecular phylogenetic analysis of *Diuris* (Orchidaceae) based on AFLP and ITS reveals three major clades and a basal species. *Australian Systematic Botany* 22: 1-15. [0.75, 7]

90. Sauquet, H., **Weston, P.H.**, Barker, N.P. Anderson, C.L., Cantrill, D.J. & Savolainen, V. (2009) Using fossils and molecular data to reveal the origins of the Cape proteas (subfamily Proteoideae). *Molecular Phylogenetics and Evolution* 51: 31-43. [4.419, 40]

91. Rossetto, M., Thurlby, K.A.G., Offord, C.A., Allen, C.B., & **Weston, P.H.** (2011) The impact of distance and a shifting temperature gradient on genetic connectivity across a heterogeneous landscape. *BMC Evolutionary Biology* 11(126):1-11. [3.221, 18]

92. Byrne, M., Steane, D., Joseph, L., Yeates, D., Jordan, G.J., Crayn, D., Aplin, K., Cantrill D., Cook, L.G., Crisp, M.D., Keogh, J.S., Melville, J., Moritz, C., Porch, N., Sniderman, J.M.K., Sunnucks P., & **Weston, P.H.** (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. *Journal of Biogeography* 38: 1635–1656. [4.590, 216]

93. Mast, A.R., Milton, E.F., Jones, E.H., Barker, R.M., Barker, W.R., & **Weston, P.H.** (2012) Time-calibrated phylogeny of the woody Australian genus *Hakea* (Proteaceae) supports multiple origins of insect-pollination among bird-pollinated ancestors. *American Journal of Botany* 99: 472-487. [3.05, 32]

94. Stimpson, M.L., **Weston, P.H.**, Telford, I.R.H., & Bruhl, J.J. (2012) First instalment in resolution of the *Banksia spinulosa* complex (Proteaceae): *B. neoanglica*; a new species supported by phenetic analysis, ecology and geography. *Phytokeys* 14: 57–80. [0.686, 6]

95. Rossetto, M., Allen, C., Thurlby, K., **Weston, P.H.**, & Milner, M. (2012) Genetic structure and bio-climatic modelling support allopatric over parapatric speciation along a latitudinal gradient. *BMC Evolutionary Biology* 12:149. [3.221, 13]

96. Clark, V.R., Perera, S.J., Stiller, M., Stirton, C.H., **Weston, P.H.**, Stoev, P., Coombs, G., Morris, D., Ratnayake-Perera, D., Barker, N.P., & MacGregor, G.K. (2012) A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation. *SpringerPlus* 1:56 [0.982, 5]

97. Milner, M.L., Rossetto, M., Crisp, M.D., & **Weston, P.H.** (2012) The impact of multiple biogeographic barriers and hybridization on species-level differentiation. *American Journal of Botany* 99: 2045–2057. [3.05, 17]

98. Ford, A.J. & **Weston, P.H.** (2012) A taxonomic revision of *Hollandaea* Anon. (Proteaceae). *Austrobaileya* 8: 670-687. [-, 0]

99. Hidayat, T., **Weston, P.H.**, Yukawa, T., Ito, M., & Rice, R. (2012) Phylogeny of subtribe Aeridinae (Orchidaceae) inferred from DNA sequences data: advanced analyses including Australasian genera. *Jurnal Teknologi (Sciences and Engineering)* 59 (suppl. 1): 87-95. [0.096, 4]

100. **Weston, P.H.** & Hill, R.S. (2013) Southern (austral) ecosystems. Pp. 612-619 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* second edition, vol. 6 (Academic Press: Waltham, MA). [-, 9]

101. Jordan, G.J., Brodribb, T.J., Blackman, C.J., & **Weston, P.H.** (2013) Climate drives vein anatomy in Proteaceae. *American Journal of Botany* 100: 1483-1493.
[3.05, 19]

102. **Weston, P.H.** & Woods, L.A. (2013) Correction of a typographical error in the protologue of *Banksia conferta* A.S.George var. *penicillata* A.S. George. *Telopea* 15: 67–69. [0.6, 0]

103. Milner, M.L., McIntosh, E.J., Crisp, M.D., **Weston, P.H.**, & Rossetto, M. (2013) Microsatellite variation for phylogenetic, phylogeography and population genetic studies in *Lomatia* (Proteaceae). *Australian Systematic Botany* 26: 186-195. [0.75, 2]

104. **Weston, P.H.** (2014) What has molecular systematics contributed to our knowledge of the Proteaceae? Pp. 365-397 in P. Besse (ed.) *Molecular Plant Taxonomy: Methods and Protocols*, *Methods in Molecular Biology*, vol. 1115 (Springer: New York). [-, 11]

105. McIntosh, E., Rossetto, M., **Weston, P.H.**, & Wardle, G. (2014) Maintenance of strong morphological differentiation despite ongoing natural hybridization between sympatric species of *Lomatia* (Proteaceae). *Annals of Botany* 113: 861-872. [4.041, 16]

106. Stimpson, M.L., Bruhl, J.J. & **Weston, P.H.** (2014) Could this be Australia's rarest *Banksia*? *Banksia vincentia* (Proteaceae), a new species known from fourteen plants from south-eastern New South Wales, Australia. *Phytotaxa* 163: 269–286. [1.24, 1]

107. Thomas, N., Bruhl, J.J., Ford, A., & **Weston, P.H.** (2014) Molecular dating of Winteraceae reveals a complex biogeographic history involving both ancient Gondwanan vicariance and long-distance dispersal. *Journal of Biogeography* 41: 894-904. [4.590, 28]

108. **Weston, P.H.**, Perkins, A.J., Indsto, J.O., & Clements, M.A. (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier, R. & P. Bernhardt (eds.) *Darwin's Orchids: Then and Now* (University of Chicago Press: Chicago). [-, 10]

109. Kooyman, R.M., Wilf, P., Barreda, V.D., Carpenter, R.J., Jordan, G.J., Sniderman, J.M.K., Allen, A., Brodribb, T.J., Crayn, D., Feild, T.S., Laffan, S.W., Lusk, C., Rossetto, M., & **Weston, P.H.** (2014) Paleo-Antarctic rainforest into the modern Old World tropics: the rich past and threatened future of the 'southern wet forest survivors'. *American Journal of Botany* 101: 2121 – 2135. [3.05, 36]

110. Lambers, H., Clode, P., Hawkins, H.-J., Laliberté, E., Oliveira, R., Reddell, P., Shane, M.W., Stitt, M., & **Weston, P.H.** (2015) Metabolic adaptations of the non-mycotrophic Proteaceae to soil with a low phosphorus availability. *Annual Plant Reviews* 48: 289–336 (Plaxton, W.C. & Lambers, H. (eds.) *Phosphorus Metabolism in Plants in the Post-genomic Era: From Gene to Ecosystem* (Wiley-Blackwell Publishing: Chichester, UK)). [-,34]

111. Mast, A.R., Olde, P., Makinson, R.O., Jones, E., Kubes, A., Miller, E. & **Weston, P.H.** (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646. [3.05, 15]

112. Thiele, K.R., **Weston, P.H.** & Mast, A.M. (2015) Paraphyly, modern systematics and the transfer of *Dryandra* into *Banksia* (Proteaceae): a response to George. *Australian Systematic Botany* 28: 194–202 [0.75, 1]

113. Milner, M.L., **Weston, P.H.,** Rossetto, M., & Crisp, M.D., (2015) Biogeography of the Gondwanan genus *Lomatia* (Proteaceae): vicariance at continental and intercontinental scales. *Journal of Biogeography* 42: 2440–2451. [4.590, 9]

114. Stimpson, M.L., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (2016) A morphometric analysis of the *Banksia spinulosa* complex (Proteaceae) and its complex taxonomic implications. *Australian Systematic Botany* 29: 55-86. [0.75, 0]

115. Onstein, R.E., Jordan, G.J., Sauquet, H., **Weston, P.H.**, Bouchenak-Khelladi, Y., Carpenter, R.J., & Linder, H.P. (2016) Evolutionary radiations of Proteaceae are triggered by the interaction between traits and climates in open habitats. *Global Ecology and Biogeography* 25: 1239–1251. [6.045, 17].

116. van der Merwe, M., Crayn, D., Ford, A., Rossetto, M., & **Weston, P.H.** (2016) Evolution of Australian *Cryptocarya* (Lauraceae) based on nuclear and plastid phylogenetic trees: evidence of recent landscape-level disjunctions *Australian Systematic Botany* 29: 157–166. [0.75, 3]

117. Citerne, H., Reyes, E., Le Guilloux, M., Delannoy, E., Sannier, J., Simmonet, F., Sauquet, H., Nadot, S., **Weston, P.H.**, & Damerval, C. (2017) Characterisation of CYCLOIDEA-like genes in

Proteaceae, a basal eudicot family with multiple shifts in floral symmetry. *Annals of Botany* 119: 367-378. [4.041, 13]

118. **Weston, P.H.**, & Jordan, G.J. (2017) Evolutionary biogeography of the Australian flora in the Cenozoic Era. Pp. 40-62 in D.A. Keith (ed.) *Australian Vegetation*, 3rd edition (Cambridge University Press: Cambridge). [-, 1]

119. Cardillo, M., **Weston, P.H.**, Reynolds, Z., Olde, P.M., Mast, A.R., Lemmon, E., Lemmon, A. & Bromham, L. (2017) The phylogeny and biogeography of *Hakea* (Proteaceae) reveals the role of biome shifts in a continental plant radiation. *Evolution* 71: 1928–1943. [4.201, 10]

120. Holmes, G., **Weston, P.H.**, Murphy, D., Gardner, S., Connelly, C., & Cantrill, D.J. (2018) The genealogy of geebungs: phylogenetic analysis of *Persoonia* (Proteaceae) and related genera in subfamily Persoonioideae. *Australian Systematic Botany* 31: 166–189. [0.75, 0]

121. **Weston, P.H.** (in press) Proteaceae. *Flora of North America North of Mexico* 10-11 (Oxford University Press: New York and Oxford). [-,-]

122. Steenbeeke, G., Dowle, M., Laurence, M.H., Liew, E.C.Y., Newby, Z.-J., Renner, M., Sommerville, K., Weston, P.H., Ward, S. (in review) Phylogeny of selected *Microtis* (Orchidaceae) in south eastern Australia and its implications for taxonomy and conservation priorities. *Telopea* [0.6, -]

Papers in Preparation

1. Stimpson, M.L., Wright, B.R., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (in review) Seedling morphology helps unravel the taxonomic intricacies in the *Banksia spinulosa* complex (Proteaceae). *Botanical Journal of the Linnean Society* [2.523, -]

2. Jobson, P.C. & **Weston, P.H.** (in prep.) Recombinations in *Dillwynia* (Fabaceae: Faboideae: Mirbelieae) for Flora of South Australia.

3. Jordan, G.J. & **Weston, P.H.** (in prep.) Estimating the age of origin of functional traits.

4. **Weston, P.H.** & Garnock-Jones, P. (in prep.) A taxonomic revision of *Knightia* (Proteaceae).

Conference Abstracts

1. **Weston, P.H.** (1984) A reappraisal of Nelson's direct method of character analysis. P. 9, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

2. Wilson, P.G. & **Weston, P.H.** (1984) A preliminary cladistic analysis of the *Metrosideros* suballiance (Myrtaceae). P. 19, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

3. **Weston, P.H.** (1984) Drifting waratahs or continents? P. 9, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

4. Crisp, M.D. & **Weston, P.H.** (1984) Waratahs – one species or two? P. 5, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

5. **Weston, P.H.** (1988) Problems with the statistical testing of panbiogeographic hypotheses. Abstracts, Symposium on *Panbiogeography of New Zealand*, Wellington.

6. **Weston, P.H.** (1989) Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae. P. 37, Program and Abstracts, Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney.

7. **Weston, P.H.** & Crisp, M.D. (1990) Transoceanic cladistic patterns in the Proteaceae. P. 51, Abstracts, *Systematics and Biogeography of the Austral Biota*, IXth meeting of the Willi Hennig Society, Canberra.

8. **Weston, P.H.** (1993) Direct methods for polarising character transformation series. P. 13, Programme and Abstracts, *Models in Phylogeny Reconstruction*, a joint conference of The Systematics Association and The Linnean Society, London.

9. Crisp, M.D., Linder, H.P., & **Weston, P.H.** (1994) Cladistic biogeography of Australia: is there more than one endemic tropical track? P. 14, Program and Abstracts, *Origin and Evolution of the Flora of the Monsoon Tropics*, a symposium of the Australian Systematic Botany Society, Kuranda.

10. **Weston, P.H.** (1996) ITS sequence variation in the Proteaceae and what it tells us about phylogeny. P. 49, Abstracts, *An International Symposium on the Biology of Proteaceae*, Melbourne.

11. **Weston, P.H.** (1997) Rolf Sattler's plant morphology and cladistic analysis. P. 54, Abstracts, *First Biennial International Conference of the Systematic Association*, Oxford, U.K..

12. **Weston, P.H.** & Crisp, M.D. (1997) Cladistic biogeography of a key woody group: Proteaceae. P. 5, Abstracts, *II Southern Connection Congress*, Valdivia, Chile.

13. Kores, P.J., Molvray, M., **Weston, P.H.**, & Chase, M.W. (1998) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 33-34, Abstracts. Monocots II Conference, Sydney.

14. **Weston, P.H.** (1999) Historical biogeography of Proteaceae. Abstracts, XVI International Botanical Congress, Saint Louis.

15. **Weston, P.H.** (2002) Proteaceae: Brown and now. P. 16, Abstracts, Robert Brown 200 Conference, Sydney.

16. Mant, J.G., **Weston, P.H.**, Peakall, R., & Schiestl, F.P. (2003) Coevolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators. P. 55, Abstracts, *Monocots III*, The Third International Conference on the Comparative Biology of the Monocotyledons, Ontario, U.S.A..

17. **Weston, P.H.,** Clements, M.A., Indsto, J.O., Mant, J., Peakall, R., & Perkins, A.J. (2005) Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae). XVII International Botanical Congress, Vienna.

18. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2006) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 39 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

19. **Weston, P.H.** (2006) A new suprageneric classification of the Proteaceae. P. 45 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

20. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K.. (2006). Floral architecture and phyllotaxis in Calycanthaceae (Laurales). Abstract 192, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

21. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2006). A phylogenetic approach to the evolution of pollen morphology in Proteaceae (Proteales). Abstract 405, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

2. Milton, E.F., **Weston, P.H.**, Mast, A. (2006) The diversification of ecologically significant traits in the species-rich Australian genus *Hakea* (Proteaceae). Abstract 324, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

23. Mast, A., **Weston, P.H.**, Jones, E., Sauquet, H., Cantrill, D., Jordan, G., & Barker, N. . (2006) The timing of disjunctions in the southern hemisphere family Proteaceae: Sensitivity analysis with 6 genes, multiple calibration points, and 70+ genera. Abstract 327, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

24. Willis, C.L., **Weston, P.H.**, & Mast, A. (2007) Inference of phylogenetic relationships in *Macadamia* and relatives (tribe Macadamieae; Proteaceae) using three chloroplast and three nuclear DNA regions. Abstract 1677, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

25. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K. (2007) Structure and development of the gynoecium in Calycanthaceae (Laurales). Abstract 1121, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

26. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). Abstract 1593, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

27. Milton, E.F., **Weston, P.H.**, Barker, W., Barker, R., & Mast, A. (2007) Inference of phylogenetic relationships in *Hakea* (Proteaceae) using morphology and four chloroplast and three nuclear DNA regions. Abstract 1712, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

28. Kubes, A., **Weston, P.H.**, Makinson, R.O., Olde, P., & Mast, A.R. (2007) Resolving relationships in *Grevillea* (Proteaceae), the third largest Australian plant genus. Abstract 1814, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

29. **Weston, P.H.**, Barker, N.P., Rutschmann, F., & Sauquet, H. (2007) 'I'm not dead yet' – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation). P. 76, Conference Program, 5th International Southern Connection Congress, Adelaide.

30. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 58, Conference Program, 5th International Southern Connection Congress, Adelaide.

31. Mast, A., Jones, E., Barker, R., Barker, W., **Weston, P.H.** (2009) The phylogeny and age of the woody Australian genus *Hakea* (Proteaceae) and the evolution of its leaf and fire persistence features. Abstract 335, Botany & Mycology 2009 (Botanical Society of America conference, Snowbird, Utah)

32. Holmes, G.D., Porter, C., Murphy, D.J., **Weston, P.H.** and Cantrill, D.J. (2009) What are the relationships among Snottygobbles and Geebungs? A preliminary phylogeny of *Persoonia* (Proteaceae). P 45, Conference Booklet, *Systematic Botany: from Science to Society*, a conference of the Australian Systematic Botany Society, Armidale.

33. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests. P. 29, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

34. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Cladistic biogeography, molecular dating, fossils and the Proteaceae. P. 18, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

35. Baum, M., Crisp, M., Rossetto, M. & **Weston, P.** (2010) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 20, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

36. **Weston, P.H.** (2010) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 68, *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*, a conference of the Australian Systematic Botany Society, Lincoln University, New Zealand.

37. **Weston, P.H.** (2011) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 34, Abstracts 2nd Book, *Plants in a Changing World*, (37th annual conference of the South African Association of Botanists, Rhodes University, South Africa).

38. **Weston, P.H.**, Indsto, J.O., Perkins, A.J., Clements, M.A., & Peakall, R. (2011) Total evidence phylogenetic analysis of the orchid tribe Diurideae and what it tells us about the evolution of pollination systems. P. 152, Abstract Book, XVIII International Botanical Congress, Melbourne.

39. **Weston, P.H.**, Wilson, P.G., Conn, B.J., Rymer, P.D. (2011) Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations. P. 266, Abstract Book, XVIII International Botanical Congress, Melbourne.

40. Nguyen, C.H., Beattie, G.A.C., Holford, P., Mabberley, D.J., & **Weston, P.H.** (2011) Determining the origin and diversification of *Murraya paniculata*: one or more species? P. 354, Abstract Book, XVIII International Botanical Congress, Melbourne.

41. Milner, M., Crisp, M.D., Rossetto, M., & **Weston, P.H.** (2011) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 281, Abstract Book, XVIII International Botanical Congress, Melbourne.

42. **Weston, P.H.** (2012) Contested, uncontested and potentially controversial taxonomic changes in the Proteaceae: how do they differ? P. 49, Program and Abstracts, *Local Knowledge, Global Delivery* (Australasian Systematic Botany Society 2012 Perth Conference Committee: Perth).

43. **Weston, P.H.,** Jones, E.H., Olde, P.M., Makinson, R.O., & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 101, *Genetics in the Harbour City* (Program and abstracts of the annual conference of the Genetics Society of Australasia, Sydney).

44. Onstein, R., Jordan, G., Bouchenak-Khelladi, Y., Xing, Y., Wright, I., Sauquet, H., Carpenter, R., **Weston, P.** & Linder, P. (2013) Leaf trait evolution in the Proteaceae. P. 11, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

45. Cantrill, D.J., Lewis, E., Murphy, D.J. & **Weston, P.H.** (2013) Variation in pollen morphology within *Persoonia* (Proteaceae) supports clades revealed by molecular data. P. 19, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

46. **Weston, P.H.**, Jones, E.H., Olde, P.M., Makinson, R.O. & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 20, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

47. Schulte, K., Micheneau, C., Simpson, L., **Weston, P.**, Crayn, D. & Clements, M. (2013) The *Dendrobium* alliance revisited: A molecular phylogenetic approach towards reconciling taxonomic concepts in Dendrobiinae (Orchidaceae). P. 32, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

48. Stimpson, M.L., Prychid, C.J., **Weston, P.H.** Whalley, R.D.B. & Bruhl, J.J. (2013) Structure and function of the cotyledonary node in the *Banksia spinulosa* complex (Proteaceae). P. 68, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

49. **Weston, P.H.** (2014) Problems and progress in plant systematics since Nancy Burbidge. P. 17, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

50. Thomas, N., Bruhl, J., Ford, A. & **Weston, P.** (2014) Molecular dating of Winteraceae reveals a complex biogeographical history involving both ancient Gondwanan vicariance and long-distance dispersal. P. 28, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

51. **Weston, P.H.** Reyes, E. & Sauquet, H. (2015) A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution. P. 35, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

52. Schulte, K., Micheneau, C., Field, A., **Weston, P.**, Crayn, D. & Clements, M. (2015) The *Dendrobium* alliance revisited: examining macroevolutionary patterns in Dendrobiinae (Orchidaceae). P. 30, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

53. Thiele, K., Barker, W.R., Crayn, D.M., Waycott, M., Holland, A., Breitwieser, I., Lockhart, P., Bayly, M., **Weston, P.H.**, & Schulte, K. (2015) Progress towards a decadal plan for Australasian biodiversity science – an update. P. 33, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

Articles in Magazines, Newsletters, etc.

1. Weston, P.H. (1988c) Proteaceae. Australian Plants 14: 259.

2. Weston, P.H. (1988d) The flower - part 2. *Australian Plants* 14: 262-263.

3. Weston, P.H. (1992) A special tree [an article about *Idiospermum australiense*]. *Friends of the Royal Botanic Gardens Newsletter* 14: 4.

4. Weston, P.H. & Crisp, M.D. (1995) Phylogenetic analysis. *Australasian Biotechnology* 5(5): 291-293.

5. Weston, P.H. (1998) Lust, lies and fungus flies. *The Gardens* 39: 8-9.

6. Weston, P.H. (2000) Flower wasps and bird orchids. *The Gardens* 44: 5.

7. Weston, P.H. (2000) An intriguing case of snottygobbles. *The Gardens* 44: 11.

8. Weston, P.H. (2001) The Nightcap Oak comes out of the bush and into the spotlight. *The Gardens* 50: 6.

9. Weston, P.H. (2001) New tree species discovered in Australia. *Forest Genetic Resources* 29: 26.

10. Weston, P.H. & Kooyman, R.M. (2002) *Eidothea hardeniana*: botany and ecology of the 'Nightcap Oak'. *Australian Plants* 21: 339-342, 344.

11. Weston, P.H. (2003) Proteaceae subfamily Persoonioideae: botany of the geebungs, snottygobbles and their relatives. *Australian Plants* 22: 62-78, 91.

12. Weston, P.H. (2005) Sex and Death in the Sydney Tropical Centre. *The Gardens* 65: 6-7, republished in re-edited form in *Australian Orchid Review* 70(5): 32-33.

14. Weston, P.H. (2009) From the President. *ASBS Newsletter* 141: 1-3.

15. Weston, P.H. (2010) Madagascar: a world of botanical wonders. *The Gardens* 84: 10-11.

16. Weston, P.H. (2010) From the President. *ASBS Newsletter* 142: 1.

17. Weston, P.H. (2010) From the President. *ASBS Newsletter* 143: 1-3.

18. Weston, P.H. (2010) From the President. *ASBS Newsletter* 144-145: 1.

19. Weston, P.H. (2010) ASBS President's Report 2009–2010. *ASBS Newsletter* 144-145: 4-6.

20. Weston, P.H. (2010) Life Membership awarded to John Clarkson. *ASBS Newsletter* 144-145: 16.

21. Weston, P.H. (2010) ASBS 2010 Conference Report, Lincoln, Canterbury, New Zealand. *ASBS Newsletter* 144-145: 17-21.

22. Weston, P.H. (2011) From the President. *ASBS Newsletter* 146: 1-2.

23. Weston, P.H. (2011) From the President. *ASBS Newsletter* 147-148: 1-3.

24. Weston, P.H. (2011) Award of Nancy T. Burbidge Medals to Professors Pauline Ladiges and Michael Crisp. *ASBS Newsletter* 147-148: 3-8.

25. Weston, P.H. (2011) The ARC-ERA journal ranking project has been aborted. *ASBS Newsletter* 147-148: 11-12.

26. Weston, P.H. (2011) Recent advances and new developments in biogeographical reconstruction methods. *ASBS Newsletter* 147-148: 14.

27. Weston, P.H. (2011) [Book review of] The Flowering of Australia's Rainforests: A Plant and Pollination Miscellany. By Geoff Williams and Paul Adam. *ASBS Newsletter* 147-148: 21-23.

28. Weston, P.H. (2011) From the President. *ASBS Newsletter* 149: 1-2.

29. Weston, P.H. (2011). ASBS President's Report 2010-2011. *ASBS Newsletter* 149: 4-7.

30. Weston, P.H. (2012) From the President. *ASBS Newsletter* 150: 1-2.

31. Weston, P.H. (2012) New proposals to change ASBS rules. *ASBS Newsletter* 150: 4-10.

32. Weston, P.H. (2012) From the President. *ASBS Newsletter* 151: 1-2.

33. Weston, P.H. (2012) A remarkable botanical find: the double discovery of *Danhatchia australis* in Australia. *The Gardens* 94: 27.

34. Weston, P.H. (2012) From the President. *ASBS Newsletter* 152: 1-2.

35. Weston, P.H. (2013) Exploring southern Africa. *The Gardens* 96: 18-19.

36. Weston, P.H. (2013) ASBS President's Report 2011-2012. *ASBS Newsletter* 153: 7-10.

37. Weston, P. (2013) Not an exact science. *Sydney Morning Herald,* 19 June 2013: 19.

38. Weston, P.H. (2015) Funding research. *The Gardens* 103:33.

39. Weston, P.H. (2016) Building a database of floral characters for researching the iconic Australian plant family Proteaceae. Report to the Winston Churchill Memorial Trust

(https://www.churchilltrust.com.au/media/fellows/Weston_P_2014_Building_a_database_of_floral_characters_of_Proteaceae.pdf).

40. Weston, P.H. (2016) Hunting Proteaceae from European dungeons to the wilds of the Western Cape. *The Gardens* 109: 16-17.

Expert report – *Hibbertia fumana*

Hibbertia fumana – Wilton and GMAC, Robert Miller, September 2018

Hibbertia fumana – WSA and GPEC, Robert Miller, December 2018

Strategic assessment for Cumberland Plain Conservation Plan

Hibbertia fumana

Hibbertia fumana, Moorebank, R. Miller September 2017.

Report prepared for Department of Planning and Environment

By

Cumberland Flora & Fauna Interpretive Services

Robert Miller - September 2018

Executive Summary

Hibbertia fumana is listed as a Critically Endangered Species under the *Biodiversity Conservation Act 2016*. There are two known populations of the species, one at Moorebank and the other at Bankstown Airport. The species is assessed as data-poor.

Survey for this report was limited by time constraints, lack of access to private property, survey outside the species flowering season and years of preceding drought conditions.

Assessment relied on the expected presence of "likely habitat", based on extant population habitat, and "potential habitat", based on speculation of historic record habitat.

The probability of the species to occur in the likely habitat is considered low due to site disturbance, however, cannot be ruled out as the Bankstown population survives in highly modified mown derived grassland environment. The probability of the species to occur in potential habitat is considered to be very low. However, a precautionary approach is recommended. Locating and protecting new populations, no matter how small, is significant to the survival of this species.

H. fumana is a small shrub that could be severely affected by anthropogenic impacts resulting from development edge effects, particularly in areas downhill of development.

The assessment identified:

- at Menangle Park an area of approximately 92ha that could contain likely habitat niches within the growth area footprint, and a further 31 ha of land containing likely habitat niches adjacent to the footprint.
- at Kayess and Milton Parks areas of likely habitat that are not affected by the growth area footprints.
- at Bunbury Curran Creek vicinity areas of potential habitat are not affected by the growth area footprints.
- in the Gilead and Appin areas approximately 8ha of land containing potential habitat niches within the growth area footprint and a further 380ha of land containing potential habitat niches adjacent to the footprint.
- in the Wilton growth area, approximately 65ha of land containing potential habitat niches within the footprint and a further 680ha of land containing potential habitat niches adjacent to the footprint.

Note that the likely and potential habitats are niches within the overall landscape, generally associated with localised soil and drainages within transition vegetation.

Although the species occurrence is assessed as low, it is recommended that further survey be carried out in the likely habitat and some of the potential habitat areas during the species' flowering season.

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Abbreviations

AVH	Australian Virtual Herbarium
BAM	Biodiversity Assessment Method
BC Act	Biodiversity Conservation Act 2016
CFFIS	Cumberland Flora & Fauna Interpretive Services
DPE	NSW Department of Planning and Environment
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
GMGA	Greater Macarthur Growth Area
IBRA	Interim Biogeographic Regionalisation for Australia
OEH	NSW Office of Environment and Heritage
PCT	Plant Community Type
sp./spp.	species (species singular / plural)
s. str.	*sensu stricto* – in the narrow sense
subsp.	subspecies
WGA	Wilton Growth Area

1. Introduction

1.1 PURPOSE

The purpose of this expert report is to determine the potential for future urban development in identified growth areas of Western Sydney to impact on *Hibbertia fumana*, which is listed as a Critically Endangered Species under the *Biodiversity Conservation Act 2016*. This report forms part of the Cumberland Plain Conservation Plan, which will be assessed under the:

- Biodiversity certification under the *Biodiversity Conservation Act 2016* (BC Act)
- Strategic assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Biodiversity Assessment Method (BAM) sets out the framework and methods to be used for assessment of impacts to biodiversity to provide preferred conservation outcomes while also supporting the development approval process. Under the BAM an expert report can be used when adequate survey is not possible. An expert report can only be used for species to which species credits apply.

The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report. The report must set out whether the subject species is likely to be present at the development site, and if present then the report must estimate, in the case of a species such as *Hibbertia fumana*, the area of habitat where the species is likely to be impacted, as well as areas from which it is known to occur in which it will be impacted.

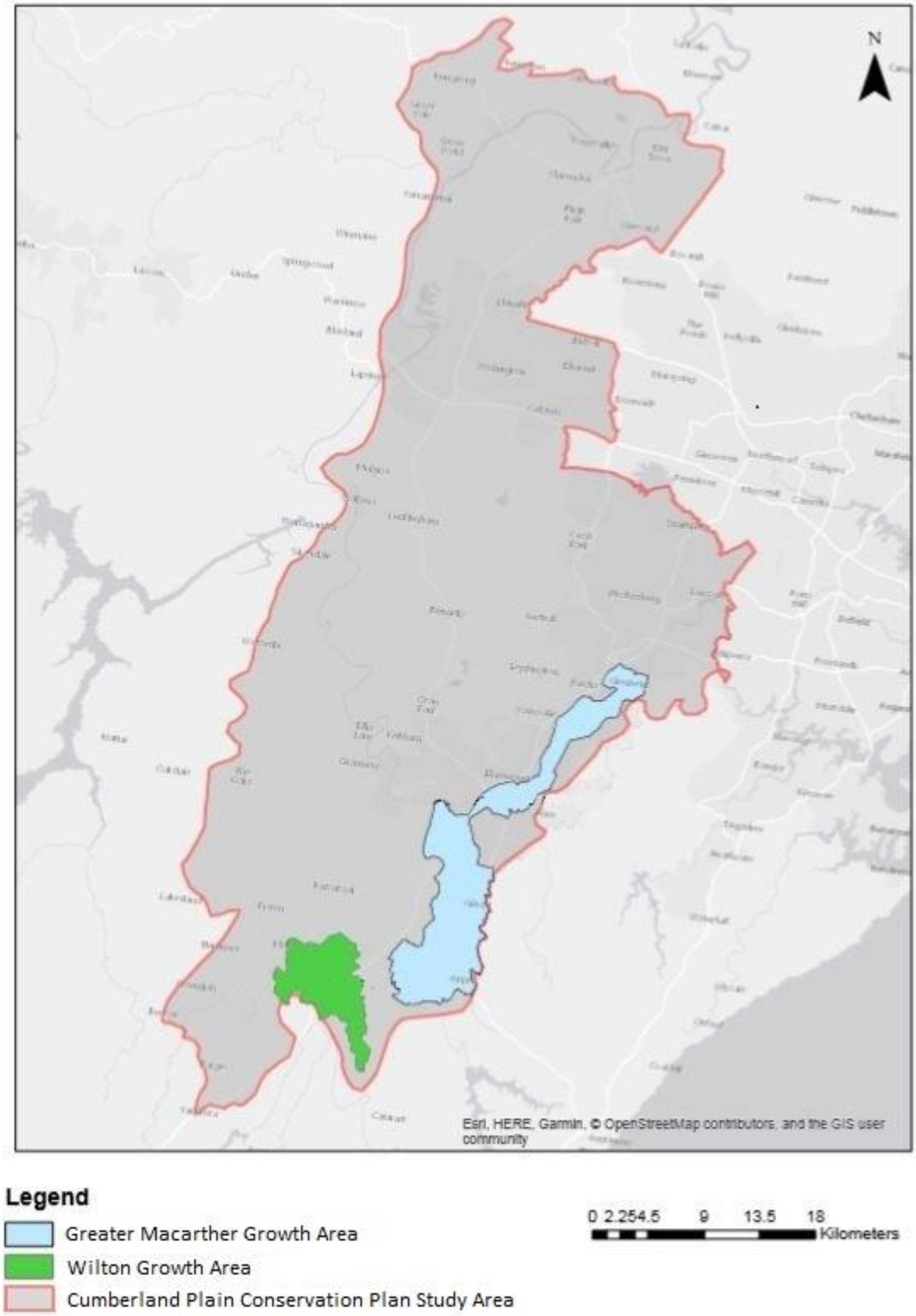
1.2 PROJECT CONTEXT

The NSW Government is planning for future urban development in Western Sydney. Four growth areas have been identified, these are Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These growth areas are all located within the Cumberland Subregion in version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) (2016).

As part of the planning for this future development, the Department of Planning and Environment (DPE) is preparing the Cumberland Plain Conservation Plan. This is a strategic regional assessment that will lead to the identification of preferred conservation outcomes for the Cumberland subregion.

1.3 STUDY AREA

The Map 1 shows the Cumberland Plain Conservation Plan Study Area and the two growth areas of Greater Macarthur (GMGA) and Wilton (WGA).



Map 1: Cumberland Plain Conservation Study Area and Growth Areas

Map source: NSW Department of Planning and Environment.

1.4 SPECIES SURVEYS

Past collections

This species was first collected by George Caley from “near South Head” in 1802 and was subsequently collected by Robert Brown “in occidental (western) Sydney” in 1804.

The type specimen is a F. W. Sieber collection Australia near Sydney. His expedition was from June until December 1823 when he collected 645 local plant specimens (Council of Heads of Australasian Herbaria Australian National Herbarium Biographical Notes Extracted from: A.E.Orchard (1999)).

One collection by Keith Ingram at Connells Point in 1941 is also thought to be that species but a degree of uncertainty prevails (refer to specimen label notes by Orme in Appendix 3). No precise locality details nor habitat information was recorded on these historic specimens.

Presumed extinct when first published in 2012, the species was re-discovered at the Moorebank Intermodal site in October 2016. It has also been recorded at Bankstown Airport in November 2017 (AVH) as part of environmental assessment of an infrastructure proposal. It is not known to occur at any other locations.

Surveys for this Bio Assessment

Surveys for the biodiversity assessment informing the development of the biocertification were constrained by private lands access issues, time and the overall size of the biocertification area.

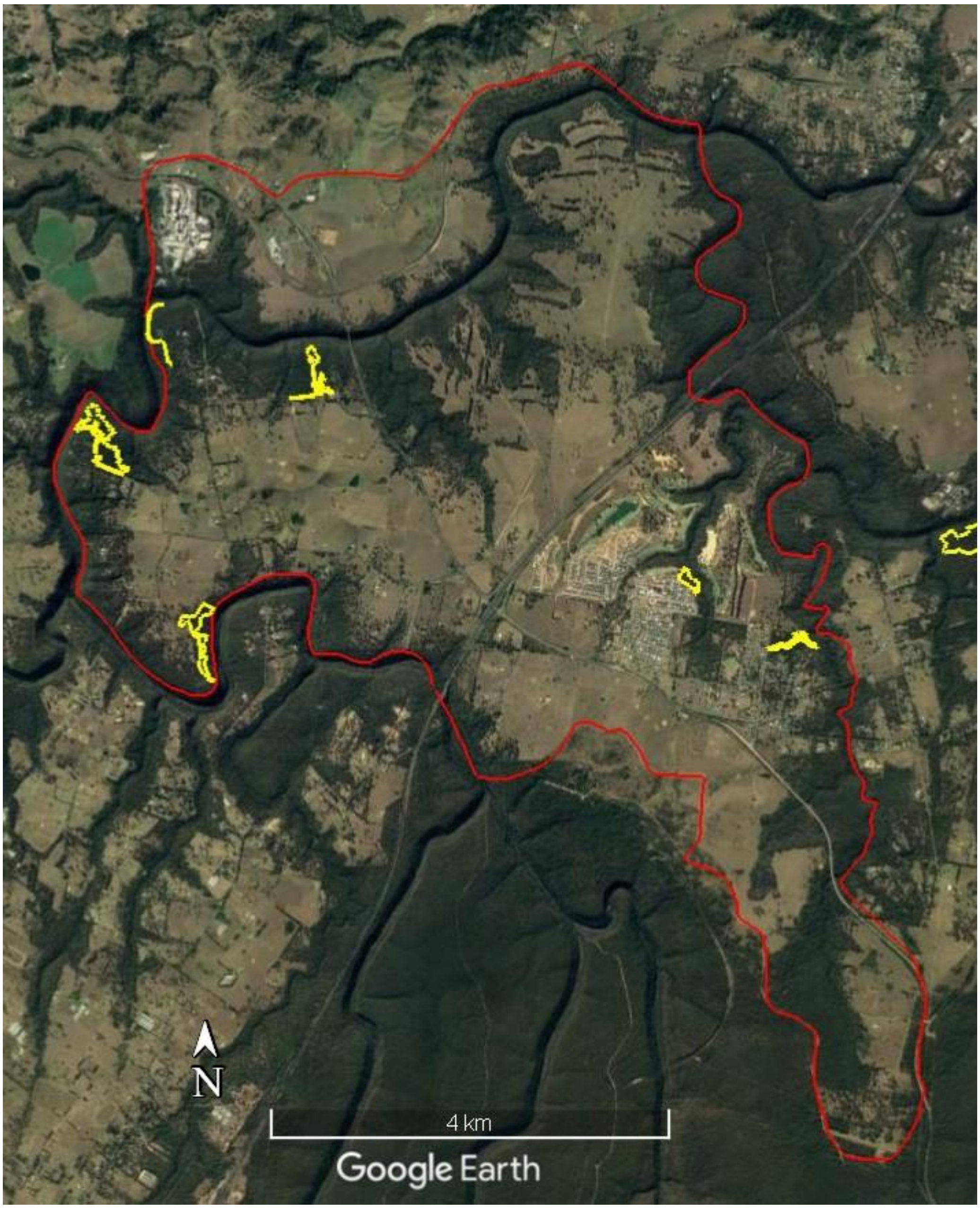
Surveys undertaken by Ecoplanning and Biosis consultancies since 2017 have largely been confined to the deemed “development footprint” and appear to have been undertaken predominantly to comply with the BAM protocols for vegetation sampling for assessment purposes with little survey for threatened species. As such, no new occurrences of threatened *Hibbertia* species including *Hibbertia fumana* were recorded by Biosis or Ecoplanning through their survey efforts.

One site was identified by DPE and Biosis as having potential to support the species, an area mapped as PCT 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain.

Access to a spatial viewer was provided by DPE to assist in the expert assessment. Whilst this tool has been useful in gaining a general overview, the information presented is limited and is acknowledged to “have been acquired and developed from numerous sources of differing dates, accuracy and completeness and may include errors in extent and content”. CFFIS are not aware of any surveys performed specifically for *Hibbertia fumana* by DPE, Ecoplanning or Biosis Consultancies. The broadscale vegetation mapping of PCTs that was provided to assist with this assessment cannot identify the habitat niches that may be present on a localised scale.

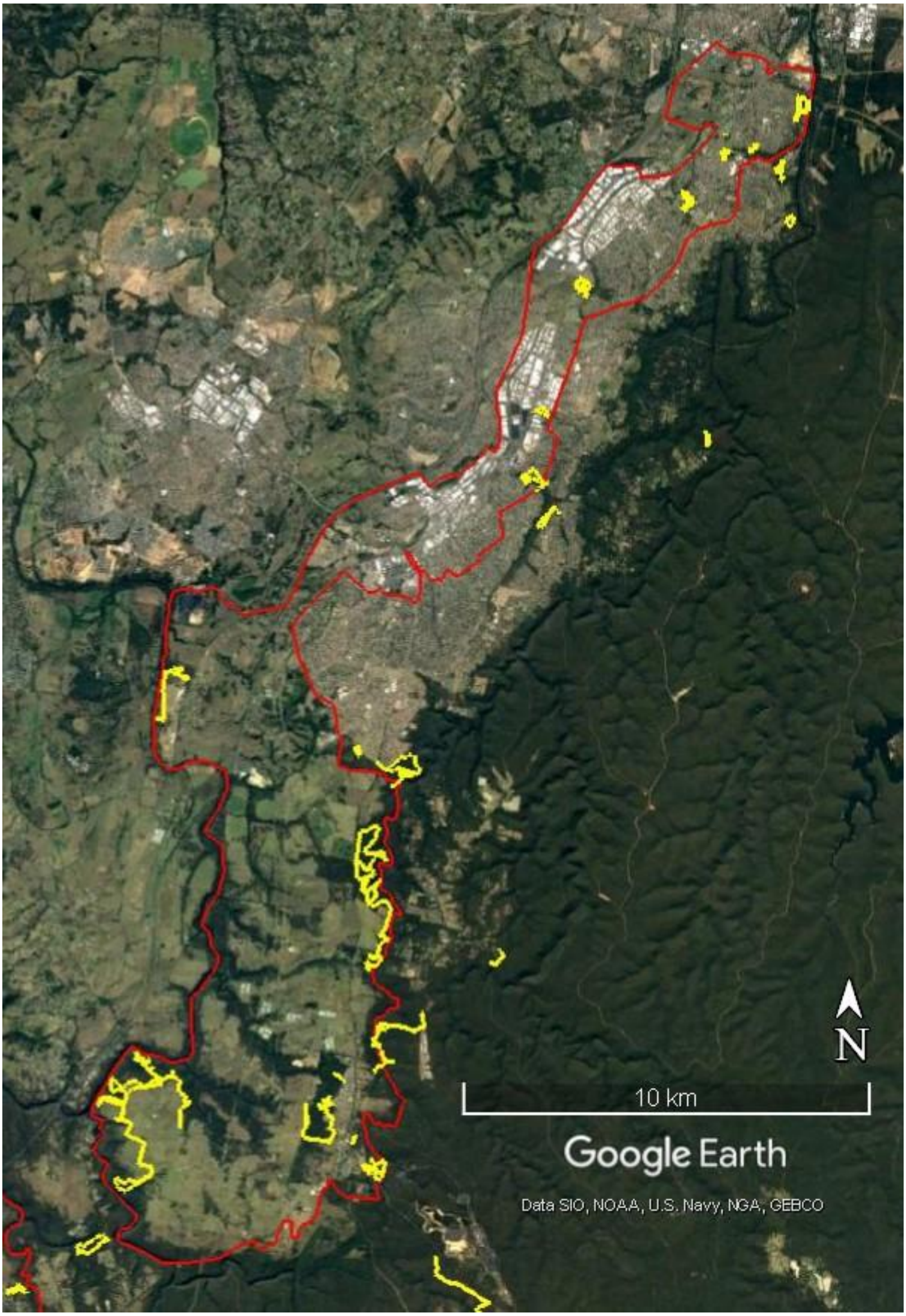
The surveys undertaken by Miller as part of this expert report relied on assessment of known habitat traits of extant sites and, although highly speculative, inferred habitat traits from historic records. PCT mapping and aerial digitised photography were used to select potential habitat areas for targeted surveys. Priority was given to finding the same habitat as occurs at the Moorebank and Bankstown Airport sites, although a variety of vegetation associations that are known habitat of other *Hibbertia* species such as *H. puberula* were surveyed to include inferred habitat from historic records. *Hibbertia puberula* co-occurs with *H. fumana* at the Moorebank site.

Map 2**Error! Reference source not found.** and Map 3 **Error! Reference source not found.**show the sites that were surveyed for this assessment.



Map 2: Google Earth image of Wilton Growth Area showing the tracks of CFFIS survey.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow.



Map 3: Google Earth Image of Greater Macarthur Growth Area and CFFIS survey tracks.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow.

<u>Species identification</u>

If a small-leaved *Hibbertia* was located that had macro morphological features resembling that of *Hibbertia fumana* then a specimen would be retained for later microscopic examination. CFFIS has also assessed the likelihood of *Hibbertia puberula* to occur in the GMGA and the WGA. *Hibbertia puberula* co-occurs with *H. fumana* at Moorebank and as both species are small-leaved, diminutive plants it is possible to misidentify *H. fumana* as *H. puberula* or other small-leaved species without careful examination (refer Photo 2). Selected specimens taken as part of the *Hibbertia puberula* assessment were microscopically examined to ensure that *Hibbertia fumana* was not inadvertently collected and dismissed as *Hibbertia puberula* or another small-leaved species. Due to the time of the year and prevailing drought conditions, plants were not in flower and depauperate, such that any specimens removed consisted of very small fragments (eco-scraps) most only a few cm in length.

The survey during June and July is not the flowering season for this species, so identification relied on stem and leaf characteristics, shown in Figure 1, Figure 2, Appendix 2 and microscopic comparison with voucher specimens. Note that positive identification of the species requires flowering parts, however, some species of *Hibbertia* can be ruled out based on stem and leaf characteristics.

Figure 1 drawing depicts *Hibbertia fumana* in bud where those buds appear +/- sessile. During the Moorebank surveys it was purported by a consultant that pedunculate flowers are a key field identification tool even in bud. This is clearly erroneous and should not be used as the sole identifying feature (refer also to Photo 3**Error! Reference source not found.** R.T. Miller and photo of the Isotype in Figure 3**Error! Reference source not found.**).

Peduncle elongation is clearly related to and is proportional to the developmental progression from buds to seed formation. Anecdotal observation by Miller suggests peduncle development is also related to environmental conditions such as moisture content of the soil and degree of exposure, for example, extended periods of low soil moisture and /or in combination with exposure appears to reduce peduncle length.

The species profile for *Hibbertia fumana* identifies some of the *Hibbertia* species with which it might be confused: “species with which it may be confused include *Hibbertia aspera* (peduncle of *H. fumana* is shorter, especially in flower, the foliage is more persistently hairy, and there are fewer stamens), *H. empetrifolia* (*H. fumana* is much more prominently stellate-hairy) and *H. riparia* (*H. fumana* has much shorter leaves). *Hibbertia superans* is another possible species for confusion, though *H. fumana* has smaller leaves” (OEH 2018).

It is unlikely that an expert would misidentify large / mature flowering plants of the above species with *Hibbertia fumana*. Confusion / unreliability is likely to arise if a population census is undertaken outside of optimal flowering time and/or the survey site is recovering from fire when high proportion of the plants will be small and immature, or if depauperate in drought conditions.

There are several other small leaved diminutive Hibbertias that could be confused including *Hibbertia dispar*, *H. pedunculata*, *H. calycina* s.str. and other undescribed taxa.

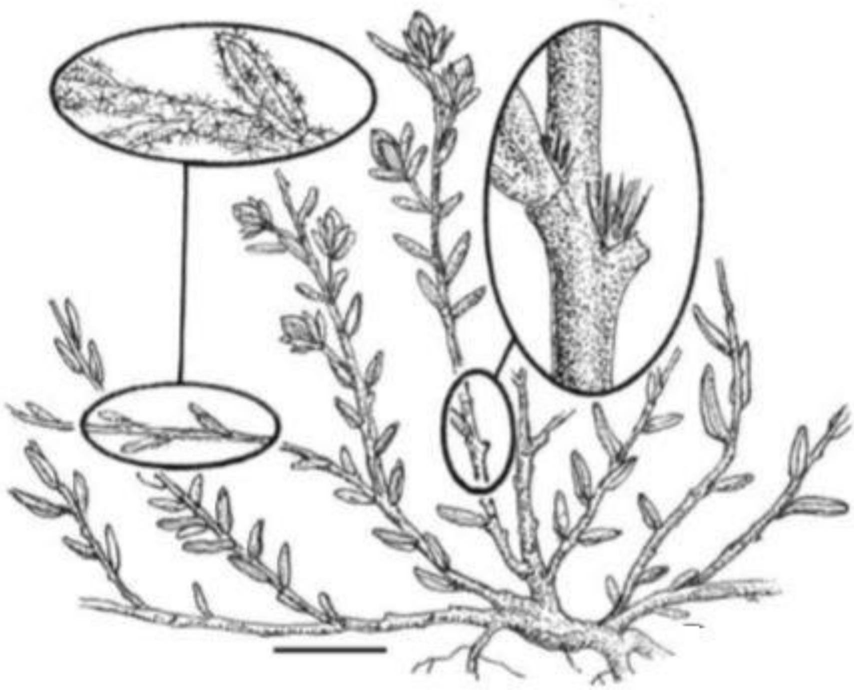


Figure 1: Stem and leaf characteristics of a flowering *Hibbertia fumana* specimen.

F.W. Sieber 147 (MEL 3111616) (Toelken and Miller 2012)

Relying solely on stem and leaf characteristics in field survey can lead to mis-identification. *Hibbertia fumana*, *H*. *aspera* and *H*. *empetrifolia* have discolorous leaves and using this character alone on non-flowering specimens without a high resolution microscopic examination could result in dismissing or mis-identifying a plant to be *H*. *fumana*. The discoloration of the under surface of the leaves in both *Hibbertia fumana* and *H*. *aspera* is due to the presence of a usually dense white/silvery tomentum whilst the leaf under surface of *H*. *empetrifolia* lacks dense tomentum but it is of a similar whitish coloration.

Apparent tomentum density and type on the stems and leaves will vary according to the section of branchlet examined and the prior climatic conditions. New growth is likely to have a higher density and a fuller range of hair types present whereas on older growth much of this tomentum will have "worn off" (Toelken), especially the longer simple hairs. Drought condition will see a marked reduction in new growth. *Hibbertia aspera*, like *H. empetrifolia*, shows much variation in different local populations as well as sometimes on the same plant (Toelken).

Both *Hibbertia aspera* and *H*. *empetrifolia* were frequently observed during the CFFIS survey, whilst *H. ericifolia* subsp. *acutifolia* was noted to be locally common in the south-eastern sector of the GMGA mostly associated with Scribbly Gum Woodland.

Microscope photographs of *H. fumana* characteristic features used during this survey by CFFIS are provided in Appendix 2 and includes comparison photos of *Hibbertia aspera*, *H*. *empetrifolia* and *H*. *dispar*.

Survey assumptions

The survey was carried out in June to August, during the non-flowering period, and it was not possible to access and survey all the many bushland remnants within the Wilton and Greater Macarthur growth areas. As such, the first assumption was:

Assumption 1. *Hibbertia fumana* would not be found growing in bushland that is unlikely to be suitable habitat.

The author is familiar with the type of habitat at the Moorebank Intermodal and Bankstown sites. Using this knowledge of geology, soil and vegetation type that is the known occupied habitat of the species, areas of bushland that would not be suitable habitat were ruled out of the assessment.

Using this knowledge of habitat requirement, the second assumption was:

Assumption 2. *Hibbertia fumana* is likely to be present in areas that are known to be suitable habitat. While surveys in suitable PCTs since the species was described in 2012 have failed to find *H. fumana*, this is a cryptic plant and the precautionary principle should be applied to the potential for the species to occur in suitable habitat.

The survey was carried out following several years of drought in western Sydney, and many shrubs, forbs and grasses were dead. This led to the third assumption:

Assumption 3. In areas of suitable habitat, where *Hibbertia fumana* specimens have not been found, the species could be present in the soil seed bank.

Identification to species of the *Hibbertia* relies on characters of the flowers. The survey was carried out in the non-flowering period which led to the fourth assumption:

Assumption 4. That specimens matching the stem and leaf characteristics of *Hibbertia fumana* could possibly be that species. Small narrow-leaved specimens were examined under the microscope to determine if the stem and leaf characteristics matched those of *Hibbertia fumana.*

1.5 JUSTIFICATION FOR USE OF EXPERT REPORT

The BAM allows for situations where an expert report will be required to replace or complement survey effort at a development site. While there has been some field survey for the Strategic Biocertification assessment, the area covered by the proposed GMGA and WGA are extensive and there have been issues with gaining access to some of the private properties.

An expert report is required to assess potential impact to *Hibbertia fumana* for the following reasons:

Insufficient survey: A large extent of the identified growth areas could not be surveyed because it was on private property and could not be accessed within the project timeframe. Expertise was required to identify and survey potential species habitat and propose additional habitat based on extant and historic records.

Survey out of flowering season: Survey during June and July is at the non-flowering period for the species, so finding cryptic species of *Hibbertia* in the field is difficult even for an expert and more so for someone who is not an expert (refer Photo 1).

1.6 CREDENTIALS OF EXPERT

Robert Miller has over 30 years' experience in field botany. Over this time Robert has identified many rare and endangered plant species and has contributed to the scientific knowledge of native flora distribution and habitat in NSW.

Robert has worked with Hellmut Toelken of the State Herbarium of South Australian, locating, collecting and identifying undescribed or rare species of *Hibbertia*. Some of these taxa were known only from historic records with non-precise locality details and depauperate or non-existent habitat information. Many of the specimens have been used for the taxonomic revision of the genus and are cited in various taxonomic publications including "Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*" published in the *Journal of the Adelaide Botanic Gardens* 26 (2013). Examples of the cited specimens include: *Hibbertia ericifolia* subsp. *acutifolia* Toelken, subsp. nov. Type: New South Wales, Sarahs Knob, R. & J. Miller s.n., 21.x.2006 (holo.: AD; iso.: BRI, CANB, NSW, PERTH) and *Hibbertia dispar* R.T.Miller s.n., 0.5 km S of Penrose Rest area, along western boundary track, Penrose State Forest, 12.x.2010 (AD, NSW).

Robert and Hellmut's paper "Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales", was published in the *Journal of the Adelaide Botanic Gardens* in 2012. The paper describes 13 new taxa including *Hibbertia fumana* Toelken and *Hibbertia puberula* subsp. *puberula,* – subsp. *extensa* R.T.Mill. and – subsp. *glabrescens* Toelken*.*

In 2017 Robert was called as an expert to identify the species of *Hibbertia* on the Moorebank bushland site that is the subject of the Intermodal development proposal.

Robert is also a recognised expert for other threatened taxa including *Pomaderris adnata*, *Solanum celatum*, *Epacris purpurascens* var. *purpurascens*, and the genus *Prostanthera* including the threatened taxa *Prostanthera discolor*, *P. stricta*, *P. densa*, *P. junonis* and has provided expertise to the OEH Saving our Species programs.

Photo 1: Very cryptic by its diminutive nature *Hibbertia fumana.*

H. fumana is difficult to detect even just prior to full petal expansion. Refer Photo 3 for close-up showing morphological features.

<u>Survey during drought</u>

The Western Sydney region has been experiencing dry conditions for several years, which means that the *Hibbertia fumana* plants are likely to be under severe drought stress and partially defoliated making this small and cryptic species more difficult to locate. It requires an expert in the species to locate and identify rare *Hibbertia* under these conditions.

<u>Reliable species identification</u>

Identification of the genus *Hibbertia* to species level requires examination of flower parts in combination with stem and leaf characters, especially tomentum type and density. It is not practical nor reliable to identify small leaved species in the field as many of these morphological features require microscopic examination and comparison to known voucher specimens.

The use of an expert report to complement survey of the growth areas avoids the problems associated with *Hibbertia* misidentifications. *Hibbertia* species can be misidentified in vegetation assessments, frequently being dismissed as “common” species.

The misidentification of both *Hibbertia puberula* and presumably *Hibbertia fumana as Hibbertia riparia* during past surveys raises the possibility that other records of *Hibbertia riparia* may in fact be *Hibbertia fumana*. Searches of the databases revealed prior surveys undertaken for various projects have recorded *Hibbertia riparia* to occur at a number of locales within the GMGA and WGA.

The *Hibbertia riparia / H. calycina / H. hirsuta* groups are currently under further detailed evaluation (Toelken pers. comm.). *Hibbertia riparia* R.Br. s. str. occurs in Tasmania (Toelken) and is unlikely to occur in NSW, the name being misapplied (Toelken pers. comm.). It was therefore anticipated that the identifications of *Hibbertia riparia* would be found to be incorrect.

Two recorded *H. riparia* sites were inspected as part of this report, one at Douglas Park (12 June 2018) and one at Wilton on 17 August 2018. A third Site at Appin was not surveyed due to access constraints.

The *Hibbertia* sp. observed off Douglas Park Drive was found to have vegetative features consistent with *H. puberula*. No plants were noted that resembled *Hibbertia fumana*, however the site inspection was limited by the extreme drought conditions and non-flowering period for the species. It remains unknown if *Hibbertia fumana* co-occurs at the site.

The Wilton locale was inspected in August and it was found that the severity of impact to the bushland from drought had markedly increased. The site was extremely dry following the years of drought, the ground was covered with a thick layer of leaf litter, and many plants were dead including large numbers of *Hibbertia aspera*. No plants resembling *H. riparia* were found at the location, so the correct identification of the species could not be ascertained.

It is considered likely that this species is the same taxon as the proximate occurrence off Douglas Park Drive which has vegetative features consistent with *H. puberula,* however there remains a possibility although low, that the *Hibbertia* may be *H. fumana*.

Photo 2: Five species of Hibbertia, photo taken 30cm above specimens, but which one is which?

Key - A: *Hibbertia aspera*, B: *H. empetrifolia*, C1: *H*. *puberula* (Lucas Heights), C2: *H*. puberula (Moorebank), D*: H*. sp. (morphological vegetative features consistent with *H*. *puberula* (East Gilead), E: *H*. *fumana*, F: *H*. *dispar*.

2. Species information

2.1 SPECIES DESCRIPTION

Hibbertia fumana was described by Toelken and Miller (2012) in their paper "Notes on Hibbertia (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. Hemistemma, mainly from the central coast of New South Wales". At the time of writing, the species was presumed extinct and had not yet been discovered at the Moorebank Intermodal site. The description was based on three herbarium specimens collected in 1802, 1804 and 1823.

The re-discovery of the species provided a broader range of specimens and a revised description which included for the first time fruit and seed, was provided by Duretto, Orme, Rodd, Stables and Toelken (2017). The following is a direct quote from that description.

Hibbertia fumana Sieber ex Toelken, Journal of the Adelaide Botanic Gardens 25: 73 (2012).

Type: Australia, near Sydney, "F.W.Sieber Nov. Holl. No. 147"

Decumbent shrublet, prostrate to weakly ascending to 20 cm high, with many branches from the base, moderately- to much-branched; branches wiry, with raised leaf bases shortly decurrent, shortly fascicled-pubescent. Vestiture persistent, consisting of more or less coarse simple hairs over fine fascicled hairs on tubercles; on branches more or less densely covered with short subequal multiangulate fascicled hairs (4–7 equal arms) and without simple hairs except for intrapetiolar tufts of hairs in leaf axils; on leaves above scattered, short antrorse fine bi- or triforked to simple hairs, sparse becoming denser onto the petiole, few simple hairs along the flanks, all wearing off soon; on leaves below dense, with short subequal multiangulate fascicled hairs (4–12 subequal arms) particularly on central vein, overtopped by few simple hairs on the flanks of the revolute margins; on outer calyx outside moderately dense, with spreading coarse antrorse simple hairs over erect-spreading multiangulate fascicled hairs (8–15 subequal arms), inside dense, with forked to simple antrorse hairs over most of surface; on inner calyx lobes outside dense with spreading multiangular fascicled hairs (2–12 subequal or unequal arms) becoming smaller towards the membranous margins, overtopped by coarse antrorse simple hairs along the central ridge, inside glabrous except for a few simple hairs towards the apex. Leaves with intrapetiolar axillary tuft of hairs to 0.7 mm long; petiole 0.2–0.45 mm long; lamina narrowly oblong, rarely linear-elliptic, (1.9–) 2.1–6.5 × 0.5–1.2 mm, obtuse, with terminal tuft of hairs on a somewhat recurved apex of the central vein, more or less abruptly constricted into petiole, above ± flat and puberulous to glabrescent, below with broadened central vein recessed below the level of revolute margins and protruding into apex, pubescent to puberulous. Flowers single, terminal, commonly on main branches; flower stalk 2–9 mm long, recurved and elongating after flowering, pubescent; bract linear to linear-triangular, 1–1.3 mm long, sometimes leaf-like to 5.5 mm long, fascicled-pubescent, on lower third to half of flower stalk. Calyx distinctly accrescent, with lobes subequally long; outer calyx lobes lanceolate, 3.5–5.7 × 1.3–1.65 mm, enlarging to 6.1 × 2.2 mm with fruit, acute to acuminate, without ridge, outside strigose-pubescent, inside finely strigose with antrorse forked hairs on much of the surface;

inner calyx lobes oblong-ovate, 4.0–5.8 × 3.1–3.5 mm, usually cuspidate, outside strigose along the central vein and tomentose towards the margins, inside glabrous with few forked hairs at the apex. Petals obovate, 4–5.2 mm long, broadly bilobed. Stamens 5 or 6 (7), subequal, clustered on one side of the ovaries; filaments 0.4–0.6 mm long, basally connate; anthers broadly oblong, 1.3–1.4 mm long, ± abruptly constricted above and below. Pistils 2; ovaries obovoid but ± laterally compressed, each with 4 ovules, fascicled-tomentose, with style attached to the centrifugal apex of the ovary then after a short curve downwards straightening up on either side of the stamens with stigmas exposed above the anthers. Fruit puberulous with simple and multiangular hairs. Seeds oblong-obovoid to almost obloid, 1.6–2.0 × 1.4–1.5 mm, smooth, light brown; aril with fleshy base surmounted by one-sided membranous cup covering c. one quarter of one side of seed.

Additional specimens examined: NEW SOUTH WALES: Central Coast: R.Brown [J.J.Bennett 4873], "In occidental Sydney 1804" (BM); G.Caley s.n., "near South Head", viii.1802 (BM); Moorebank in western Sydney, J.Rodd & M.Stables, 19.x.2016 (NSW, 3 specimens); Moorebank in western Sydney, A.E.Orme 1572, 16.xi.2016 (AD, NSW).

Photo 3: *Hibbertia fumana* in pre-flower at Moorebank Intermodal Site

R. Miller September 2017.

Fig. 1. *Hibbertia fumana*. **a**, habit; **b**, branch; **c**, branch detail showing tufts of hairs in leaf axil; **d**, leaf, adaxial surface; **e**, leaf, abaxial surface; **f**, flower; **g**, flower, petals removed; **h**, inner sepal, abaxial surface; **i**, inner sepal, adaxial surface; **j**, outer sepal, abaxial surface; **k**, outer sepal, adaxial surface; **l**, flower with fruit; **m**, seed. Scale bar: **a** = 80 mm; **b** = 15 mm; **c** = 2.5 mm; **d & e** = 4 mm; **f** = 6 mm; **g & l** = 8 mm; **h–k** = 5 mm; **m** = 3 mm. Drawn from *Orme 1572*.

Figure 2: *Hibbertia fumana* Lesley Elkan in *Telopea* 20: 143–146

Figure 3: Isotype of *Hibbertia fumana.*

F.W Sieber held within the William and Lynda Steere Herbarium as digitised imagery in the C. V. Starr Virtual Herbarium New York Botanic Gardens showing apparent +/- sessile flower buds.

2.2 LIFE CYCLE

The NSW Threatened Species Scientific Committee Final Determination for listing of *Hibbertia fumana* states that "Little is known about the life history of *Hibbertia fumana*. Seed production and plants of different ages were recorded within the only known population (A. Orme in litt. November 2016). The species does sucker (A. Orme in litt. November 2016) suggesting it may be able to resprout from rootstock following fire."

Peak flowering is recorded as spring to early summer, although the species appears to be capable of minor sporadic flowering at other times of the year as a response to suitable climatic conditions (Miller pers. obs.).

2.3 DISTRIBUTION AND ABUNDANCE

Historically the species was collected by Caley "near South Heads", eastern Sydney, in 1802, by Robert Brown in 1804 "occidental Sydney" and by Sieber 1823 "near Sydney New Holland".

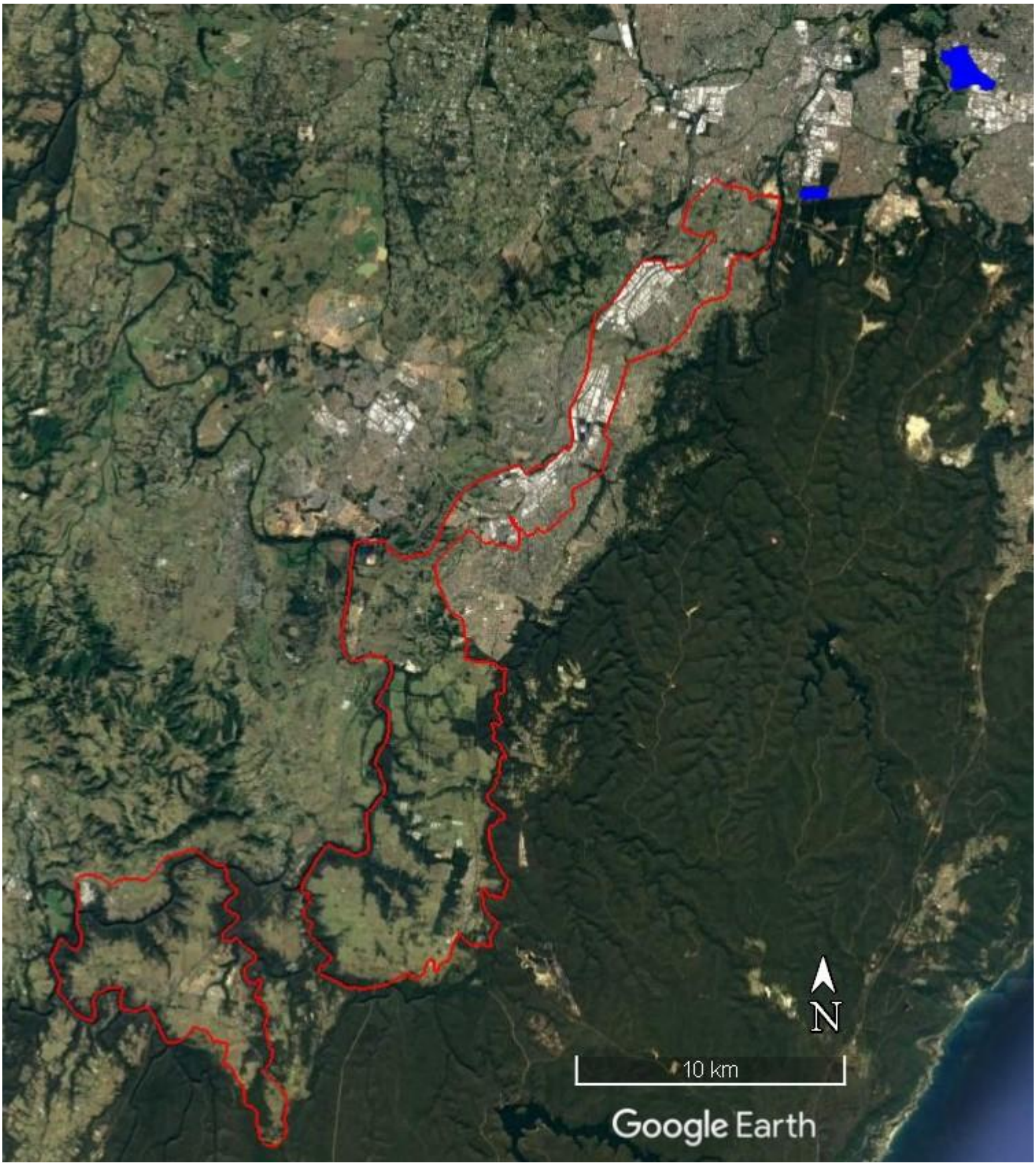
Recently a specimen from the Keith Ingram herbarium collection has been determined as most likely to be that species by Andrew Orme. It was collected at Connells Point in February 1941.

South Head and Connells Point are now highly urbanised environments and as such this diminutive species is unlikely to have persisted at either locale. If the species has persisted it is most likely so in the Connells Point environs. Targeted searches may be warranted in the Poulton Creek vicinity including Poulton Park.

Currently known from one extant population at Moorebank of c. 400 and an unknown number of plants in the Bankstown Airport vicinity.

At the time of the species listing in October-November 2016 (Arcadis and Parsons & Brinckerhoff Australia/New Zealand (WSP)) 370 plants were recorded at Moorebank and a further "approximately 29 plants" were recorded in September 2017 (Arcadis and Cumberland Ecology).

The impact upon the population at the Moorebank site from an intense fire in April 2018 is unknown.



Map 4: Indicative area of *Hibbertia fumana* populations.

Key - Areas of known *H. fumana* populations (blue) and the Wilton and Greater Macarthur growth areas (red).

2.4 HABITAT REQUIREMENTS

Historic collections

The *Hibbertia fumana* profile states: “Habitat of an 1802 Caley collection 'near South Head' are uncertain, with potential communities in that area including coastal shale sandstone communities and open forest or forest communities on lateritised shale lenses. No similar alluvial sand deposits are identified in that area.” (OEH 2018)

It is speculated by Miller that the most likely habitat for the Caley collection is transitional vegetation associated with “Swamps” or wet heath, especially the transition from shale influence communities to heath and/or open woodland. Although unsuitable habitat now, the Woollarah Golf Course site is likely to have consisted of a mosaic of vegetation types including swamp transition to woodland and the original habitat at Centennial Park is well documented “Originally a swamp and then set aside as land for the water source for Sydney, Centennial Park” (Centennial Park Trust). The diverse micro-habitats at Centennial Park supported numerous now locally rare or endangered taxa including *Hibbertia virgata E.Cheel NSW 86014*, Centennial Park, ix.1900 (NSW); and *A.A.Hamilton NSW 86016*, Centennial Park, 23.viii.1912 (AD, NSW) (Toelken in. prep.) and it is likely to have also supported *Hibbertia fumana*.

Extant populations

The OEH website states that *Hibbertia fumana* is known to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation) - within the Cumberland Dry Sclerophyll Forests class *Hibbertia fumana* is associated with

- Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain and Sydney Basin Bioregion and
- Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion

Dry sclerophyll forests (shrubby sub-formation) - the Vegetation Types that *Hibbertia fumana* is associated within the Sydney Sand Flats Dry Sclerophyll Forests class include

- Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion and
- Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion

At Bankstown Airport the AVH record states that the “Site is heavily managed and is routinely slashed to a height of about 10cm. Soils are grey heavy clay with ironstone fragments present at surface. Other native species observed indicate a derived form of Cooks River / Castlereagh Ironbark forest community. Main weed observed *Eragrostis curvula*.”

Photo 4: Indicative habitat of *Hibbertia fumana* at Bankstown Airport, regularly slashed.

At the Moorebank site the species is found growing in the transition zone between Castlereagh Ironbark Forest and Castlereagh Scribbly Gum woodland in open forest of *Eucalyptus sideroxylon, E. fibrosa, E. parramattensis, E. sclerophylla* and *Melaleuca decora* with a diverse understorey of shrubs including *Hakea sericea, Callistemon linearis, Bursaria spinosa, Grevillea parviflora* subsp. *parviflora, Acacia brownii, Acacia bynoeana, Pultenaea retusa, Pultenaea villosa, Hibbertia puberula* subsp. *puberula* and *H. aspera* subsp. *aspera*. The herb/grass layer is dominated by *Goodenia hederacea, Dianella revoluta, Thysanotus, Gonocarpus, Poa, Stylidium graminifolium, Patersonia, Themeda, Diuris* and *Microtis* (Telopea 2017).

Prior to the recent fire, the density of the understorey was variable across the site and ranged from sparse to extremely dense especially within the long-unburnt sections of the Castlereagh Scribbly Gum woodland. The variation in density is presumed to be due to the fire history, localised clearance events including recent remediation works, as well as minor changes in topography and drainage especially in swales.

In general, the topography of the land is described as flat although this is disrupted by the passage of Anzac Creek and by numerous minor depressions or swales likely to be remnants of past creek alignments and/or overflow channels that support Castlereagh Swamp Woodland. These swales and minor excavations / scrapings form small ephemeral pondages.

From limited brief inspections *Hibbertia fumana* was observed to be of sporadic occurrence across the site and appeared to be absent from ephemeral pondage locales preferring open slightly higher ground. Soils are described as fine sandy clay loam, grey brown in colour.

2.5 ANTHROPOGENIC THREATS TO THE HABITAT

Threats to the habitat of *Hibbertia fumana* that are relevant to sites within or adjacent to urban development include:

- Loss of habitat. Loss of the existing habitats across much of the distribution has occurred and may occur for as-yet-missed populations of the species.
- The Moorebank population consists of approximately 370 individuals only.
- Development of the adjacent lands at Moorebank for a major transport hub may affect the plants, and there is a rarely-used railway line bisecting the site. At Bankstown airport infrastructure development could impact the population.
- Fire either too frequently (limiting recruitment) or too rarely (allowing midstorey thickening) are likely to impact the species.
- Clearing for fire protection zones and infrastructure works could remove habitat.
- Damage to habitat by trail biking, 4WDs and mountain bikes.
- High densities of weeds and invasive grasses occur at the top of ridgelines; there is significant potential for encroachment into areas where the species occurs.
- A number of weeds are likely to impact on the plant, with particular concern for low shrubs, dense shrubs and smothering grasses.
- Changes to hydrological processes can impact habitat by reducing subsoil infiltration, drying out seepages, or concentrating flow paths through habitat.
- Nutrification can increase weed potential.
- Road maintenance and slashing works.

Field inspection of bushland remnants in the heavily urbanised sectors of GMGA provide irrefutable proof of severe degradation arising from anthropogenic impacts and urbanisation (refer photos 4 through 8). Without exception, all creeks and many of the remnants were heavily weed infested arising from a range of factors not limited to nutrification, stormwater discharge, garden refuse and fill dumping and exotic seed dispersal by various vectors.

Damage to zones adjacent urban development can also be caused by clearing for fire hazard reduction, control burning frequently, and recreation activities such as 4WD vehicle access, mountain bikes and kids' cubby house building.

Photo 5: Control burn at Bunbury Curran Park, Macquarie Fields.

Photo 6: Chronic weed infestations characterise the riparian zone of Bunbury Curran Creek.

The photo above was taken in the southwestern corner of Bunbury Curran Park west of TAFE NSW Macquarie Fields.

Weeds include: Balloon Vine (*Cardiospermum grandiflorum*), Fennel (*Foeniculum vulgare*), African Olive (*Olea europaea* subsp. *africana*), Large-leaved Privet (*Ligustrum lucidum*), Small-leaved Privet (*Ligustrum sinense*) Kikuyu (*Pennisetum clandestinum*), African Lovegrass (*Eragrostis curvula*), Rhodes Grass (*Chloris gayana*), Mothvine (*Araujia hortorum*), Honeysuckle (*Lonicera japonica*), Wild Tobacco (*Solanum mauritianum*) and Blackberry (Rubus fruticosus aggregate).

Hibbertia fumana is a small shrub that would not survive in bushland that is severely weed infested, or that is severely burnt on a regular basis.

Photo 7: Pembroke Park Impacts of urbanisation - invasive weed species dominate the shrub, vine and ground layers.

Photo 8: At Pembroke Park Red Ash (*Alphitonia excelsa*) and Forest Red Gum (*Eucalyptus tereticornis*) cut down to construct bike jumps and cubby houses and the shrub layer cleared.

Photo 9: Smith's Creek Reserve typical condition of bushland adjoining residential properties on the southern side of Smith's Creek, highly weed degraded, cleared for hazard reduction, fill and refuse dumping.

3. Description of the study area

3.1 LAND USE HISTORY

The Cumberland Plain was first occupied by the Aboriginal peoples, who enjoyed a plentiful supply of fresh water and foods including fruit, tubers, fish, animals, birds and honey (Hills District Council website).

With the arrival of Europeans, land-use changed to timber gathering and agriculture, permanently altering the landscape. Particularly since the end of the Second World War urban settlement and industry have expanded west from Sydney into the Cumberland subregion. Over the last 40 years many rural properties have been subdivided as lifestyle and hobby farm properties.

Currently there is great pressure for further residential development to the west of Sydney in the Cumberland subregion.

3.2 LANDSCAPE CONTEXT

The changes in land use have caused the clearing of a large proportion of the natural bushland of the Cumberland subregion. In 2011 the Cumberland Plain Recovery Plan stated “Only 13% of the pre-1750 extent of the region’s vegetation remains as intact bushland, with an additional 12% occurring as scattered trees in disturbed areas (NPWS 2002). Consequently, much of the region’s biodiversity is listed as threatened under State and/or Commonwealth legislation.”

Widespread clearing of the remaining habitat has continued with much of the extant vegetation now being assessed as Critically Endangered. Previously recorded from South Head and Western Sydney, *Hibbertia fumana* appears to have suffered a reduction in range caused by urbanisation.

3.3 NATIVE VEGETATION

Since 2011 there has been further clearing, there are now 15 vegetation communities that are listed as Critically Endangered, Endangered or Vulnerable in the Cumberland Plain.

The Cumberland Plain Recovery Plan states that “there are seven threatened species, four endangered populations and nine threatened ecological communities listed on the NSW *Threatened Species Conservation Act* 1995 that are found only on the Cumberland Plain. Seven of these are also listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999.” The remaining bushland is highly fragmented and much of it occurs on private lands.

Within the GMGA and the WGA eleven Plant Community Types (PCTs) are mapped (mapping provided by the NSW Department of Planning and Environment). These PCTs are:

- Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion, PCT 830

- Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, PCT 835
- Grey – Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion. PCT 849
- Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion. PCT 850
- Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion. PCT 877
- Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 883
- Red Bloodwood – Grey Gum woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 1081
- Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateau of the Sydney Basin Bioregion. PCT 1083
- Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion. PCT 1181
- Water Gum- Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion. PCT 1292
- Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion. PCT 1395

3.4 POTENTIAL HABITAT

Within the Sydney Basin bio-region *Hibbertia fumana* is known from the IBRA subregion of Cumberland and is predicted to occur in the Pittwater IBRA sub-region. No geographic constraints are currently listed for the species. The subregions of known and predicted occurrence are shown in **Error! Reference source not found.**. The areas shown in pink and purple are the sub-regions where the species or community is known or predicted to occur. They may not occur throughout the sub-region but may be restricted to certain areas.

The OEH species profile sheet states: “found in the transition zone between Castlereagh Ironbark Forest and Castlereagh Scribbly Gum woodland in open forest of *Eucalyptus sideroxylon, E. fibrosa, E. parramattensis, E. sclerophylla*”. The species has the potential to occur in similar intergrade alluvial habitats rich in sands and laterite in other parts of western Sydney.

Hibbertia fumana is currently known only from two locations in western Sydney. A single population at Moorebank and a single population in Bankstown (AVH record) but has the potential to occur elsewhere in greater Sydney.

At Moorebank it is found in areas of open woodland in a long intergrade between Castlereagh Scribbly Gum Woodland and Castlereagh Ironbark Forest. The AVH record for *Hibbertia fumana* at Bankstown records “Site is heavily managed and is routinely slashed to a height of about 10cm. Soils are grey heavy clay with ironstone fragments present at surface. Other native species observed indicate a derived form of Cooks River / Castlereagh Ironbark forest community."

Map 5: Known and predicted distribution of *Hibbertia fumana*.

Source OEH website 2018.

The habitat of an 1802 Caley collection 'near South Head' is uncertain, with potential communities in that area including coastal shale sandstone communities and open forest or forest communities on lateritised shale lenses. No similar alluvial sand deposits are identified in that area.

OEH has identified that *Hibbertia fumana* has the potential to occur in the following plant community within the Wilton and Greater Macarthur Growth Areas:

- 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain

4. Assessment of species presence and suitable habitat

4.1 SPECIES RECORDS AND HABITAT ASSESSMENTS

Hibbertia fumana is poorly known and is site managed and assessed as data-poor. There are no records of the species within or adjoining the proposed growth areas. Only two known extant populations exist Moorebank c. 1.6 km to the north-east of the northern boundary of GMGA and approximately 36 km from WGA, and Bankstown Airport 9 km from the northern boundary of GMGA and approximately 41 km from WGA.

The broad scale vegetation assessment that has been carried out across the growth areas does not identify local scale habitat potential.

4.2 PRIOR SPECIES SURVEYS

Private land holdings comprise much of the lands within the GMGA and WGA, restricting access opportunities for botanical surveys and incidental sightings. This is a likely contributing reason for the lack of prior records of threatened *Hibbertia* species including *Hibbertia fumana* within the proposed growth areas.

From the information provided, no prior targeted searches have been undertaken for this species as part of the biocertification assessment process. One small area of mapped potential habitat (PCT 883) at Milton Park, Macquarie Fields was investigated by Biosis. The data provided is limited to that found within the spatial viewer.

The level of data is insufficient to base an assessment of presence/absence for a Critically Endangered species purely as a desktop study.

The Threatened Species Expert Report Overview spreadsheet, provided by DPE, shows that *Hibbertia fumana* was not recorded from the area mapped as PCT 883 in Milton Park based on the records of Bionet and Biosis and Ecoplanning consultant surveys. Nor was it found during surveys of the Greater Macarthur and Wilton Growth areas by these consultants.

CFFIS conducted a site inspection of Milton Park and the adjacent Macquarie Fields Leisure Centre. We found that the regional scale vegetation mapping could not provide the level of detail required to identify potential species habitat.

Local scale variations indicate the need for site-specific survey of the growth areas for *H. fumana* or its habitat.

Photo 10: Milton Park, the majority of the trees are *Eucalyptus tereticornis,* PCT 849 thinned.

Photo 11: Area between Macquarie Fields Leisure Centre and Macquarie Road, site is dominated by Ironbarks.

4.3 ASSESSMENT OF SPECIES PRESENCE

The previous survey data provided by Biosis and Ecoplanning Consultants was insufficient to assess the probability of occurrence of *Hibbertia fumana* from a desk top study. The species has demonstrated an ability to persist within suitable derived habitat, it was therefore appropriate to undertake specific targeted surveys.

The area mapped as PCT 883 and surrounds were surveyed by CFFIS for the species. We also surveyed for habitat appropriate to the species in areas of potential tertiary sediments and shale sandstone interface across the growth areas and adjacent lands, based on geology, soils and landform maps where access was provided.

4.3.1 LIKELIHOOD OF SPECIES PRESENCE

The possibility of *Hibbertia fumana* occurring within the GMGA is assessed as low because potential habitat sites with similar attributes to known extant sites are highly modified and of limited extent. However, the presence of this species cannot be dismissed entirely on disturbance factors because the Bankstown Airport population survives in a highly modified environment. Bannerman and Hazelton (1990) in *Soil Landscapes of the Penrith 1:100,000 Sheet* map the entire site as disturbed terrain, although field observation by Miller and others have identified areas to retain the original soil profile.

There are no habitats similar to the known extant sites mapped as occurring within the WGA. The possibility of those PCT's being undocumented within WGA is assessed as negligible.

Historic occurrence records indicate the species could also be found "in coastal shale sandstone communities and open forest or forest communities on lateritised shale lenses" (OEH Threatened Species Profile). Large tracts of shale sandstone interface exist within the WGA and GMGA. Therefore, the potential for suitable habitat for the species within the WGA, and other areas of the GMGA, although unlikely, cannot be dismissed.

Hibbertia fumana is currently assessed as being Critically Endangered and is data -poor. In this context, a precautionary approach is recommended. Locating and protecting new populations, no matter how small, is significant to the survival of this species.

4.3.2 JUSTIFICATION FOR DETERMINATION

Greater Macarthur Growth Area

Just one small area of known habitat PCT 883 is located in the Milton Park area at Macquarie Fields. This area was surveyed in June and July and the species was not found. Milton Park is intensively managed for recreation, however further survey during the species flowering period would be appropriate.

Hibbertia fumana is reported to occur at Bankstown Airport within a highly modified environment that is “routinely slashed to a height of about 10cm” resulting in a “derived form of Cooks River / Castlereagh Ironbark forest community. Main weed observed *Eragrostis curvula*.” (AVH). This new record demonstrates that the species can be found on differing soils to that of the Moorebank occurrence.

The Bankstown occurrence provides evidence that the species can persist within a suitable derived habitat. It is therefore possible that *H. fumana* could occur within the GMGA. If it does occur, it is most likely in a transitional vegetation zone either between shale / alluvial or shale / sandstone environs. Limited potential habitat areas occur within the GMGA.

Shale alluvial transitional sites may include potentially inadequately surveyed areas in the Menangle Park vicinity and other areas in the northern sector of GMGA, especially those now modified to a derived grassland environment.

Shale / Sandstone transitional vegetation occurs in the middle and southern sectors of GMGA but is mostly confined to above the escarpment edges of the various creeks and rivers. Scattered occurrences of sandstone outcroppings have been noted elsewhere including in the northern sector of the GMGA, for example, at Milton Park and Kayess Park at Ingleburn.

One record of *Hibbertia riparia* (which could potentially be *H. fumana* and/or *H. puberula*) is noted at Appin, the co-ordinates placing the occurrence in Shale / Sandstone transition.

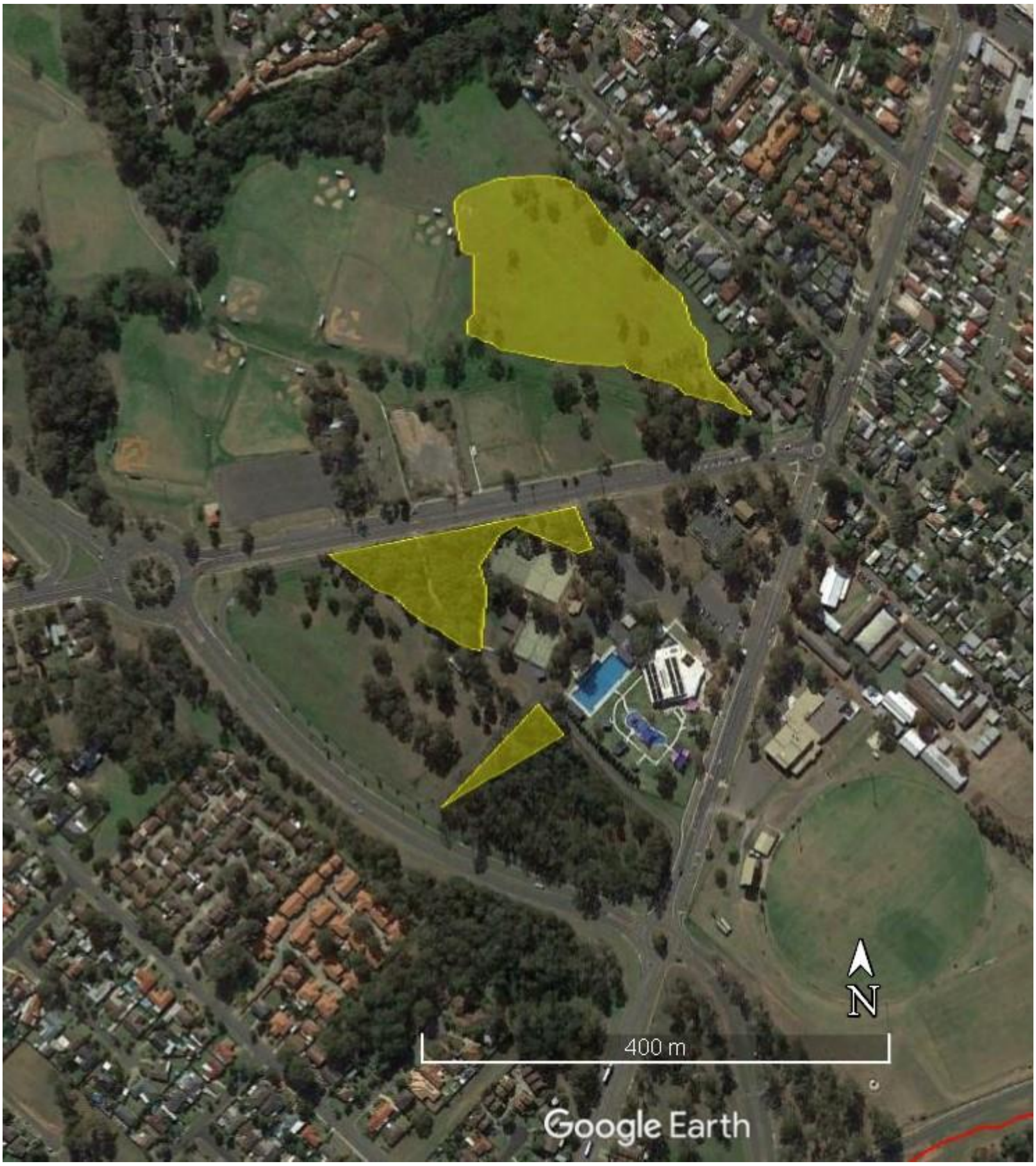
Milton Park environs

The vegetation remnants in Milton Park vicinity are variously mapped as PCT 835 along the unnamed branch of Bunbury Curran Creek and PCT 849 Grey Box – Forest Red Gum grassy woodland elsewhere with the exception of a small area to the north of Macquarie Road and south of Bingara Road which is mapped as PCT 883 Hard-leaved Scribbly Gum – Parramatta Red Gum woodland.

Site inspection revealed that some areas of vegetation in the vicinity of the Macquarie Fields Leisure Centre had Ironbark species dominating the upper canopy. Areas of ironstone gravel were noted. Other species observed included Woollybutt (*Eucalyptus longifolia*), *Cryptandra spinosa*, *Daviesia ulicifolia*, *Bursaria spinosa*, *Lepidosperma laterale*, *Kunzea ambigua*, and *Melaleuca decora*.

The area north of Macquarie Road mapped as PCT 883 and PCT 849 is comprised of a few clumps and scattered remnant trees of both *Eucalyptus sclerophylla* and *E. tereticornis* in a regularly slashed recreation reserve. *Eucalyptus sclerophylla* occurs, on the higher ground to the north on soils observed to have a high quartz content in association with the underlying sandstone plates. Scribbly Gum exists as approximately 1/3 of the areas of remnant trees. Scattered trees of *E. tereticornis* dominate the ephemeral creek / drainage line and are the major tree species in the remainder of the area.

The areas of remnant *Eucalyptus sclerophylla* are characterised by scattered sandstone plate outcroppings and relatively sandy soil. Hard-leaved Scribbly and *Angophora bakeri* / *floribunda* intergrade are likely to have covered much of the site extending to the west to near the sports fields where sandstone outcropping is prominent. Dense mown swathes of *Eragrostis curvula* dominate the ground layer and unmown tussocks the tree bases. Apart from one clump of *Kunzea ambigua* and sapling Eucalypts, few other native species noted had more than one to a few individuals surviving above ground. Twelve native species were observed mostly at the bases of some remnant trees.



Map 6: Image of areas containing likely habitat at Milton Park and Macquarie Road Reserve.

The moister drainage line to the south and the gentle rise to Macquarie Road is dominated by *Pennisetum clandestina*, *Eragrostis curvula* and assorted other weeds, no native understorey species were observed in this mown environment.

It is unknown whether *Eucalyptus parramattensis* exists or existed at this site.

The polygon mapped as 883 is highly disturbed and it is unlikely that this area would now support an occurrence of *Hibbertia fumana.* However, as Ironbark is dominant in the adjoining Macquarie Field Leisure Centre area adjacent Macquarie Road, it is likely that a transitional vegetation type previously existed between the Ironbark, Forest Red Gum and Scribbly Gum Woodland in this vicinity that may have supported *Hibbertia fumana* and/or *H. puberula.*

As a precaution it is recommended that a targeted search be undertaken under non-drought conditions in the species peak flowering season by an experienced *Hibbertia* specialist.

Kayess Park environs

Biosis mapped Kayess Park environs to support Intact PCT 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, 849 - Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion and Cumberland Plain Urban Native / Exotic.

Site inspection of the 20 July 2018 determined that PCT 835 mapped along the creek lines was unsuitable habitat for *H. fumana*.

An area of Ironbark occurs in the central area which grades into Grey Box - Forest Red Gum and Ironbark in the western portion. A fire was noted to have impacted much of the site especially the grassland area. This was evidenced by burnt Blackberry canes, bases of many Whisky Grass tussocks and dead *Acacia decurrens*.

The park is cleared and very weedy across much of the location especially on the more fertile shale derived soils. Localised sandstone outcroppings are apparent, and areas of sandy soil also present in the derived grassland. The sandstone influence extends upslope into the Ironbark forest environs but appears absent within areas supporting Grey Box and Forest Red Gum.

In general *Eucalyptus tereticornis* dominates eastern creek slopes. Ironbark species dominate sandstone influenced ridge top, including *Eucalyptus beyeriana*. The northwest corner is dominated by *Eucalyptus tereticornis, E. moluccana* and *E. crebra*?

In the context of its size and location much of the “intact” remnant vegetation is in reasonable condition. Sections of the remnants have a lot of rubbish dumping and weed invasion especially along drainage lines.

Potential threatened *Hibbertia* habitat occurs in the sandy soil at and below sandstone outcroppings including the derived grassland. Prior to clearing the sandy soil may have supported a small localised area of Scribbly Gum woodland as found at Milton Park or a localised variant of Shale Sandstone transitional vegetation.

Map 7: Image of area containing likely habitat at Kayess Park.

Species noted within the burnt derived grassland include: *Centella asiatica, Tricoryne elatior, Drosera hookeri, Goodenia paniculata, Juncus* sp., *Cheilanthes sieberi, Acacia decurrens, Themeda australis, Lomandra filiformis* subsp. *coriacea*, *L. multiflora*, *Microlaena stipoides, Eragrostis brownii*, *E. leptostachya*, *Dianella caerulea, D. revoluta, D. longifolia, Crassula sieberiana., Hibbertia diffusa*, *Opercularia diphylla*, *Helichrysum apiculatum*, *Einadia hastata*, *Bursaria spinosa.*

At the time of inspection, the most prominent weeds were African Lovegrass (*Eragrostis curvula*), Whisky Grass (*Andropogon virginicus*) and Blackberry. A wide variety of other pasture species were noted to have occasional occurrence including Fleabane (*Conyza* sp.), Fire Weed (*Senecio madagascariensis*), Catsear (*Hypochaeris* sp.) and Rambling Dock *(Acetosa sagittata)*.

Menangle Park Paceway environs

From data provided no targeted surveys were undertaken for threatened species within and to the north of Menangle Park Raceway environs. One BAM plot and one fauna survey within the immediate riparian zone of the Nepean River provides the only survey data undertaken for the biocertification assessment for this area.

A brief site inspection of the Menangle Paceway revealed a highly modified environment with some areas of potential habitat for the species. Relictual terraces and associated swales were noted. Native species were observed to exist in a number of locales even in areas routinely slashed and used for activities associated with horse racing. Soils ranged from alluvial to laterised clays.

The area to the north of Fitzpatrick Street was not inspected but viewed from a distance. It is assessed as likely to contain potential habitat, but the species composition of the ground layer remains unknown.

A Klaphake, V. 1992-05-10 record for *Drosera burmannii* describes land to the north in the vicinity of Fitzpatrick street as “Pasture near railway line N, 200 m below Fitzpatrick St, Menangle Park. In swampy pastureland on sloping land with *Eleocharis minuta*, *E. atricha*, *Lipocarpha microcephala*, *Ranunculus inundata*. Growing on the edge of the swamp in damp soil. Soil sand-based.”

Banksia integrifolia is the primary species for the Elderslie Banksia Scrub Forest which is described as “generally associated with alluvium of Tertiary age, on soils which are sandy, with drainage varying from good to poor (Benson 1977). *Banksia integrifolia* is a species component of the sandy tertiary sediments of Bankstown Airport environs especially adjacent to the *Hibbertia puberula* subsp. *glabrescens* population.

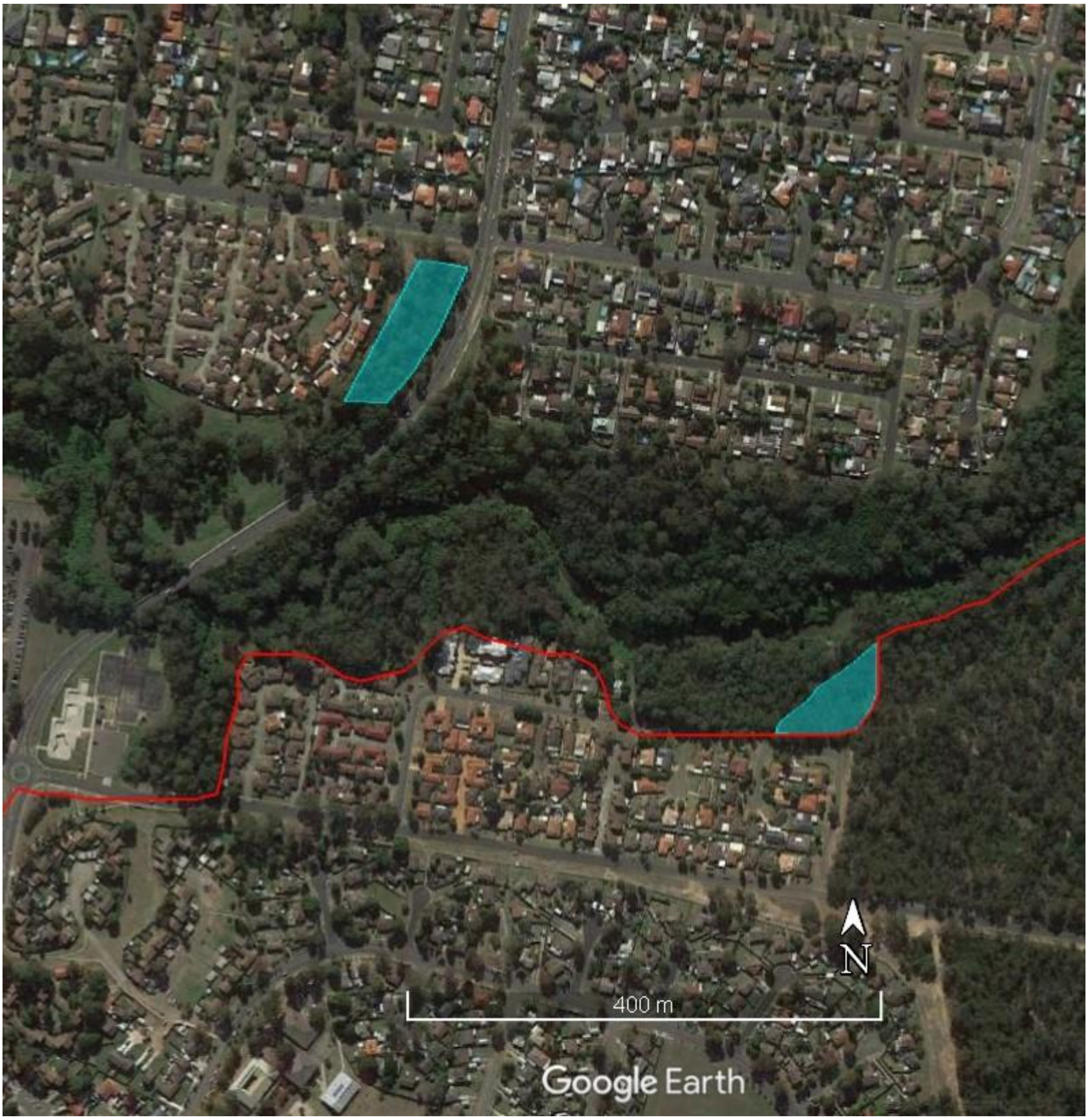
The known Bankstown Airport occurrence is reported from soils that are “grey heavy clay with ironstone fragments present at surface” (AVH) and sandy tertiary alluvium is known to be present at some locales.

There is a similarity between the Bankstown Airport environs and the Menangle Park site as both contain alluvial deposits adjacent shale communities.

Map 8: Image of areas containing likely habitat at and adjacent to the Menangle Park Paceway.

Bunbury Curran Creek vicinity

Several areas of Bunbury Curran Creek vicinity have potential habitat for rare *Hibbertia* based on implied habitat derived from historic records.



Map 9: Image of areas containing potential habitat at Bunbury Curran Creek, based on habitat inferred from historic collections.

Wilton Growth Area

The possibility that *Hibbertia fumana* occurs within the WGA sector is uncertain but cannot be ruled out due to the implied habitat derived from historic records. The OEH Threatened Species Profile indicates the species could be found on shale sandstone interface. Shale / Sandstone transitional vegetation is widespread throughout the WGA.

Hibbertia fumana is most unlikely to occur within the proposed urban footprint. The majority of proposed urban footprint is confined to the Wianamatta Shale derived soils which on current knowledge is unsuitable habitat for the species. Much of this land was known, in part, as the Cowpastures and were amongst the first lands to be cleared for agriculture purposes with European occupation. The native ground layer in many of these areas has been replaced by exotic species.

Within the growth area and adjacent the development footprint, we note that the Biosis quadrat Plot B27, near the Georges River at Wilton, records the following species: "Euca punc 15%, Euca fibr 1%, Ango baker 1%, Euca spar 5%, Euca parr 1%, Kunz amb 25%, Call line 1%, Ento stri 15%, Aris vagan2%, Loma fili 1%, Loma mult 0.3%, Aust pube 0.2%". The presence of *Callistemon linearis* and *Eucalyptus parramattensis* indicate a periodically moist environ within the transitional vegetation which may support several threatened taxa such as *Grevillea parviflora* and *Hibbertia puberula*. Both taxa co-occur at the Moorebank site with *H. fumana*. *Epacris purpurascens* is also likely to occur in the vicinity.

A L.A.S Johnson record for *Eucalyptus parramattensis* supports the presence of Parramatta Red Gum in the general area: Douglas Park, 0.75 miles [1.1 km] S of Nepean River, on east rim of gorge. Habitat: Somewhat lateritic soil at edge of shale and sandstone. In regrowth with *Angophora oblonga*, *E. fibrosa*, *Acacia glaucescens*.

It is unknown whether Threatened *Hibbertia* taxa exist in this general locale as access so far has not been granted.

4.4 ASSESSMENT OF SUITABLE HABITAT

The assessment of suitable habitat has been described in section 4.3, assessment of species presence, because the survey during the non-flowering period required the presumption that if suitable habitat were present then the species could also be present.

The species could be present in areas of shale / sandstone transition, in microhabitats such as seepage zones below or above sandstone outcrops. Broad scale vegetation survey and mapping do not identify habitats at this scale. Survey during the flowering season is recommended.

4.4.1 DETERMINATION OF SPECIES POLYGONS

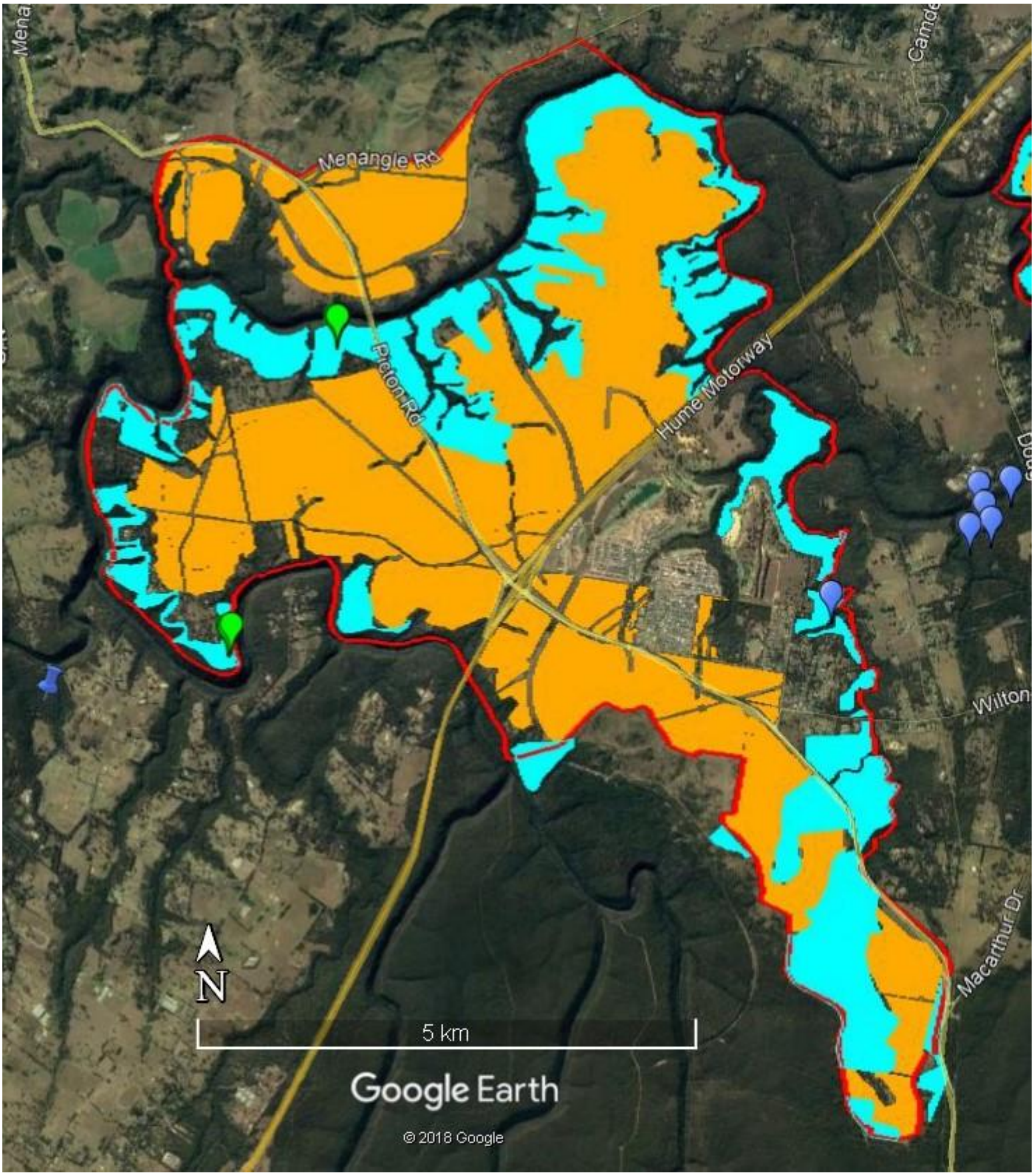
Determination of potential habitat for *Hibbertia fumana* includes areas identified outside but adjacent to the deemed biocertification area. Anthropogenic impacts are well documented to adversely affect vegetation well beyond the direct urban footprint (refer section 2.5).

Maps 10 to 13 show an overview of areas containing likely and potential habitat of *Hibbertia fumana* within the GMGA and WGA. The areas shaded in yellow are habitats assessed as having attributes similar to known extant populations and the entire area should be considered likely habitat. The polygons shaded in blue are based on broad scale mapping units both vegetation and soils and are indicative that potential habitat niches may exist within those areas. The habitat niches are inferred from historic records only.

Mixed native / exotic derived grassland / herbland including *Themeda australis* & *Hibbertia diffusa* that is likely habitat at Menangle Park Paceway vicinity.

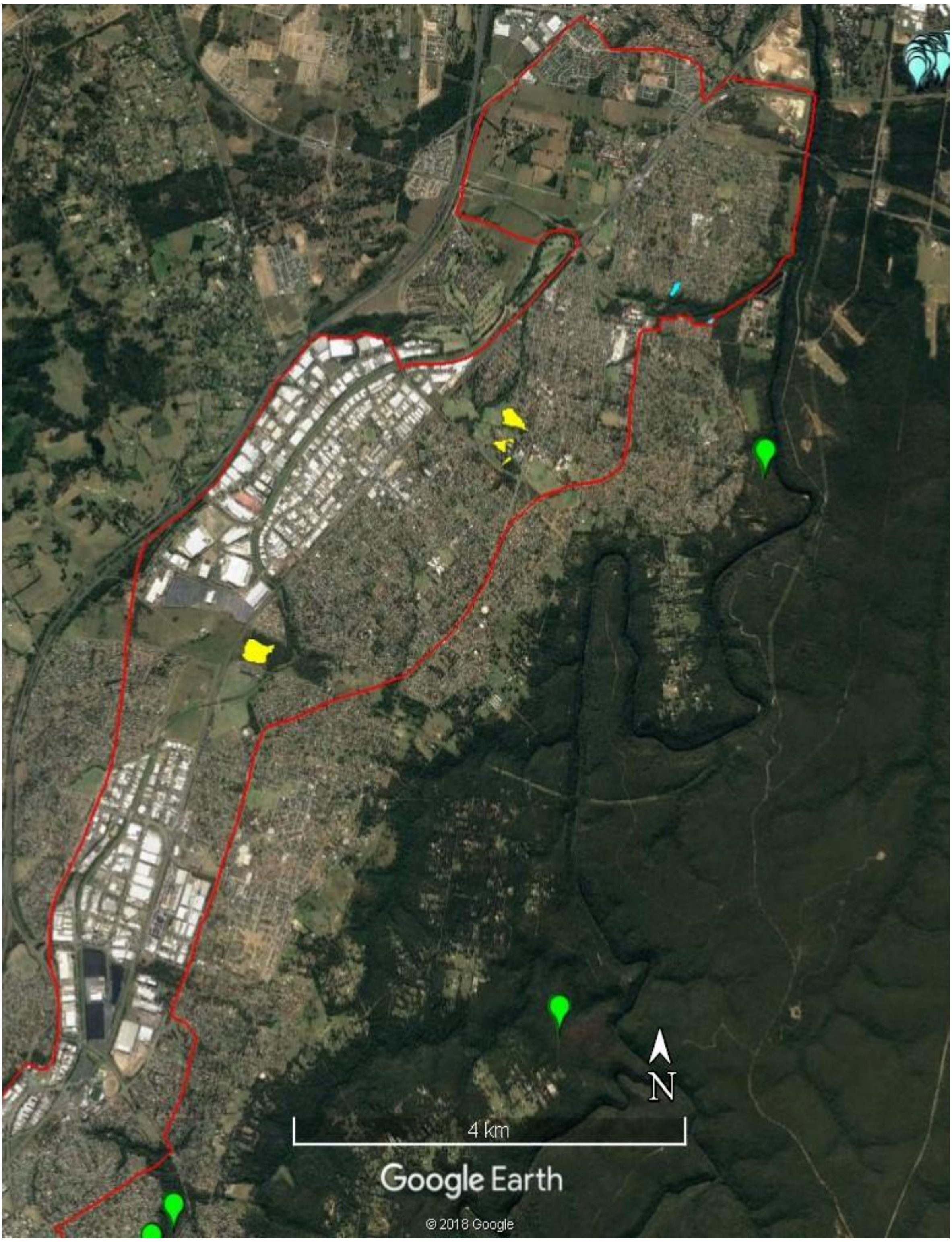
Areas of indigenous shrubs including *Melaleuca erubescens*, *Dillwynia seiberi*, *Pultenaea villosa*, *Daviesia ulicifloia.* This is a habitat that may also support *Hibbertia fumana*.

Photo 12: Indicative of likely habitat in the Manangle Park Paceway vicinity.



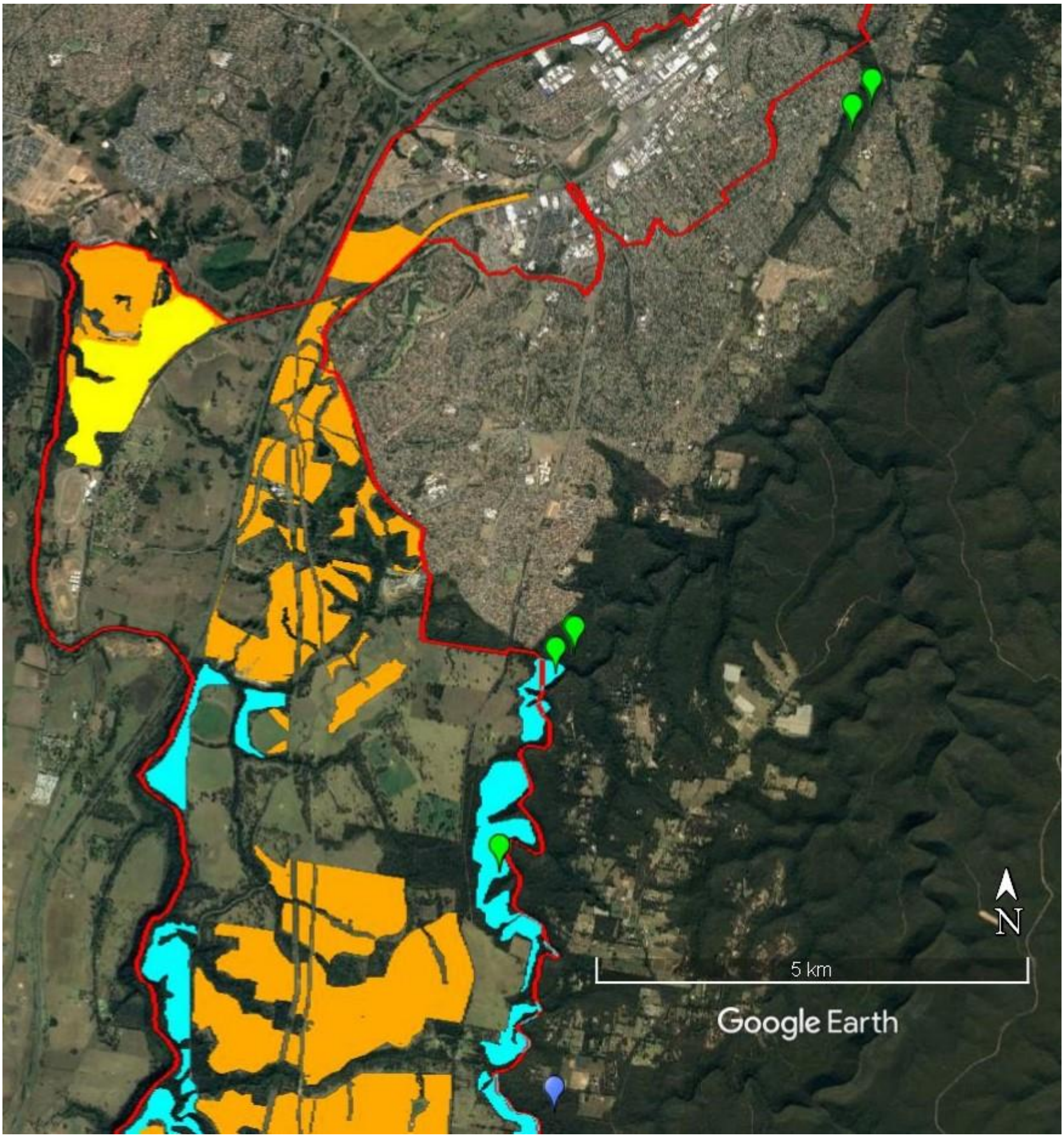
Map 10: Areas containing potential habitat in the Wilton Growth Area.

Key: Red – outline of growth area, blue – areas of potential habitat niches, orange – growth area footprint, green dots – locations of *Hibbertia puberula?* plants, purple dots – records of *Hibbertia riparia*.



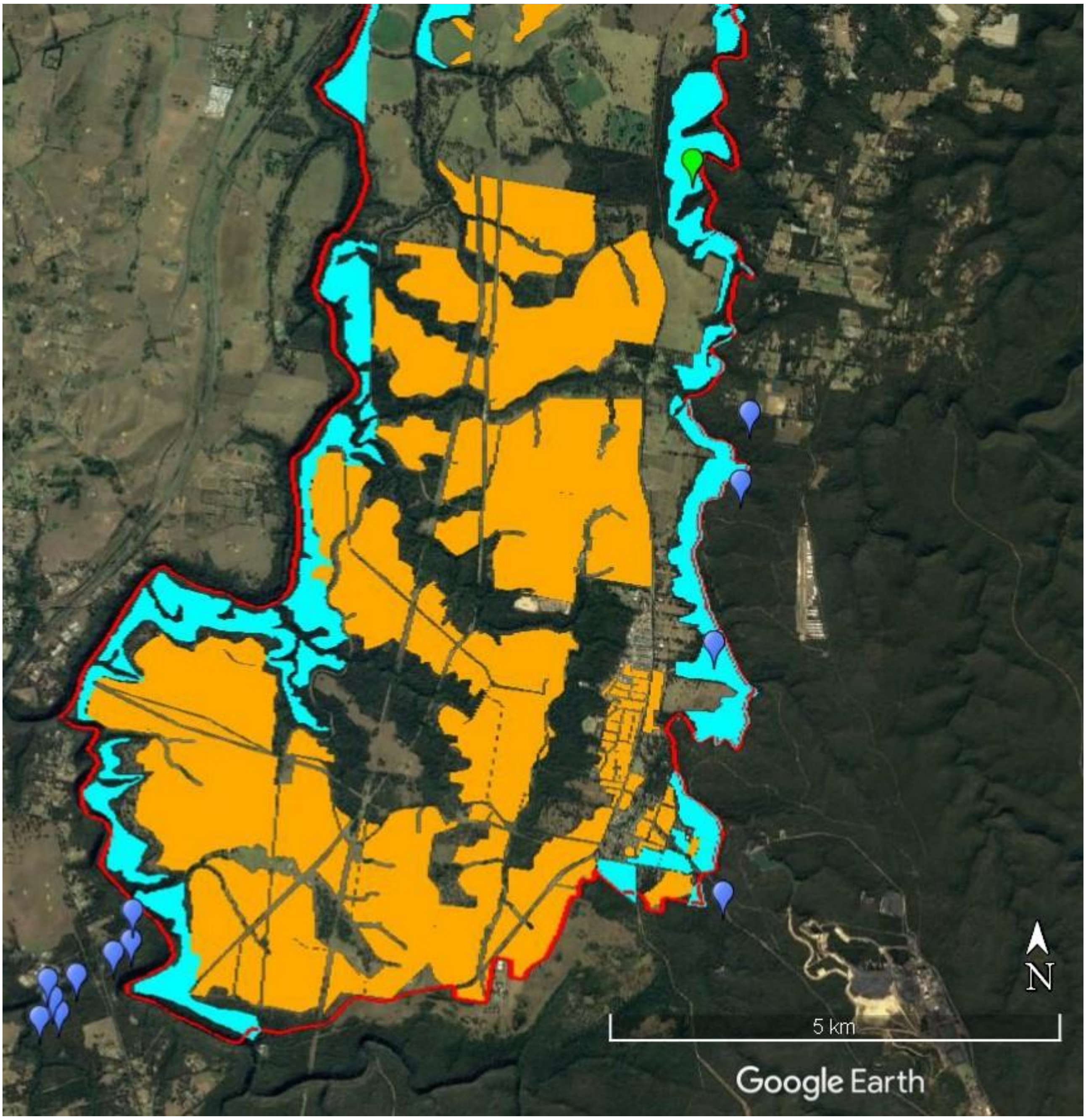
Map 11: Areas of likely habitat, north section of Greater Macarthur Growth Area.

Key: Red –outline of growth area, yellow – areas of likely habitat, blue – areas of potential habitat niches, green dots – locations of *Hibbertia puberula?* plants, blue dots (top right of map at Moorebank) – records of *Hibbertia fumana*.



Map 12: Areas of potential habitat, middle section of Greater Macarthur Growth Area.

Key: Red –outline of growth area, yellow – areas of likely habitat, blue – areas of potential habitat niches, orange – growth area footprint, green dots – locations of *Hibbertia puberula?* plants, purple dots – records of *Hibbertia riparia*.



Map 13: Areas of potential habitat, southern section of the Greater Macarthur Growth Area.

Key: Red – outline of growth area, blue – areas of potential habitat niches, orange – growth area footprint, green dots – locations of *Hibbertia puberula?* plants, purple dots – records of *Hibbertia riparia*.

4.4.2 JUSTIFICATION FOR DETERMINATION

The species likely habitat polygons for Milton Park, Kayess Park and Menangle Park in the GMGA are based on limited field inspections undertaken in adverse environmental conditions outside the flowering period. Therefore, the polygons are indicative only.

The majority of potential habitat polygons for the WGA are based on regional mapping data provided by DPE as access issues limited field inspection. Similar access issues arose with other potential habitat areas within southern and central portions of the GMGA. Unless indicated potential habitat polygons for the southern and central portions of the GMGA are also based on regional mapping data.

4.5 ESTIMATE OF AREA OF HABITAT OR NUMBER OF INDIVIDUALS

4.5.1 ESTIMATES

The assessment provides the following estimates:

- at Menangle Park an area of approximately 92ha that could contain likely habitat niches within the growth area footprint, and a further 31 ha of land containing likely habitat niches adjacent to the footprint.
- at Kayess Park and Milton Park – Macquarie Fields Leisure Centre vicinity areas of likely habitat that are not affected by the growth area footprints. However, Milton Park is managed for recreation and it is very unlikely that the species would survive at that location. Macquarie Fields Leisure Centre vicinity contains remnant bushland some of which may support the species. The derived grassland in the Kayess Park vicinity may support the species.
- at Bunbury Curran Creek vicinity areas of potential habitat are not affected by the growth area footprints.
- in the Gilead and Appin areas approximately 8ha of land containing potential habitat niches within the notional development footprint and a further 380ha of land containing potential habitat niches adjacent to the footprint.
- in the Wilton growth area, approximately 65ha of land containing potential habitat niches within the footprint and a further 680ha of land containing potential habitat niches adjacent to the footprint.

4.5.2 JUSTIFICATION FOR ESTIMATES

Assessment relied on personal knowledge of the species habitat for extant populations and speculation about the habitat of historic records, combined with vegetation mapping and soil and landscape features, to determine “likely habitat” (based on extant population habitat) and "potential habitat" (based on speculation of historic record habitat) locations within and adjacent the growth areas footprints.

The probability of the species to occur in the likely habitat is considered low due to site disturbance, however, cannot be ruled out as the Bankstown population survives in a highly modified mown derived grassland environment refer Photo 12). The probability of the species to occur in potential habitat is considered to be very low. However, a precautionary approach is recommended. Locating and protecting new populations, no matter how small, is significant to the survival of this species.

It was not possible to provide accurate habitat areas or counts due to the following:

- Access was not granted to the majority of development footprint.
- The region has undergone a period of protracted drought and small diminutive species, forbs and even many of the larger resilient shrubs were observed to be in severe drought stress or dead. *Hibbertia puberula* grows in close proximity to *Hibbertia fumana* at both extant sites. At all locations where *Hibbertia* species with vegetative morphological features consistent with *H. puberula* were found only a few individuals were noted, most were almost dead. It is well documented that the above ground populations of many genera including *Hibbertia* species fluctuate widely in response to various conditions such as rainfall and time since last fire.
- Most sites inspected within the WGA and many within GMGA were also noted to have senescing or dead shrubs, high levels of leaf, bark and branch fall and dead understorey an indication of both a long fire interval and severe drought. Apparent diversity and population numbers of many species significantly decline, retreating to the soil seedbank under such conditions. It is inconclusive to undertake population census or estimates under such circumstances.
- The cryptic nature of small-leaved *Hibbertia* when not in flower also make their detection extremely difficult and population count or area calculation unreliable.
- The use of a surrogate site(s), as a base for the estimation, in this case, is deemed not credible. *Hibbertia fumana* is a data-poor species. Insufficient or no reliable data exists in regards to population density and population fluctuation over time at any of the known sites.

5. Information used in the assessment

Information used in this assessment includes taxonomic papers, BioNet and ALA records of the target species, Critically Endangered Listing, online Threatened Species profile and associated documents, personal observations and site inspections, and the spatial viewer including the layers: survey access and coverage, (BAM plots, polygons and transects), PGA layer and geology and soils.

6. References

Bannerman S.M. and Hazelton P.A., 1990, *Soil Landscapes of the Penrith 1:100,000 Sheet map and report*, Soil Conservation Service of NSW.

Duretto, M., Orme, A., Rodd, J., Stables M. and Toelken, H. 2017. *Hibbertia fumana* (Dilleniaceae), a species presumed to be extinct rediscovered in the Sydney region, Australia. *Telopea* 20: 143–146 and available at https://openjournals.library.sydney.edu.au/index.php/TEL/article/view/11684/11653

Hills District Council website, https://webcache.googleusercontent.com/search?q=cache:-vpeh8rPRVEJ:https://www.thehills.nsw.gov.au/files/assets/public/library-documents/local-studies/aborigines-in-the-hills-district.pdf+&cd=3&hl=en&ct=clnk&gl=au

National Parks and Wildlife Service. 2002. *The Native Vegetation of the Cumberland Plain Final Edition*. NSW National Parks and Wildlife Service, Hurstville, available at http://www.environment.nsw.gov.au/resources/nature/cumbPlainMappingInterpguidelines.pdf

NSW Department of Environment, Climate Change and Water, 2010. *Cumberland Plain Recovery Plan*, available at http://www.environment.nsw.gov.au/research-and-publications/publications-search/cumberland-plain-recovery-plan

OEH website *Hibbertia fumana* - Sydney Basin: Distribution and vegetation associations, last updated: 29 May 2018, available at https://www.environment.nsw.gov.au/threatenedspeciesapp/profileData.aspx?id=20323&cmaName=Sydney+Basin

Orchard A.E. 1999. A History of Systematic Botany in Australia, in *Flora of Australia Vol.1*, 2nd ed., ABRS.

Toelken, H. R. and Miller, R. T., 2012. Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in *Journal of Adelaide Botanic Gardens* 25 (2012) 71–96 and available at https://data.environment.sa.gov.au/Content/Publications/JABG25P071_Toelken.pdf

7. Appendices

Appendix 1. CURRICULUM VITAE

Robert Miller *Curriculum Vitae*

Contact Details:

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	0410 244 865
Email	janrob02@gmail.com

Current Position:

Principal of Cumberland Flora & Fauna Interpretive Services

Qualifications:

Associate Diploma Horticulture from the University of Western Sydney (formerly Hawkesbury Agricultural College), conferred on 17 April 1982

Journal Articles

H.R. Toelken & R.T. Miller **2012** Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in Journal of the Adelaide Botanic Gardens, Vol. 25.

Miller J and Miller R **2005** Aquatic macroinvertebrates of headwater streams in the south east forests – diversity and conservation management issues, Wetlands (Australia) 23 (1).

Employment Record

1993 – present

Cumberland Flora and Fauna Interpretive Services

Principal - flora surveys, plant identifications, vegetation assessment, project impact assessment, bush regeneration, rehabilitation, habitat enhancement, seed collection and propagation services.

1990 - 1997

Sylvan Grove Native Gardens

Curator of gardens and adjoining bushland - maintenance of and improvement to the plant collection, training and supervision of staff, liaison with other botanic gardens, guided tours, technical advice.

1982 - 1990

Sylvan Grove Native Gardens

Horticulturist Specialising in Australian Flora - collection, propagation, identification, and growing of native plants.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES INFORMATION AND RELEVANT EXPERIENCE

Cumberland Flora and Fauna Interpretive Services have provided technical expertise since 1993 to numerous clients including Local Government, NSW Roads and Maritime, NSW Office Environment Heritage NPWS and community groups. Following is a list of some of our projects and clients:

REPORT	CLIENT
Expert advice for Conservation Assessment of *Solanum celatum* Eren Delgado1 16/04/2018, Science Division, NSW Office of Environment and Heritage	OEH
Saving our Species (SoS) project for *Pomaderris adnata* a post fire population census Grid D 2018	OEH
Provision of expert advice to update the current ecological data for southern NSW threatened flora species, as part of the review of biodiversity assessments under the Biodiversity Conservation Act 2016.	OEH

REPORT	CLIENT
Expert witness in botany Residents Against Intermodal Development Moorebank Incorporated v NSW Minister for Planning and Anor – NSW Land & Environment Court Class 1 Proceedings No. 2017/81889. Review of project documentation, in particular the various biodiversity assessments including the BAM assessment for the project and Individual Expert Witness report of Dr David Robertson 15 October 2017; Site inspections to identify the location of and/or potential habitat for *Hibbertia fumana*, *Hibbertia puberula*, *Grevillea parviflora*, *Persoonia nutans*, *Acacia bynoeana*, provision of an expert report in accordance with Division 2 of Part 31 of the UCPR; confer with the other parties experts at a joint conference and produce a joint expert report; and f appear at the section 34 conciliation conference	EDO
Saving our Species (SoS) project for *Pomaderris adnata* a population census 2017	OEH
Central Coast Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Great Lakes Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2015 – Vegetation Consultant	OEH
Clarence Colliery Discharge Investigation April 2015	OEH
Vegetation Assessment as part of the Lachlan Wetlands Condition Assessment Project October 2013 – May 2014	Lachlan Catchment Management Authority
Field expertise and guidance in the Sydney basin to PhD candidate Karen Muscat studying the molecular phylogenetics and morphology of the genus Dianella with close scrutiny of the variation in the D. *caerulea* group of species in eastern Australia	Volunteer to University of Melbourne
Survey for *Pomaderris adnata* to determine population size, structure, occupancy and threats 2014	NPWS Illawarra Region
Survey of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats. Collection of voucher herbarium material for taxonomic review June 2014	OEH
Survey of the southern populations of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats May 2014	OEH
Investigation of works within the Sublime point precinct Illawarra Escarpment State Conservation Area February 2014.	NPWS Illawarra Region
Identification of Hibbertia species in proposed control burn sites Victoria Road precinct Dharawal National Park.	NPWS Illawarra Region
Assessment of impact of infrastructure upgrade Victoria Road, Dharawal National Park – location of threatened species.	NPWS Illawarra Region
APPEAL IN RESPECT OF PROPERTY AT Lot 1 and 2 DP 224431 Site 2 Sturdee Avenue, Bulli	Roy 'Dootch' Kennedy

REPORT	CLIENT
Expert Witness Report Relating to Some Environmental Issues Land & Environment Court of New South Wales PROCEEDINGS NO 10982 of 2012	Roy 'Dootch' Kennedy
Field surveys, collection, pressing, curation of botanical specimens and contributions of notes in association with the manuscript "Notes on Hibbertia subgen. Hemistemma (Dilleniaceae) 7. Eight new species, a new combination and four new subspecies from mainly central New South Wales H.R. Toelken & R.T. Miller 2006 - 10 July 2012	Volunteer to Adelaide Botanic Gardens
Vegetation Surveys and assessments & input into the preparation of REF for proposed car-park and amenities Victoria Road Precinct Dharawal National Park November 12.	NPWS Illawarra Region
Office of Environment and Heritage – Priority Action Statement Expert Consultant Interviews June 2012 – January 2013	OEH
Vegetation Surveys and assessments & input into the preparation of REF for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking tracks in Dharawal National Park input into conservation risk assessments 2011 – 12.	NPWS Illawarra Region
Nomination to list Prostanthera saxicola R. Br. S. Str. as an Endangered Species under the NSW TSC Act September 2011	
Field surveys, collection, pressing and curation of botanical specimens of undescribed Kunzea to assist in the taxonomic circumscription of previously presumed extinct, rare and/or poorly known taxa for Dr. H.R. Toelken Honorary Research Associate State Herbarium Science Resource Centre Department of Environment and Natural Resources SA 2011	Volunteer to Adelaide Botanic Gardens
Significant Plant Survey – Maddens Plains Forest Path to Mount Mitchell Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Significant Plant Survey – Wongawillii Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Kembla State Forest Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Site Inspections and Vegetation Survey of Proposed Minor Track Re-Alignments: Forest Path to Woodward Track & Sublime Point to Austinmer Track Maddens Plains To Sublime Point Precinct Illawarra Escarpment State Conservation Area August 2010	NPWS Illawarra Region

REPORT	CLIENT
Sandon Point Aboriginal Place and Kuradji Lands Vegetation Management Plan April 2010	Illawarra Aboriginal Land Council, Wollongong Council, Southern Rivers Catchment Management Authority.
Forest Path to Woodward Track Precinct Track-head Realignment Maddens Plains IESCA Vegetation Survey April 2010.	NPWS Illawarra Region
Bushland Conservation Project 95 Glendiver Road, The Oaks 2008	A & S Fitzsimmons / Hawkesbury Nepean Catchment Management Authority
Significant Plant Survey – Maddens Plains Forest Path to Woodward Track Precinct Illawarra Escarpment State Conservation Area June 2007	NPWS Illawarra Region
Nomination of Hibbertia "Bankstown Airport" (R.T. Miller & C.P. Gibson s.n. 18/10/2006) as Critically Endangered under the Environment Protection and Biodiversity Conservation Act	Bankstown Bushland Society
Proposal to Demolish A Derelict Amenities Block at Deepwater Park Webster Street Milperra Environmental Assessment of Impacts	Bankstown City Council
Significant Plant Survey – Sublime Point to Panorama House Precinct Illawarra Escarpment Conservation Area August – September 2006	NPWS Illawarra Region
A Consultant for Priority Action Statement Workshop July 2005	NPWS
PHD research assistance – 'The Benefits of Riparian Vegetation in Maintaining Water Quality as Assessed Using Biological Indicators".	UNSW
Plan of Management for Part Lot 11 Dp 1049307 Kurrajong Road Prestons January 2005	Sule College
Preliminary Investigation & Vegetation Survey of Lands At Prestons Bounded By Maxwells Creek, Kurrajong Road, Ash Road & The Western Sydney Orbital December 2003	Sule College
Supply and collection of seed for a research project entitled: Factors Affecting Seed Germination and Microrrihzal Development of the Epacrid: *Woolsia pungens* (2001-2003)	UNSW
Compensatory Habitat Assessment Western Sydney Orbital March 2004	RTA
Compensatory Habitat Assessment Western Sydney Orbital July 2002	RTA
Compensatory Habitat Assessment of Flora at Rouse Hill, Doonside, Cecil Hills & Kemps Creek for The Western Sydney Orbital March 2002	RTA
Compensatory Habitat Assessment Western Sydney Orbital November 2001	RTA
Preliminary Vegetation Survey Between Lawson Rd & Alfords Point Rd, Menai as Part of The Proposed Bangor Bypass 2001	RTA
8-Part Tests for The Proposed Bangor Bypass 2000	RTA
Preliminary Vegetation Survey for The Proposed Bangor Bypass 2000	RTA
Species Impact Statement for the Western Sydney Orbital 2000	Sinclair Knight Mertz

REPORT	**CLIENT**
Review of Environmental Assessments – Proposed Cricket Ground - Louisa Reserve, The Crest of Bankstown 2000	Bankstown Bushland Society
Review of Environmental Assessments – Proposed Olympic Criterium Circuit the Crest Statement of Environmental Effects	Bankstown Bushland Society
Vegetation Survey – 60 Yanderra Road, Yanderra 1999	Mr. Brian Timmis
Review and Comments on Environmental Assessment – Bankstown City Council - Proposed Cricket Ground – 8 – Part Test- The Crest 1999	Bankstown Bushland Society
Vegetation Survey and Review of Proposed Sand Mining Restoration Works – Howard Park, Lansvale 1999	Chipping Norton Lakes Authority
Rare Species Survey – Blue Mountains & Central Western Slopes 1999	National Parks & Wildlife Service
Vegetation Survey - Kookaburra Road and Camden Valley Way Intersection 1999	Roads & Traffic Authority
Chullora Detention Basin Wetlands Habitat Enhancement 1998	Business Land Group DUAP
Vegetation Study Maxwells Creek Trunk Drainage Stage 1 Vegetation Assessment 1998	Bewsher Consulting
Vegetation Study Prestons Urban Release Area Part 3 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 2 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 1 1998	Liverpool City Council
Survey of Remnant Flora for Proposed Nth Liverpool Rd to Edensor Rd Interim Transitway 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management Discussion Paper 1998	Roads & Traffic Authority
Eastern and Western Alignments WSO Cecil Hills Flora Study 1998	Roads & Traffic Authority
Valmay Road Development Vegetation Study 1998	LesryK Pty Ltd
Western Sydney Orbital Prestons To West Baulkham Hills Descriptive Inventory of Remnant Bushland 1998	Roads & Traffic Authority
Vegetation Survey River Road M5 East 1998	Roads & Traffic Authority
Tree Survey, Great Western Highway, Faulconbridge 1998	Roads & Traffic Authority
Eve & Marsh Street Wetlands M5 East 1997	Roads & Traffic Authority
Beverley Grove Bush M5 East 1997	Roads & Traffic Authority
Vegetation Survey - Salt Pan Creek Bridge Duplication M5 East 1997	Roads & Traffic Authority

REPORT	CLIENT
Survey of Flora: Trees and Shrubs, Princes Highway Interchange M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Adjacent to Proposed Exhaust Stack Henderson Avenue, M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Illoura Reserve, Adjacent to Air Intake Vent M5 East 1997	Roads & Traffic Authority
Lansdowne Reserve Survey of Remnant Flora 1997	Bankstown City Council
Villawood Drain Vertebrate Fauna Survey 1997	Bankstown City Council
Kelso Wetlands Survey of Remnant Flora 1997	Bankstown City Council
Deverall Park Survey of Remnant Flora 1997	Bankstown City Council
Louisa & McClean Reserves Bass Hill Survey of Remnant Flora 1997	Bankstown City Council
The Crest of Bankstown Survey of Remnant Flora 1997	Bankstown City Council
Lawson Bridge Roadworks Survey of Remnant Flora 1997	Roads & Traffic Authority
Davidson Street Scrub Survey of Remnant Flora 1997	Strathfield Council
Freshwater Creek Bushland Survey of Remnant Flora 1996	Bankstown Bushland Society for the EPA
Vegetation Survey Forest Lawn Cemetery Roadworks, Leppington 1996	Roads & Traffic Authority
Vegetation Survey Catherine Fields Road Intersection, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Springfields Road Intersection and Camden Valley Way, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Deepfields Road Intersection Camden Valley Way, Catherine Fields 1996	Roads & Traffic Authority
Picnic Point Reserve Vegetation Survey 1996	Bankstown City Council
East Hills Park Vegetation Survey 1996	Bankstown City Council
Monash Reserve Vegetation Survey 1995	Bankstown City Council
Vegetation Consultant on Plan of Management for Cox's Creek for the Endangered Green and Gold Bell Frog 1995	Urban Bushland Management
Smith Park Vegetation Survey 1995	Bankstown City Council
Flora and Fauna Survey, Villawood Stormwater Channel 1995	Bankstown City Council
Virginius Reserve Vegetation Survey 1994	Bankstown City Council
Carysfield Park Vegetation Survey 1993	Bankstown City Council

Ongoing research projects:

Private taxonomic research into the Australian plant genera Prostanthera, Westringia, Dianella, Thelionema, Viola and Hibbertia.

Private research into the invertebrate fauna of the Illawarra with particular emphasis on the Mayfly genus Atalophlebia

Flora of Bankstown" a botanical inventory

Botanical inventories of the Sublime Point and Maddens Plains precincts in the Illawarra Escarpment State Conservation Area

Other Publications & Reports

Miller, R.T. (1984 to 2006) numerous papers for the Prostanthera and Westringia Study Group Newsletters.

Miller, R.T. (1991) Vegetation Consultant on Eloura Nature Reserve Vegetation Survey: Report to Liverpool City Council, Greening Australia.

Miller, R.T. Vegetation Consultant on Salt Pan Creek Stage 1 Vegetation Survey: Report to Bankstown City Council, Ian Olsen.

Gibson, C.P. & Miller, R.T. Plant Species List for Bankstown's Natural Heritage: McLaughlin, L., BCC.

Gibson, C.P. & Miller, R.T. Flora of Bankstown Scientific Inventory of Botanical Heritage: Report to Australian National Parks and Wildlife Service, Gibson, C.P. and Miller, R.T. (in preparation).

Nomination of Prostanthera saxicola R. Br. s. str. As an Endangered Species under the NSW TSC Act November 2011

Special Projects

- "Flora of Bankstown" a botanical inventory
- Founder & Convener Cookson's Landcare Group Bulli (2003 – 2007)
- President, Society for Growing Australian Plants, East Hills Region, 1987-1995.

- Vice President, Society for Growing Australian Plants, East Hills Region, 1996.
- Plant Steward, Society for Growing Australian Plants, East Hills Region, 1987-1996.
- Leader of the Prostanthera Study Group Australian Plant Society, 1992 - 2010.
- Editor and publisher of Prostanthera & Westringia Study Group's Newsletter *The National Mint* and the Study Groups' Journal – *Lasianthos*.
- Vice President and Founding Member, Bankstown Bushland Society.
- Coordinator Grants Application, Bankstown Bushland Society.
- Bushland Regeneration Grants Project Manager, Bankstown Bushland Society:
  - Deverall Park Restoration and Rehabilitation Swamp Woodland ($17,880).
  - The Crest of Bankstown Restoration and Rehabilitation ($27,850).
  - Airport and Ashford Reserves Restoration and Rehabilitation Swamp Woodland ($45,000).
- Co-recipient of Save the Bush grant for Flora of Bankstown by Hon. Ross Kelly, Minister for Arts, Sports and Environment, 1992-93 ($11,050).
- Founding Member of Illawarra Grevillea Park, Bulli.
- Curator, Lamiaceae collection, Illawarra Grevillea Park, Bulli.
- Former Bankstown City Council's Bushfire Taskforce Community Representative.
- Former presenter of an adult education course in gardening at Bankstown Evening College.
- Development and curation of a private regional herbarium.
- Expert Witness for NSW Police murder trial
- Former appointee as Trustee of the Georges River State Recreational Trust by the Minister for the Environment (the Hon. Tim Moore).

Appendix 2. TAXONOMIC DETAILS FOR IDENTIFICATION OF *Hibbertia fumana*

Photo 13: *Hibbertia fumana* indumentum of axillary shoot and +/- sessile flower bud (R.T. Miller)

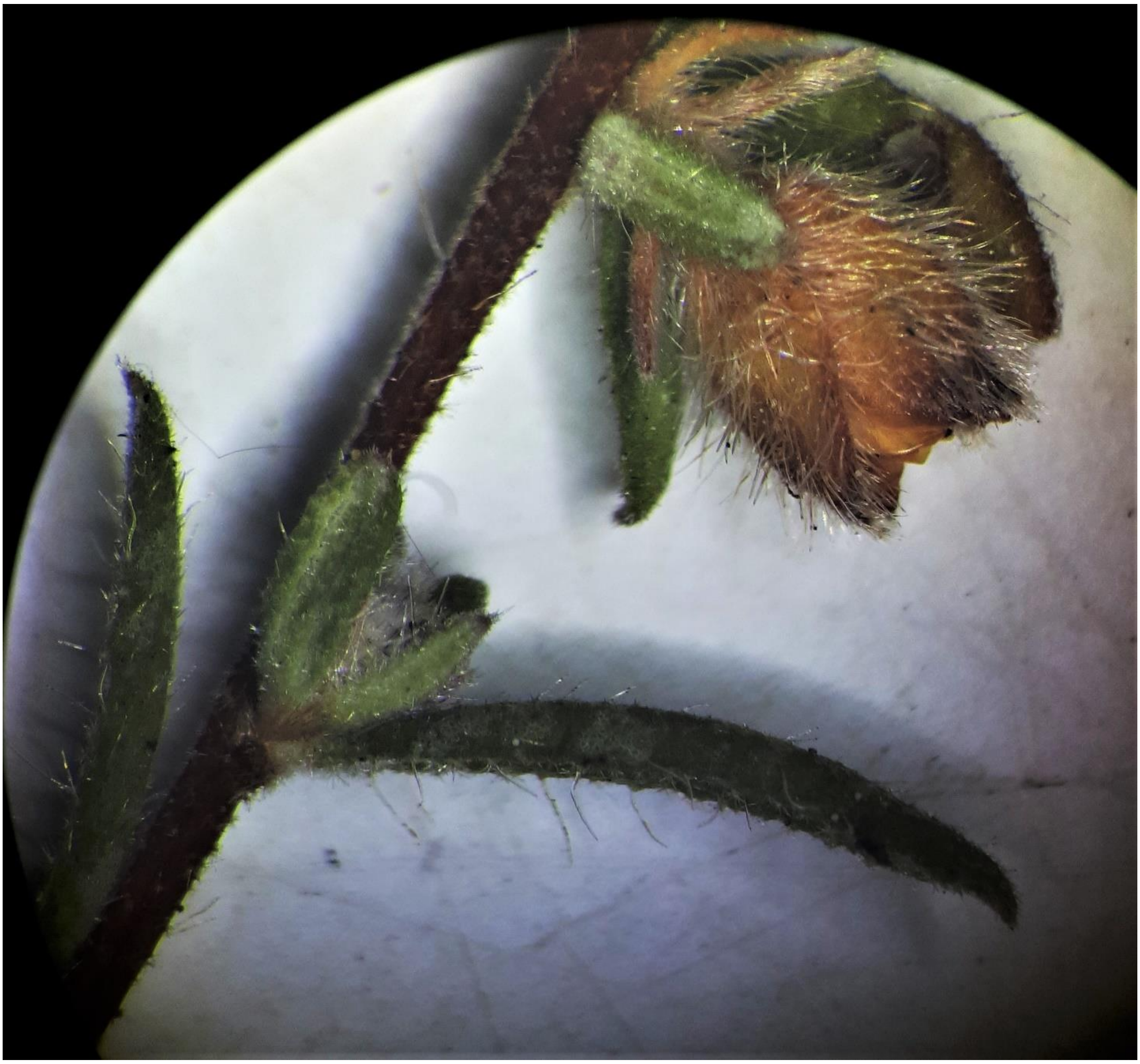


Photo 14: *Hibbertia fumana* indumentum of leaf, axillary shoots and flower buds (R.T. Miller).

Photo 15: *Hibbertia fumana* elongated flower peduncle after petal dehiscence on terminal shoots and indumentum characteristics of leaf undersurface and calyxes. (R.T. Miller).

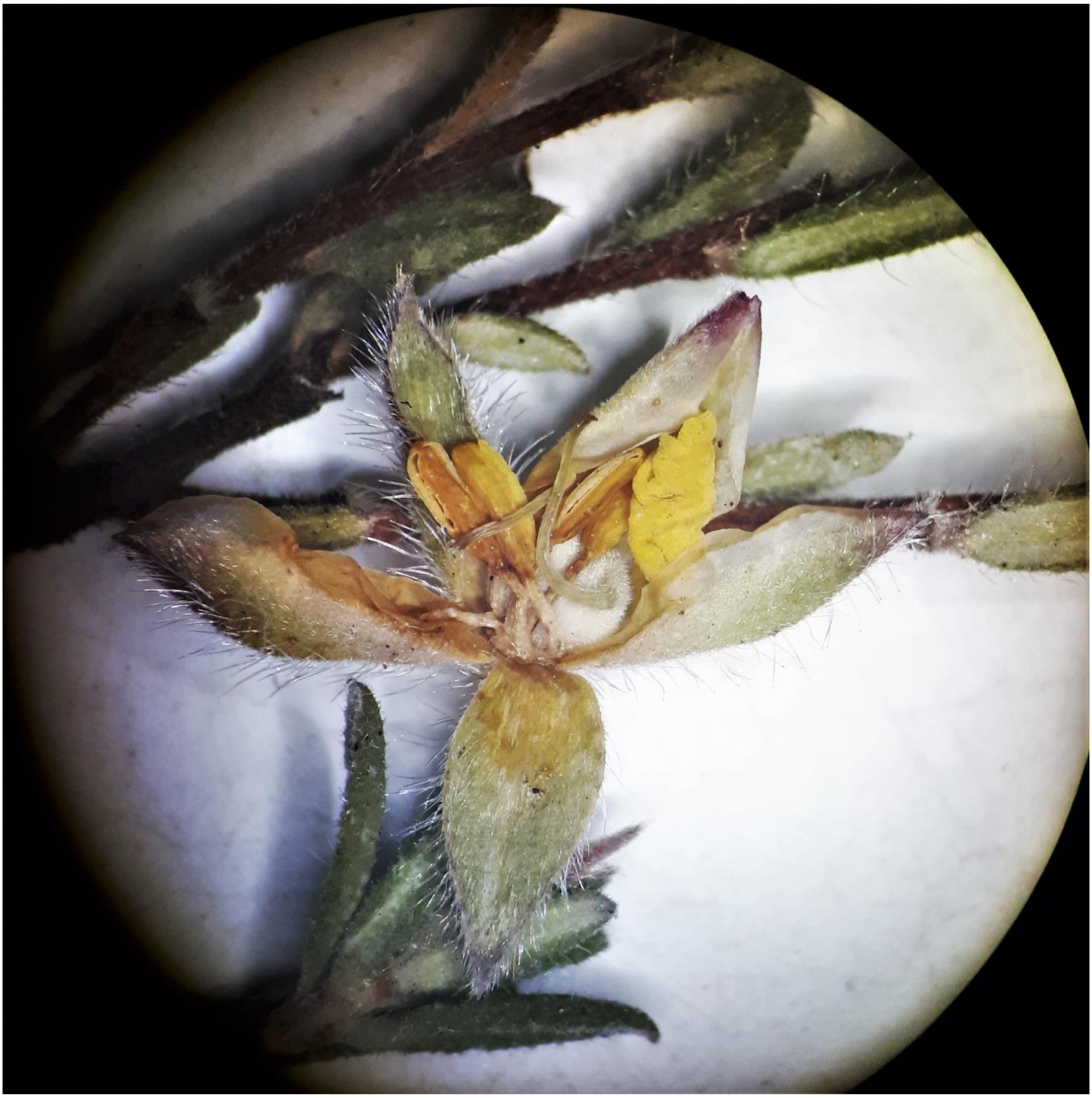


Photo 16: *Hibbertia fumana* flower morphology (R.T. Miller).

Photo 17: *Hibbertia fumana* interpetiolar tuffs in leaf axils and short subequal multiangulate fascicled hairs characters of the branchlets (Robert T. Miller)

Photo 18: Tomentum characteristics of *Hibbertia fumana* approximate 5 cm from shoot apex. (R.T. Miller).

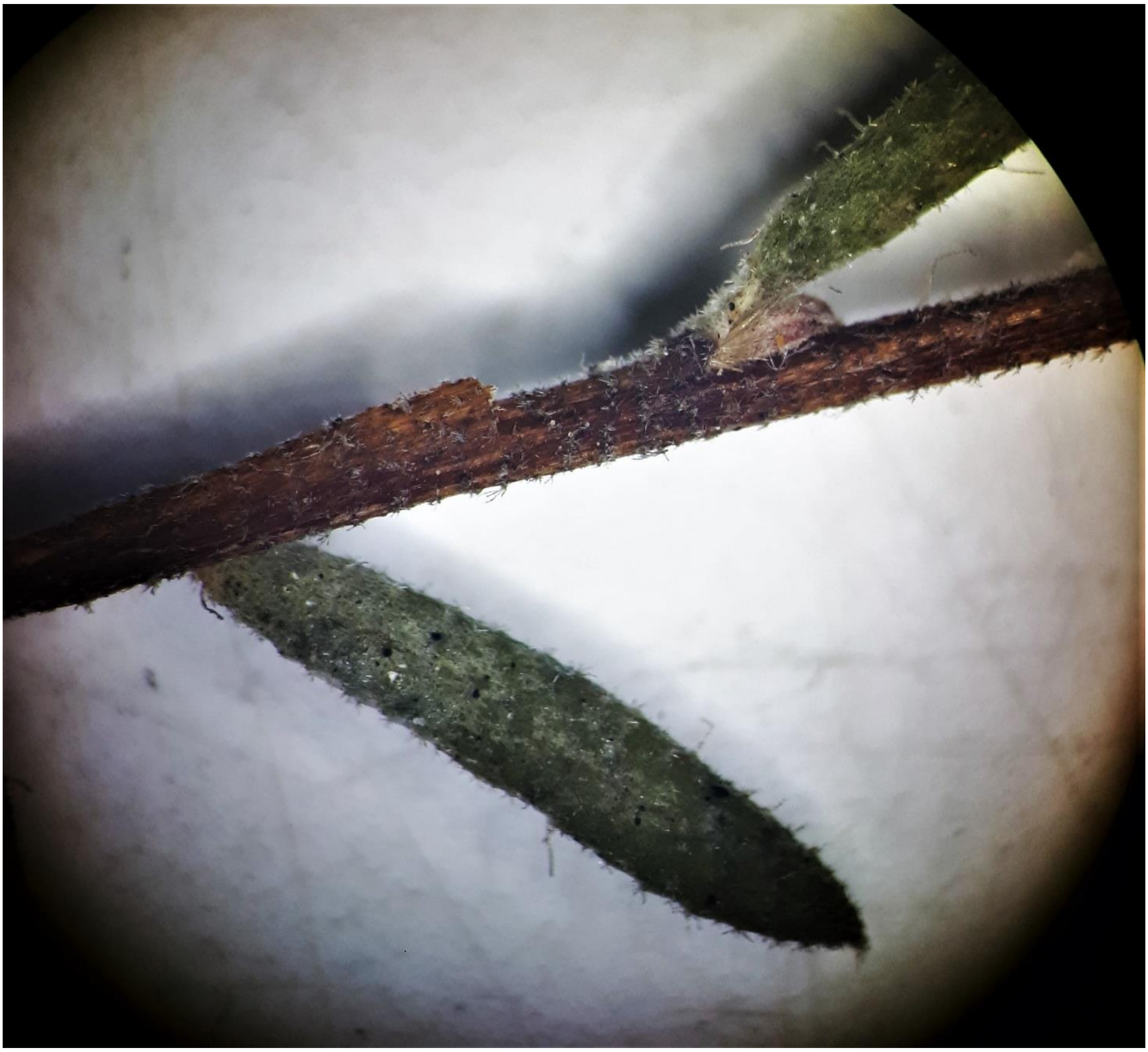


Photo 19: Leaf upper surface showing a reduction in tomentum. Leaf sample is approximately 12cm from tip (R.T. Miller).

Appendix 3. COMPARISON OF TAXONOMIC DETAILS FOR *Hibbertia* SPECIES

Photo 20: Plant of *Hibbertia empetrifolia* (R.T. Miller).

Photo 21: Closeup of leaf undersurface of *Hibbertia empetrifolia* (R.T. Miller).

Photo 22: *Hibbertia aspera* (R.T. Miller).

Photo 23: *Hibbertia aspera* showing tomentum on suckering new growth (R.T. Miller).

Photo 24: *Hibbertia dispar* showing procumbent growth habit, small-leaves and pedunculate flowers (R.T. Miller).

Photo 25: *Hibbertia dispar* showing apparent glabrous leaves and stems and +/- glabrescent floral parts of older growth in which much of the tomentum has "worn off".

Photo 26: *Hibbertia dispar*: closeup of new growth showing tomentum characteristic

Photo 27: *Hibbertia dispar* showing much of the tomentum of the calyxes being "worn off".

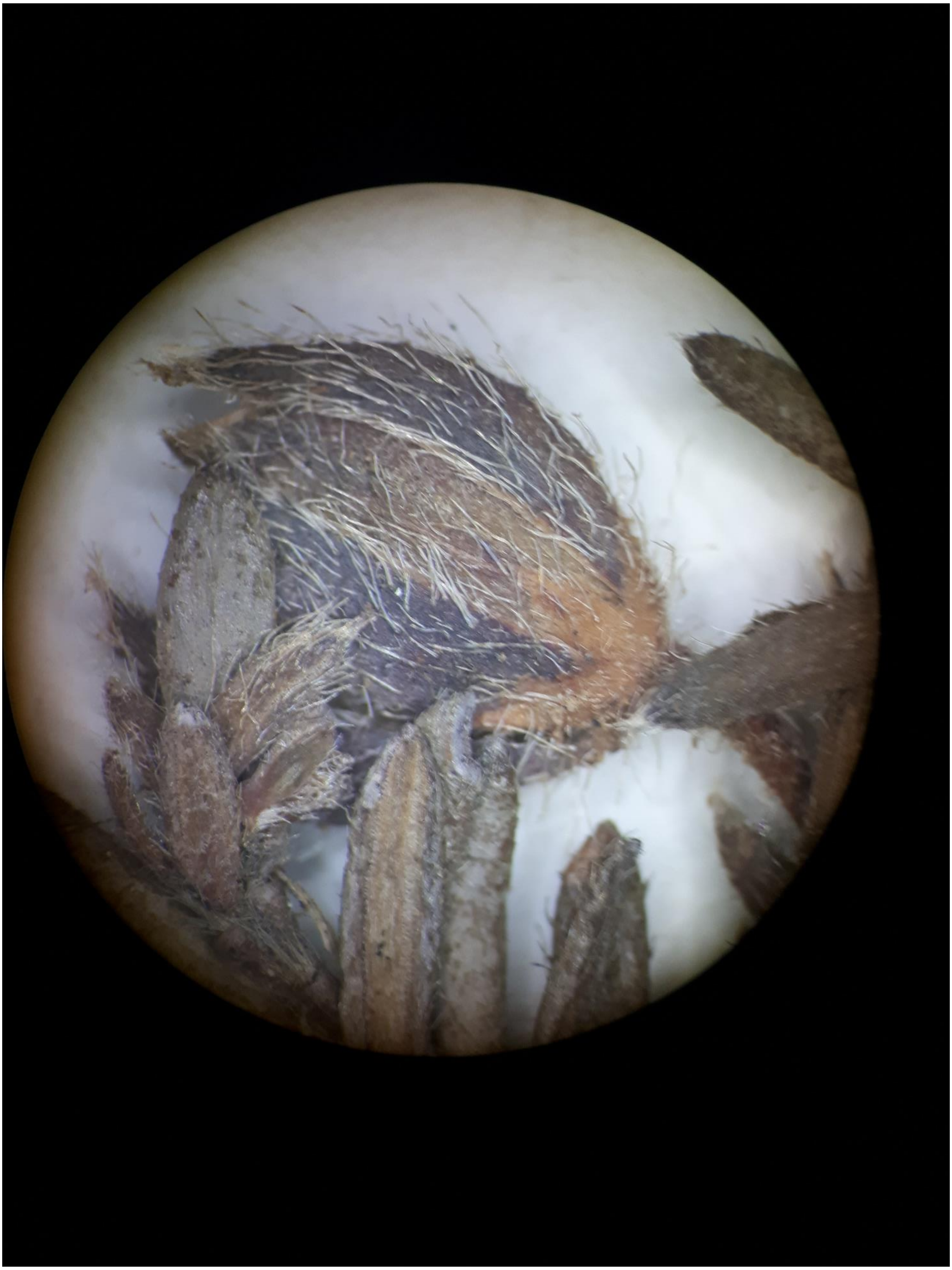
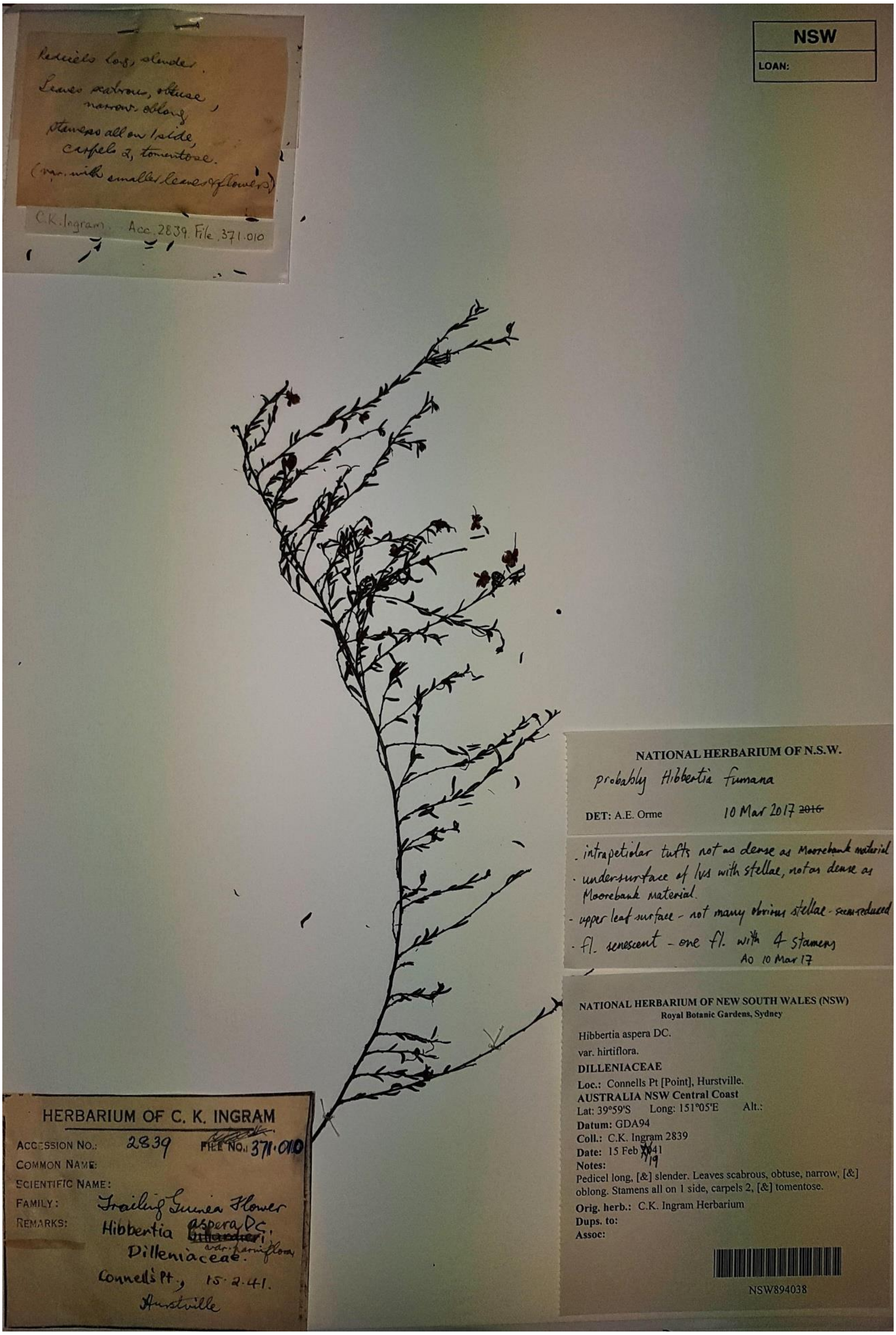


Photo 28: *Hibbertia dispar* showing the tomentum of the calyxes before being “worn off”.

Appendix 4. SPECIMEN OF *Hibbertia fumana* FROM CONELLS POINT 1941



Strategic assessment for Cumberland Plain Conservation Plan
Aerotropolis and Greater Penrith
Hibbertia fumana

Hibbertia fumana, Moorebank, R. Miller September 2017.

Report prepared for Department of Planning and Environment

By

Cumberland Flora & Fauna Interpretive Services

Robert Miller - December 2018

Executive Summary

Hibbertia fumana is listed as a Critically Endangered Species under the *Biodiversity Conservation Act 2016*. There are two known populations of the species, one at Moorebank and the other at Bankstown Airport. There is limited data on the life history and ecology of the species.

Survey for this report was restricted by time constraints, lack of access to private property, and years of preceding drought conditions. Survey targeted areas of suitable habitat identified from the habitat of extant populations and DPE vegetation mapping.

Areas adjacent to the development footprint were included in the survey because *H. fumana* is a small shrub that could be severely affected by anthropogenic impacts.

Outcomes of the assessment:

There were no prior records of the species within or adjoining the proposed growth areas.

There has been just a short period in which the species would have been formally considered in the assessment process as the species was thought to be extinct when described in 2012 and was only recently rediscovered in late 2016. This would be the primary reason for the lack of records.

No plants of *Hibbertia fumana* were found during survey for this assessment.

Non-detection should not be interpreted as the species not being present, but simply as not seen. Survey followed years of drought in Western Sydney and the species could have retreated to the soil seed bank.

The possibility of *Hibbertia fumana* occurring within the GPEC is assessed as low because potential habitat sites found within the biodiversity certification area do not have the same complexity of attributes as known extant sites.

Within the Kemps Creek area of the WSA the likelihood of *H. fumana* occurrence was assessed to range from moderate to low potential adjacent the footprint.

Note that the potential habitats are niches within the overall landscape, generally associated with localised soil and drainages within transition vegetation.

Outcomes of this assessment are that 32 ha of habitat with a low probability of the species occurring are within the development footprint, and that more than 100 ha of habitat with moderate to low probability of species occurrence are outside the footprint but are likely to suffer from anthropogenic impacts caused by the development. More than 10 ha with moderate potential have recently been partly cleared.

As *Hibbertia fumana* is a Critically Endangered species a precautionary approach is recommended. Locating and protecting new populations, no matter how small, is significant to the survival of this species.

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Abbreviations

AVH	Australian Virtual Herbarium
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
CFFIS	Cumberland Flora & Fauna Interpretive Services
DPE	NSW Department of Planning and Environment
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GPEC	Greater Penrith to Eastern Creek Urban Release Investigation Area
IBRA	Interim Biogeographic Regionalisation for Australia
OEH	NSW Office of Environment and Heritage
PCT	Plant Community Type
sp./spp.	species (species singular / plural)
s. str.	*sensu stricto* – in the narrow sense
subsp.	subspecies
UBBS	Urban Bushland Biodiversity Survey of Western Sydney NPWS 1997
WSA	Western Sydney Aerotropolis Growth Area

1. Introduction

1.1 PURPOSE

The purpose of this expert report is to determine the potential for future urban development in identified growth areas of Western Sydney to impact on *Hibbertia fumana*, which is listed as a Critically Endangered Species under the *Biodiversity Conservation Act 2016*. This report forms part of the Cumberland Plain Conservation Plan, which will be assessed under the:

- Biodiversity certification under the *Biodiversity Conservation Act 2016* (BC Act)
- Strategic assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Biodiversity Assessment Method (BAM) sets out the framework and methods to be used for assessment of impacts to biodiversity to provide preferred conservation outcomes while also supporting the development approval process. Under the BAM an expert report can be used when adequate survey is not possible. An expert report can only be used for species to which species credits apply.

The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report. The report must set out whether the subject species is likely to be present at the development site, and if present then the report must estimate, in the case of a species such as *Hibbertia fumana*, the area of habitat where the species is likely to be impacted, as well as areas from which it is known to occur in which it will be impacted.

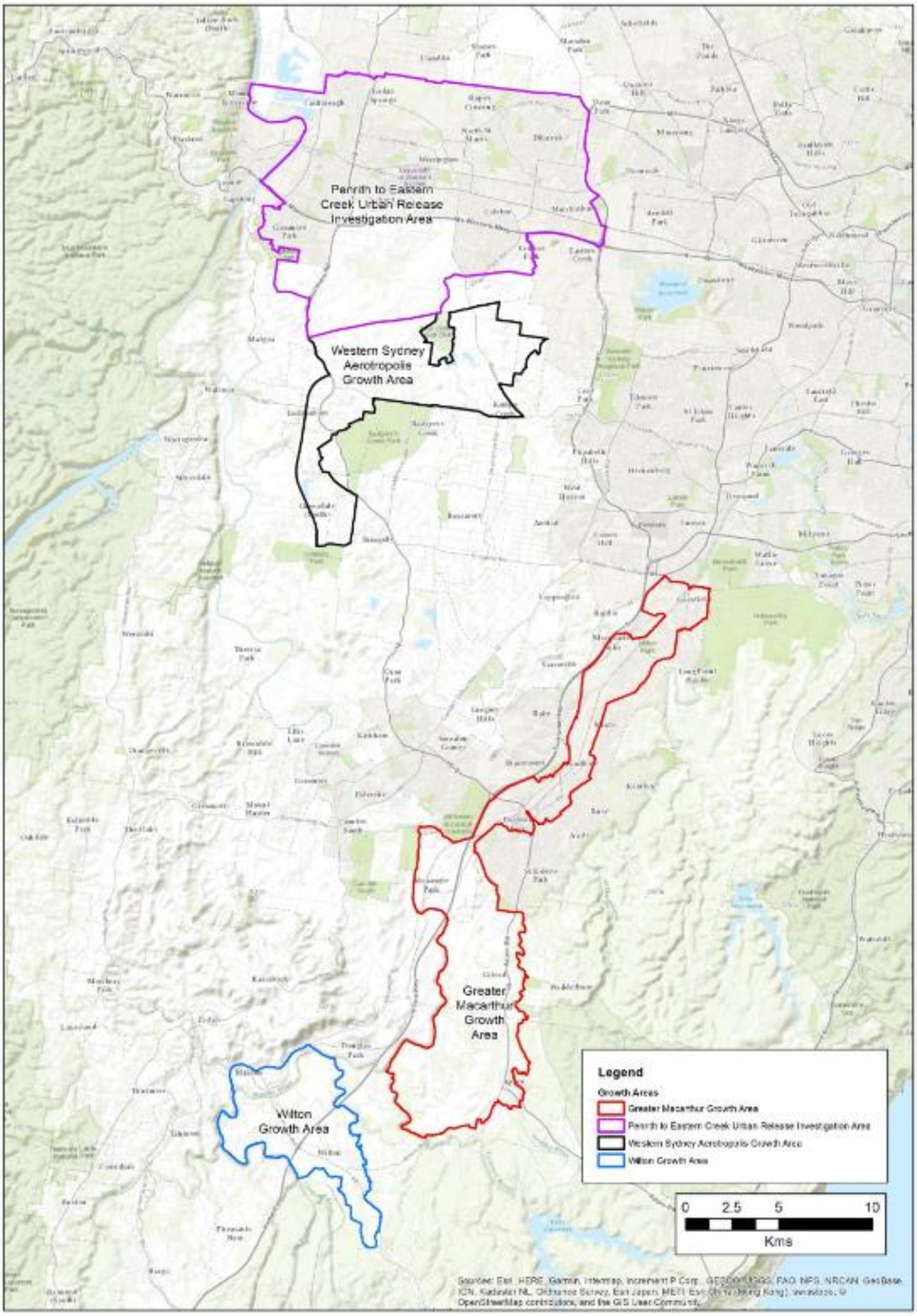
1.2 PROJECT CONTEXT

The NSW Government is planning for future urban development in Western Sydney. Four growth areas have been identified, these are Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These growth areas are all located within the Cumberland Subregion in version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) (2016).

As part of the planning for this future development, the Department of Planning and Environment (DPE) is preparing the Cumberland Plain Conservation Plan. This is a strategic regional assessment that will lead to the identification of preferred conservation outcomes for the Cumberland subregion.

1.3 STUDY AREA

The Map 1 shows the growth areas of Greater Penrith to Eastern Creek (GPEC) and Western Sydney Aerotropolis (WSA) which are the subject of this report, and the Greater Macarthur and Wilton growth areas which are the subject of a separate report.



Map 1: The four Western Sydney Growth Areas

Map source: NSW Department of Planning and Environment.

1.5 JUSTIFICATION FOR USE OF EXPERT REPORT

The BAM allows for situations where an expert report will be required to replace or complement survey effort at a development site. While there has been some field survey for the Strategic Biodiversity Certification assessment, the area covered by the proposed GPEC and WSA growth areas are extensive and there have been issues with gaining access to some of the private properties.

An expert report is required to assess potential impact to *Hibbertia fumana* for the following reasons:

Insufficient survey: A large extent of the identified growth areas could not be surveyed because it was on private property and could not be accessed within the project timeframe. Expertise was required to identify and survey potential species habitat and propose additional habitat based on extant and historic records.

Survey following extended drought conditions: Western Sydney has been experiencing dry to drought conditions for several years. Numerous usually resilient native trees and shrubs were observed to have experienced severe drought stress causing partial and/or full defoliation and many had died. Although unknown, it is likely that a large proportion of the *Hibbertia fumana* population could be reduced to the soil seed bank in these circumstances. As such, expertise is required to identify potential habitat for the species.

Compounding the effect of reduced soil moisture, following drought many areas have a significant increase in leaf, twig and branch drop making this small and cryptic species more difficult to locate or possibly covering them completely. The discernible population is likely to be significantly reduced from this cause.

Herbivory of a wide range of native species can severely impact small plants during dry conditions.

Rainfall events in months prior to this assessment allowed many *Hibbertia* species to produce new growth and therefore flowers. However, the rainfall was insufficient to replenish subsoil moisture. A dry period and unusually hot conditions prior to, and during, this assessment resulted in moisture stress for many plants. In the case of some *Hibbertia* species this is noticeable by unusually early petal dehiscence making their detection difficult.

It requires an expert in the species to locate and identify rare *Hibbertia* under these conditions.

Reliable species identification: Identification of the genus *Hibbertia* to species level requires examination of flower parts in combination with stem and leaf characters, especially tomentum type and density. It is not practical nor reliable to identify small leaved species in the field as many of these morphological features require microscopic examination and comparison to known voucher specimens. The use of an expert report to complement survey of the growth areas avoids the problems associated with *Hibbertia* misidentifications.

1.6 CREDENTIALS OF EXPERT

Robert Miller has over 30 years' experience in field botany. Over this time Robert has identified many rare and endangered plant species and has contributed to the scientific knowledge of native flora distribution and habitat in NSW.

Robert has been certified as an expert for *Hibbertia fumana* and *H. puberula* under the Biodiversity Assessment Methodology.

Robert has worked with Hellmut Toelken of the State Herbarium of South Australian, locating, collecting and identifying undescribed or rare species of *Hibbertia*. Some of these taxa were known only from historic records with non-precise locality details and depauperate or non-existent habitat information. Many of the specimens have been used for the taxonomic revision of the genus and are cited in various taxonomic publications including "Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*" published in the Journal of the Adelaide Botanic Gardens 26 (2013). Examples of the cited specimens include: *Hibbertia ericifolia* subsp. *acutifolia* Toelken, subsp. nov. Type: New South Wales, Sarahs Knob, R. & J. Miller s.n., 21.x.2006 (holo.: AD; iso.: BRI, CANB, NSW, PERTH) and *Hibbertia dispar* R.T.Miller s.n., 0.5 km S of Penrose Rest area, along western boundary track, Penrose State Forest, 12.x.2010 (AD, NSW).

Robert and Hellmut's paper "Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales", was published in the Journal of the Adelaide Botanic Gardens in 2012. The paper describes 13 new taxa including *Hibbertia fumana* Toelken and *Hibbertia puberula* subsp. *puberula,* – subsp. *extensa* R.T.Mill. and – subsp. *glabrescens* Toelken*.*

In 2017 Robert was called as an expert to identify the species of *Hibbertia* on the Moorebank bushland site that is the subject of the Intermodal development proposal.

Robert has recognised expertise for other threatened taxa including *Pomaderris adnata*, *Solanum celatum*, *Epacris purpurascens* var. *purpurascens*, and the genus *Prostanthera* including the threatened taxa *Prostanthera discolor*, *P. stricta*, *P. densa*, *P. junonis* and has provided expertise to the OEH Saving our Species programs.

2. Species information

2.1 SPECIES DESCRIPTION

Hibbertia fumana was described by Toelken and Miller (2012) in their paper "Notes on Hibbertia (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. Hemistemma, mainly from the central coast of New South Wales". At the time of publishing, the species was presumed extinct and had not yet been discovered at the Moorebank Intermodal site. The description was based on three herbarium specimens collected in 1802, 1804 and 1823.

The re-discovery of the species provided a broader range of specimens and a revised description which included for the first time fruit and seed, was provided by Duretto, Orme, Rodd, Stables and Toelken (2017). The following is a direct quote from that description.

Hibbertia fumana Sieber ex Toelken, Journal of the Adelaide Botanic Gardens 25: 73 (2012).

Type: Australia, near Sydney, "F.W. Sieber Nov. Holl. No. 147"

Decumbent shrublet, prostrate to weakly ascending to 20 cm high, with many branches from the base, moderately- to much-branched; branches wiry, with raised leaf bases shortly decurrent, shortly fascicled-pubescent. Vestiture persistent, consisting of more or less coarse simple hairs over fine fascicled hairs on tubercles; on branches more or less densely covered with short subequal multiangulate fascicled hairs (4–7 equal arms) and without simple hairs except for intrapetiolar tufts of hairs in leaf axils; on leaves above scattered, short antrorse fine bi- or triforked to simple hairs, sparse becoming denser onto the petiole, few simple hairs along the flanks, all wearing off soon; on leaves below dense, with short subequal multiangulate fascicled hairs (4–12 subequal arms) particularly on central vein, overtopped by few simple hairs on the flanks of the revolute margins; on outer calyx outside moderately dense, with spreading coarse antrorse simple hairs over erect-spreading multiangulate fascicled hairs (8–15 subequal arms), inside dense, with forked to simple antrorse hairs over most of surface; on inner calyx lobes outside dense with spreading multiangular fascicled hairs (2–12 subequal or unequal arms) becoming smaller towards the membranous margins, overtopped by coarse antrorse simple hairs along the central ridge, inside glabrous except for a few simple hairs towards the apex. Leaves with intrapetiolar axillary tuft of hairs to 0.7 mm long; petiole 0.2–0.45 mm long; lamina narrowly oblong, rarely linear-elliptic, (1.9–) 2.1–6.5 × 0.5–1.2 mm, obtuse, with terminal tuft of hairs on a somewhat recurved apex of the central vein, more or less abruptly constricted into petiole, above ± flat and puberulous to glabrescent, below with broadened central vein recessed below the level of revolute margins and protruding into apex, pubescent to puberulous. Flowers single, terminal, commonly on main branches; flower stalk 2–9 mm long, recurved and elongating after flowering, pubescent; bract linear to linear-triangular, 1–1.3 mm long, sometimes leaf-like to 5.5 mm long, fascicled-pubescent, on lower third to half of flower stalk. Calyx distinctly accrescent, with lobes subequally long; outer calyx lobes lanceolate, 3.5–5.7 × 1.3–1.65 mm, enlarging to 6.1 × 2.2 mm with fruit, acute to acuminate, without ridge, outside strigose-pubescent, inside finely strigose with antrorse forked hairs on much of the surface;

inner calyx lobes oblong-ovate, 4.0–5.8 × 3.1–3.5 mm, usually cuspidate, outside strigose along the central vein and tomentose towards the margins, inside glabrous with few forked hairs at the apex. Petals obovate, 4–5.2 mm long, broadly bilobed. Stamens 5 or 6 (7), subequal, clustered on one side of the ovaries; filaments 0.4–0.6 mm long, basally connate; anthers broadly oblong, 1.3–1.4 mm long, ± abruptly constricted above and below. Pistils 2; ovaries obovoid but ± laterally compressed, each with 4 ovules, fascicled-tomentose, with style attached to the centrifugal apex of the ovary then after a short curve downwards straightening up on either side of the stamens with stigmas exposed above the anthers. Fruit puberulous with simple and multiangular hairs. Seeds oblong-obovoid to almost obloid, 1.6–2.0 × 1.4–1.5 mm, smooth, light brown; aril with fleshy base surmounted by one-sided membranous cup covering c. one quarter of one side of seed.

Additional specimens examined: NEW SOUTH WALES: Central Coast: R.Brown [J.J.Bennett 4873], "In occidental Sydney 1804" (BM); G.Caley s.n., "near South Head", viii.1802 (BM); Moorebank in western Sydney, J.Rodd & M.Stables, 19.x.2016 (NSW, 3 specimens); Moorebank in western Sydney, A.E.Orme 1572, 16.xi.2016 (AD, NSW).

Figure 1 shows taxonomic features of *H. fumana*, and Figure 2 shows an image of the species isototype.

2.2 LIFE CYCLE

The NSW Threatened Species Scientific Committee Final Determination for listing of *Hibbertia fumana* states that "Little is known about the life history of *Hibbertia fumana*. Seed production and plants of different ages were recorded within the only known population (A. Orme in litt. November 2016). The species does sucker (A. Orme in litt. November 2016) suggesting it may be able to resprout from rootstock following fire."

Peak flowering is recorded as spring to early summer, although the species appears to be capable of minor sporadic flowering at other times of the year as a response to suitable climatic conditions (Miller pers. obs.).

2.3 DISTRIBUTION AND ABUNDANCE

Historically the species was collected by Caley "near South Heads", eastern Sydney, in 1802, by Robert Brown in 1804 "occidental Sydney" and by Sieber 1823 "near Sydney New Holland".

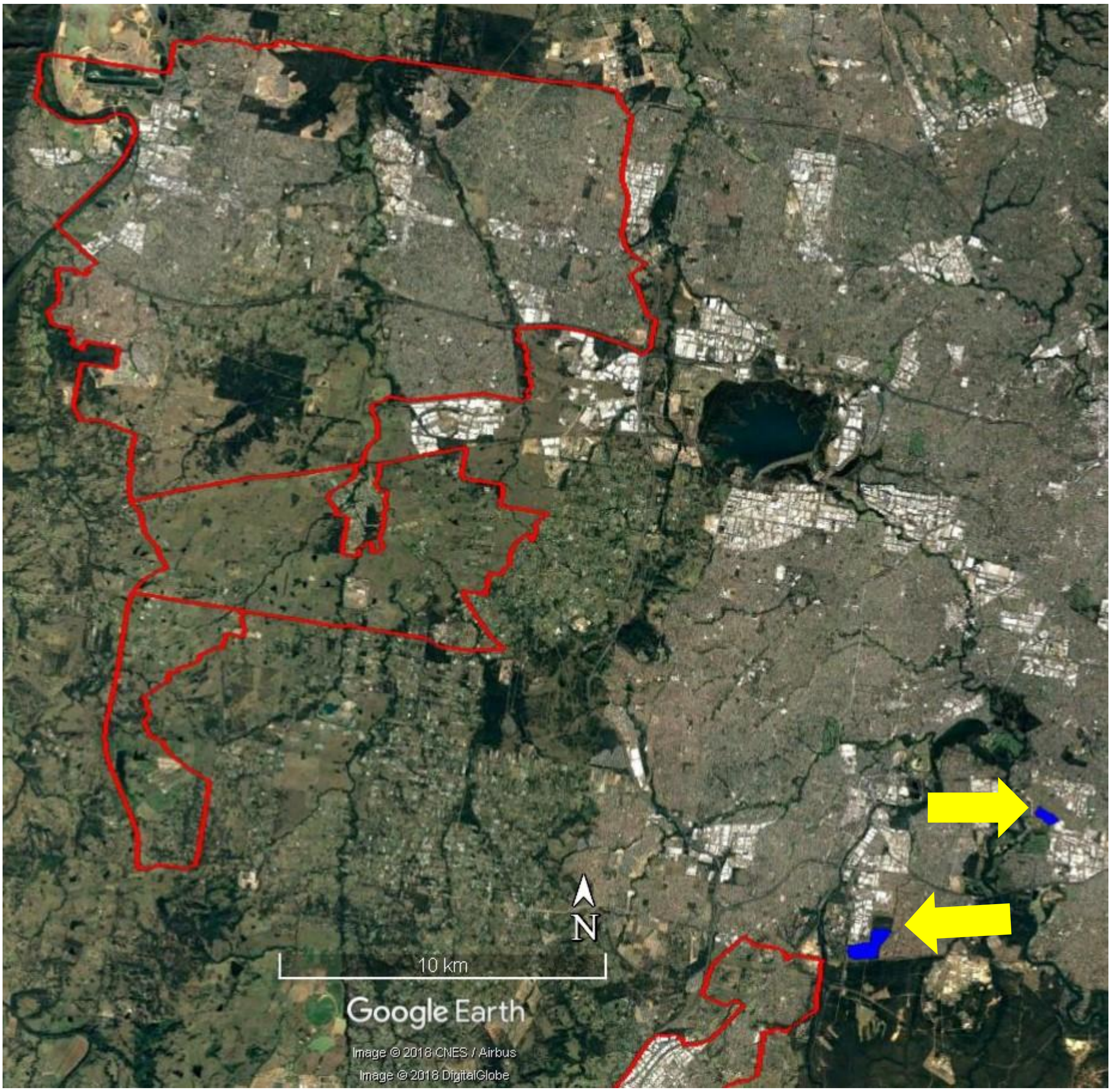
Recently a specimen from the Keith Ingram herbarium collection has been determined as most likely to be that species by Andrew Orme. It was collected at Connells Point in February 1941.

South Head and Connells Point are now highly urbanised environments and as such this diminutive species is unlikely to have persisted at either locale. If the species has persisted it is most likely so in the Connells Point environs. Targeted searches may be warranted in the Poulton Creek vicinity including Poulton Park.

Currently known from one extant population at Moorebank of c. 400 and an unknown number of plants in the Bankstown Airport vicinity.

At the time of the species listing in October-November 2016 (Arcadis and Parsons & Brinckerhoff Australia/New Zealand (WSP)) 370 plants were recorded at Moorebank and a further “approximately 29 plants” were recorded in September 2017 (Arcadis and Cumberland Ecology).

The impact upon the population at the Moorebank site from an intense fire in April 2018 is unknown.



Map 2: Indicative area of known *Hibbertia fumana* populations.

Key - Areas of known *H. fumana* populations (blue) and the Western Sydney growth areas (red).

Fig. 1. *Hibbertia fumana*. **a**, habit; **b**, branch; **c**, branch detail showing tufts of hairs in leaf axil; **d**, leaf, adaxial surface; **e**, leaf, abaxial surface; **f**, flower; **g**, flower, petals removed; **h**, inner sepal, abaxial surface; **i**, inner sepal, adaxial surface; **j**, outer sepal, abaxial surface; **k**, outer sepal, adaxial surface; **l**, flower with fruit; **m**, seed. Scale bar: **a** = 80 mm; **b** = 15 mm; **c** = 2.5 mm; **d & e** = 4 mm; **f** = 6 mm; **g & l** = 8 mm; **h–k** = 5 mm; **m** = 3 mm. Drawn from *Orme 1572*.

Figure 1: *Hibbertia fumana* Lesley Elkan in *Telopea* 20: 143–146

Figure 2: Isotype of *Hibbertia fumana.*

F.W Sieber held within the William and Lynda Steere Herbarium as digitised imagery in the C. V. Starr Virtual Herbarium New York Botanic Gardens showing apparent +/- sessile flower buds.

2.4 HABITAT REQUIREMENTS

<u>Historic collections</u>

The *Hibbertia fumana* profile states: “Habitat of an 1802 Caley collection 'near South Head' are uncertain, with potential communities in that area including coastal shale sandstone communities and open forest or forest communities on lateritised shale lenses. No similar alluvial sand deposits are identified in that area.” (OEH 2018)

It is speculated by Miller that the most likely habitat for the Caley collection is transitional vegetation associated with “Swamps” or wet heath, especially the transition from shale influence communities to heath and/or open woodland. Although unsuitable habitat now, the Woollarah Golf Course site is likely to have consisted of a mosaic of vegetation types including swamp transition to woodland and the original habitat at Centennial Park is well documented “Originally a swamp and then set aside as land for the water source for Sydney, Centennial Park” (Centennial Park Trust). The diverse micro-habitats at Centennial Park supported numerous now locally rare or endangered taxa including *Hibbertia virgata* E.Cheel *NSW 86014*, Centennial Park, ix.1900 (NSW); and A.A.Hamilton *NSW 86016*, Centennial Park, 23.viii.1912 (AD, NSW) (Toelken in prep.) and it is likely to have also supported *Hibbertia fumana*.

<u>Extant populations</u>

The OEH website states that *Hibbertia fumana* is known to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation) - within the Cumberland Dry Sclerophyll Forests class *Hibbertia fumana* is associated with

- Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain and Sydney Basin Bioregion and
- Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion

Dry sclerophyll forests (shrubby sub-formation) - the Vegetation Types that *Hibbertia fumana* is associated within the Sydney Sand Flats Dry Sclerophyll Forests class include

- Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion and
- Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion

At Bankstown Airport the AVH record states that the “Site is heavily managed and is routinely slashed to a height of about 10cm. Soils are grey heavy clay with ironstone fragments present at surface. Other native species observed indicate a derived form of Cooks River / Castlereagh Ironbark forest community. Main weed observed *Eragrostis curvula*.”

Photo 1: Indicative habitat of *Hibbertia fumana* at Bankstown Airport, regularly slashed.

At the Moorebank site the species is found growing in the transition zone between Castlereagh Ironbark Forest and Castlereagh Scribbly Gum woodland in open forest of *Eucalyptus sideroxylon, E. fibrosa, E. parramattensis, E. sclerophylla* and *Melaleuca decora* with a diverse understorey of shrubs including *Hakea sericea, Callistemon linearis, Bursaria spinosa, Grevillea parviflora* subsp. *parviflora, Acacia brownii, Acacia bynoeana, Pultenaea retusa, Pultenaea villosa, Hibbertia puberula* subsp. *puberula* and *H. aspera* subsp. *aspera*. The herb/grass layer is dominated by *Goodenia hederacea, Dianella revoluta, Thysanotus, Gonocarpus, Poa, Stylidium graminifolium, Patersonia, Themeda, Diuris* and *Microtis* (Telopea 2017).

Prior to the recent fire, the density of the understorey was variable across the site and ranged from sparse to extremely dense especially within the long-unburnt sections of the Castlereagh Scribbly Gum woodland. The variation in density is presumed to be due to the fire history, localised clearance events including recent remediation works, as well as minor changes in topography and drainage especially in swales.

In general, the topography of the land is described as flat although this is disrupted by the passage of Anzac Creek and by numerous minor depressions or swales likely to be remnants of past creek alignments and/or overflow channels that support Castlereagh Swamp Woodland. These swales and minor excavations / scrapings form small ephemeral pondages.

From limited brief inspections *Hibbertia fumana* was observed to be of sporadic occurrence across the site and appeared to be absent from ephemeral pondage locales preferring open slightly higher ground. Soils are described as fine sandy clay loam, grey brown in colour.

2.5 ANTHROPOGENIC THREATS TO THE HABITAT

Threats to the habitat of *Hibbertia fumana* that are relevant to sites within or adjacent to urban development include:

- Loss of existing habitats across the growth areas may occur for as-yet-missed unrecorded populations of the species.
- Development of the adjacent lands at Moorebank for a major transport hub may affect the plants, and there is a rarely-used railway line bisecting the site. At Bankstown airport infrastructure development could impact the population.
- Fire either too frequently (limiting recruitment) or too rarely (allowing midstorey thickening) are likely to impact the species.
- Clearing for fire protection zones and infrastructure works could remove habitat.
- Damage to habitat by trail biking, 4WDs, mountain bikes and rubbish dumping.
- High densities of weeds and invasive grasses occur at the top of ridgelines; there is significant potential for encroachment into areas of potential habitat.
- A number of weeds are likely to impact on the plant, with particular concern for low shrubs, dense shrubs and smothering grasses.
- Changes to hydrological processes can impact habitat by reducing subsoil infiltration, drying out seepages, or concentrating flow paths through habitat.
- Nutrification can increase weed potential.
- Road maintenance and slashing works can destroy habitat.

Field inspection of bushland remnants in the heavily urbanised sectors of GPEC growth area provide irrefutable proof of severe degradation caused by anthropogenic impacts and urbanisation (refer photos 2 through 6). Many of the remnants were heavily weed infested arising from a range of factors not limited to nutrification, stormwater discharge, garden refuse and fill dumping and exotic seed dispersal by various vectors.

Damage to zones adjacent urban development are often caused by clearing for fire hazard reduction, frequent control burning, and recreation activities.

Hibbertia fumana is a small shrub that would not survive in bushland that is heavily weed infested, or that is severely burnt on a regular basis. Fencing and on-going maintenance of the fencing around bushland remnants might reduce the severity of some of these impacts.

Photo 2: Indiscriminate access and rubbish dumping threatens the biological integrity of the former Air Services Australia Site.

Photo 3: Garden refuse dumped on top of the endangered species *Pultenaea parvifolia*.

Photo 4: Rubbish dumping in Castlereagh Nature Reserve.

Photo 5: Clearance of understorey for asset protection zones.

Photo 6: Dirt bike tracks and weed invasion in bushland adjacent housing at Shalvey.

3. Description of the study area

3.1 LAND USE HISTORY

The Cumberland Plain was first occupied by the Aboriginal peoples, who enjoyed a plentiful supply of fresh water and foods including fruit, tubers, fish, animals, birds and honey (Hills District Council website).

With the arrival of Europeans, land-use changed to timber gathering and agriculture, permanently altering the landscape. Particularly since the end of the Second World War urban settlement and industry have expanded west from Sydney into the Cumberland subregion. Over the last 40 years many rural properties have been subdivided as lifestyle and hobby farm properties.

Currently there is great pressure for further residential development to the west of Sydney in the Cumberland subregion.

3.2 LANDSCAPE CONTEXT

The changes in land use have caused the clearing of a large proportion of the natural bushland of the Cumberland subregion. In 2011 the Cumberland Plain Recovery Plan stated "Only 13% of the pre-1750 extent of the region's vegetation remains as intact bushland, with an additional 12% occurring as scattered trees in disturbed areas (NPWS 2002). Consequently, much of the region's biodiversity is listed as threatened under State and/or Commonwealth legislation."

Widespread clearing of the remaining habitat has continued with much of the extant vegetation now being assessed as Critically Endangered. Previously recorded from South Head and Western Sydney, *Hibbertia fumana* appears to have suffered a reduction in range caused by urbanisation.

3.3 NATIVE VEGETATION

Since 2011 there has been further clearing, there are now 15 vegetation communities that are listed as Critically Endangered, Endangered or Vulnerable in the Cumberland Plain.

The Cumberland Plain Recovery Plan states that "there are seven threatened species, four endangered populations and nine threatened ecological communities listed on the NSW *Threatened Species Conservation Act* 1995 that are found only on the Cumberland Plain. Seven of these are also listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999." The remaining bushland is highly fragmented and much of it occurs on private lands.

Within the GPEC and the WSA nineteen Plant Community Types (PCTs) are mapped (mapping provided by the NSW Department of Planning and Environment). These PCTs are:

- 724 - Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion

- 725 - Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion
- 774 – Coast Banksia scrub on sand in the Elderslie area, Sydney Basin Bioregion
- 781 - Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion
- 806 - Derived grasslands on shale hills of the Cumberland Plain (50-300m asl)
- 807 – Derived grasslands on shale plains of the Cumberland Plain (<100m asl)
- 808 – Derived shrubland on Tertiary Gravels of the Cumberland Plain
- 830 - Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849 - Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- 850 - Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 877 - Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883 - Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1067 - Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion
- 1081 - Red Bloodwood – Grey Gum woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1105 – River oak open forest of major streams, Sydney Basin Bioregion and SE Corner Bioregion
- 1181 - Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion
- 1253 – Sydney Peppermint – White Stringybark – Smooth Barked Apple Forest on shale outcrops, Sydney Basin Bioregion
- 1292 – Water Gum – Coachwood Riparian Scrub along sandstone streams, Sydney Basin Bioregion
- 1395 - Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1800 - Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley

3.4 POTENTIAL HABITAT

Within the Sydney Basin Bioregion *Hibbertia fumana* is known from the IBRA subregion of Cumberland and is predicted to occur in the Pittwater IBRA sub-region (OEH website 2018). No geographic constraints are currently listed for the species. The subregions of known and predicted occurrence are shown in Map 3. The areas shown in pink and purple are the sub-regions where the species or community is known or predicted to occur. They may not occur throughout the sub-region but may be restricted to certain areas.

The OEH species profile sheet states: "found in the transition zone between Castlereagh Ironbark Forest and Castlereagh Scribbly Gum woodland in open forest of *Eucalyptus sideroxylon, E. fibrosa, E. parramattensis, E. sclerophylla*". The species has the potential to occur in similar intergrade alluvial habitats rich in sands and laterite in other parts of western Sydney.

Hibbertia fumana is currently known only from two locations in western Sydney. A single population at Moorebank and a single population in Bankstown (AVH record) but has the potential to occur elsewhere in greater Sydney.

At Moorebank it is found in areas of open woodland in a long intergrade between Castlereagh Scribbly Gum Woodland and Castlereagh Ironbark Forest. The AVH record for *Hibbertia fumana* at Bankstown records "Site is heavily managed and is routinely slashed to a height of about 10cm. Soils are grey heavy clay with ironstone fragments present at surface. Other native species observed indicate a derived form of Cooks River / Castlereagh Ironbark forest community."

Map 3: Known and predicted distribution of *Hibbertia fumana*.

Source OEH website 2018.

The habitat of an 1802 Caley collection 'near South Head' is uncertain, with potential communities in that area including coastal shale sandstone communities and open forest or forest communities on lateritised shale lenses. No similar alluvial sand deposits are identified in that area.

Hibbertia fumana has the potential to occur within the Greater Penrith to Eastern Creek and Western Sydney Aerotropolis Growth Areas in the following PCTs and in transition zones between these PCTs:

- PCT 724 - Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion
- PCT 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion
- PCT 808 – Derived shrubland on Tertiary Gravels of the Cumberland Plain
- PCT 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain
- PCT 1067 - Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion

Biosis has mapped PCTs 883, 725, and 724 as occurring within the Wianamatta Regional Park/ Ropes Crossing areas and PCTs 725, 724 and 1067 as occurring within the Kemps Creek area.

4. Assessment of species presence and suitable habitat

4.1 EXISTING RECORDS AND SURVEYS

Hibbertia fumana is assessed as site managed. There is limited data on the life history and ecology of the species. There are no records of the species within or adjoining the proposed growth areas. Only two known extant populations exist, at Moorebank approximately 14 km to the south-east of the southern boundary of WSA, and Bankstown Airport 17 km from the southern boundary of WSA.

Private land holdings comprise much of the area within the GPEC and WSA, restricting access opportunities for botanical surveys and incidental sightings. This is a likely contributing reason for the lack of prior records of threatened *Hibbertia* species, possibly including *Hibbertia fumana,* within the proposed growth areas.

There has been just a short period in which the species would have been formally considered in the assessment process as the species was thought to be extinct when described in 2012 and was only recently rediscovered in late 2016.

Even now, it would be likely that the species would not be adequately considered within many assessments as such species are frequently dismissed with statements of “unlikely, no suitable habit present” or “only known from one population” and therefore no targeted searches would be undertaken. As *Hibbertia fumana* was originally misidentified and therefore dismissed at

Moorebank as a common species it is possible this may have occurred at other locales. It was therefore deemed appropriate to consider the possibility of *Hibbertia fumana* being recorded in the data records as another entity. Species of *Hibbertia* with which it might have been confused are discussed in detail in Section 4.3.2.

<u>Potentially misidentified *Hibbertia* within database records</u>

Searches of databases revealed records of *Hibbertia riparia* at a number of locales within and adjacent to the growth areas. The name *Hibbertia riparia* is considered by Toelken to be misapplied to NSW taxa. Prior to the updated taxonomy a number of undescribed species were included within the name *Hibbertia riparia* then considered to be “a variable species complex”.

As *Hibbertia fumana* has its stamens on one side of the ovaries it is possible that it may have been captured within the then *H*. *riparia* variable concept. To illustrate this point, Miller has observed that *Hibbertia puberula* is frequently still misidentified as *Hibbertia riparia*.

Reviewing the data set it also became apparent that there were a number of records for *Hibbertia serpyllifolia* in the general Western Sydney area. Recent taxonomic work (Toelken 2013) investigating “The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*”, has identified that the name *Hibbertia serpyllifolia* is misapplied to NSW. The species concept is now considered to be confined to coastal forests of mid-northern Queensland. All records from other states are now recognised as new taxa e.g. *Hibbertia ericifolia* group or misidentifications of existing taxa.

As *Hibbertia* are notoriously difficult to identify, and more so if not in flower, it is not surprising to find records of *Hibbertia* sp. within the data set.

The Western Sydney Urban Bushland Biodiversity Survey 1997 undertook the first comprehensive survey of the biota across the region including bushland remnants within the GPEC and WSA area. Although the taxonomy of *Hibbertia* has changed significantly since that time, the records of *Hibbertia* contained within provide additional insight into the potential occurrences of threatened *Hibbertia* species.

The Straede T.M. 1990 “Vegetation of the proposed Londonderry Waste Disposal Site” report for Waste Management Authority, Sydney found *Hibbertia cistiflora* in the Castlereagh – Londonderry Crown Lands. It is unknown if this species occurs in the area or is a misidentification. Like *Hibbertia fumana, H*. *cistiflora* also has its anthers to one side of the ovaries.

The current survey was limited in extent and did not visit the area of the Straede survey which is outside the growth area. The surveys conducted by CFFIS did not locate any specimens of *Hibbertia cistiflora*. There are no other records in the district and most vouchered records in the Sydney Metropolitan area occur north of the Harbour and are associated with sandstone ridges often in proximity to shale caps and Sandstone Shale Transition Forest associations.

It is noted in Toelken & Miller 2012 that subsp. *quadristaminea* is "often wrongly identified in herbaria as *H. serpyllifolia*, but subsp. *quadristaminea* has few stamens only in one dorsal cluster" c.f. *Hibbertia ericifolia* (*H. serpyllifolia* misapplied) possessing usually 8-16 but up to 30 stamens, dependant on the subspecies surrounding and obscuring the ovaries. This highlights that even herbaria have mis-assigned *Hibbertia* specimens. The fact that *H. cistiflora* has its anthers on one side of the ovaries opens the slight possibility that the Straede record could be what is now *Hibbertia fumana*, however it is most likely to be *H. puberula*. It is possible that Straede had another taxon from within the then *H. riparia* variable species complex previously identified, thereby determining it to be *H. cistiflora*. There is also a *Hibbertia riparia* record from the adjacent Castlereagh Nature Reserve which we have determined to be most likely *Hibbertia puberula* as the current CFFIS survey recorded *Hibbertia puberula* within the Nature Reserve.

It is unknown if the *Hibbertia serpyllifolia* UBBS Site (P1) Londonderry – Castlereagh Crown survey by R.S. Lembit & T.A. James - woodland south of Devlin Road & NW end of Nutt Road record was based on field identification of fertile or infertile material. If it was based on fertile material it is most likely to be an unverified record of *Hibbertia ericifolia* group. If it was based on infertile material it is most likely to be *Hibbertia puberula* or possibly *H. fumana.* CFFIS has recorded *Hibbertia puberula* in this vicinity.

Hibbertia pedunculata recorded at Mulgoa (Blue Mountains NP Sydney Sandstone complex) Coveny, R. 1976 – 95 Species lists for Mulgoa (off Fairlight Road – Nepean River) Blue Mountains NP is likely to be that species, however there is a possibility that it could also be potentially be *H. fumana* or *H. puberula* if the Coveny observation was based on field identification of infertile material.

4.2 SURVEYS COMPLETED FOR THE BIOCERTIFICATION

From the information provided, no prior targeted searches have been undertaken for this species as part of the biodiversity certification assessment process.

Surveys undertaken by Ecoplanning and Biosis consultancies since 2017 have largely been confined to the deemed "development footprint" and appear to have been undertaken predominantly to comply with the BAM protocols for vegetation sampling for assessment purposes with little survey for threatened species. As such, no new occurrences of threatened *Hibbertia* species including *Hibbertia fumana* were recorded by Biosis or Ecoplanning through their survey efforts.

Access to a spatial viewer was provided by DPE to assist in the expert assessment. Whilst this tool has been useful in gaining a general overview, the information presented is limited and is acknowledged to "have been acquired and developed from numerous sources of differing dates, accuracy and completeness and may include errors in extent and content". CFFIS are not aware of any surveys performed specifically for *Hibbertia fumana* by DPE, Ecoplanning or Biosis Consultancies. The broadscale vegetation mapping of PCTs that was provided to assist with this assessment cannot identify the habitat niches that may be present on a localised scale.

The level of data available is insufficient to base an assessment of presence/absence for a Critically Endangered species purely as a desktop study.

4.3 SURVEYS COMPLETED FOR THIS ASSESSMENT

Surveys for the biodiversity assessment informing the development of the biodiversity certification were constrained by private lands access issues, time and the overall size of the biodiversity certification area.

4.3.1 SURVEY METHODS

The surveys undertaken by Miller as part of this expert report relied on assessment of known habitat traits of extant sites and, although highly speculative, inferred habitat traits from historic records. PCT mapping and aerial digitised photography were used to select potential habitat areas for targeted surveys. Priority was given to finding the same habitat as occurs at the Moorebank and Bankstown Airport sites, although a variety of vegetation associations that are known habitat of other *Hibbertia* species such as *H. puberula* were surveyed to include inferred habitat from historic records. *Hibbertia puberula* co-occurs with *H. fumana* at the Moorebank site and grows nearby to *H. fumana* site at Bankstown Airport.

Biological data sets were searched for records of *Hibbertia fumana* within the study area. The BioNet and ALA searches failed to find any records of the species in the growth areas. Searches included Urban Bushland Biodiversity Survey of Western Sydney (UBBS) NPWS 1997. *Hibbertia* species are notoriously mis-identified, and as the species was described in 2012 any records prior to that time would be under a different name. Searches were made of all *Hibbertia* records within and adjacent to the growth areas to ascertain if any misidentifications might be included in the data set.

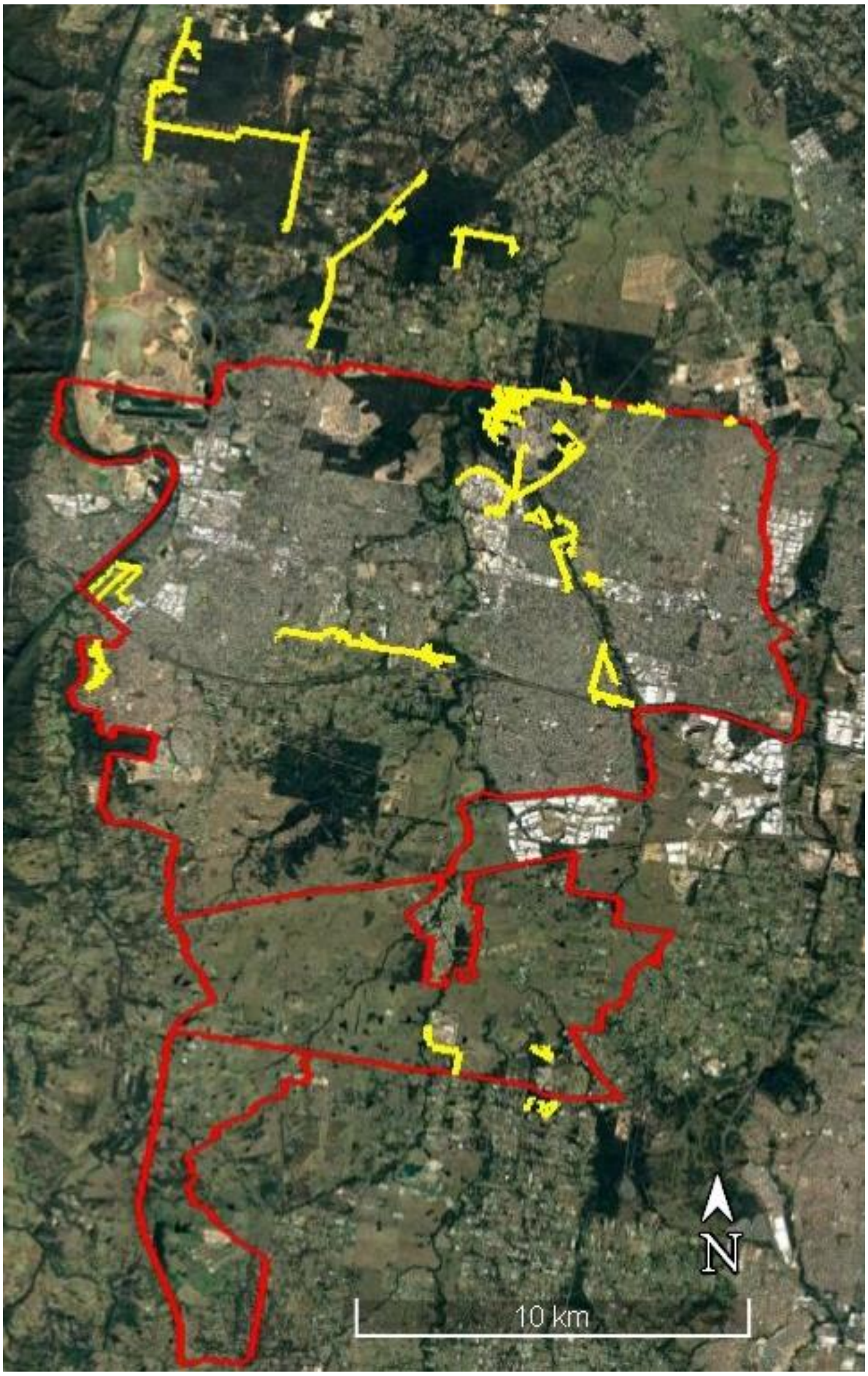
Records of *Hibbertia pedunculata*, *Hibbertia* sp., *Hibbertia* sp. A, *Hibbertia serpyllifolia* and *Hibbertia riparia* were included within the target survey effort where practical and where access had been granted. The large number of entries for *Hibbertia aspera* precluded visiting all known sites.

Searches were also made for indicative co-occurring species other than *Hibbertia* such as *Grevillea parviflora* subsp. *parviflora* to further refine the survey effort.

The prolonged rainfall deficient / drought period prior the survey effort posed significant challenges to the survey. Areas were targeted such as powerline easements where competition for moisture from large trees and shrubs was reduced and the targeted flora may have had greater chance of persisting through the dry period. This strategy was significant in locating one threatened *Hibbertia* adjoining Wianamatta Regional Park, namely *H. puberula*.

The greatest impediment to locating *Hibbertia* species during the survey was early petal drop of some species, thought to be increased due to the dry period and unusually high temperatures. This was most evident on 2nd November where petal drop of *Hibbertia puberula* had commenced before 8.30am (temperature of 30) and was complete by 9.30 am (temperature 32). As such, survey needed to start early in the day. There is no data available for the daily length of flowering times for *Hibbertia fumana*. Casual observations are not possible as access to known sites is restricted.

Map 4 shows the sites that were surveyed for this assessment, using targeted survey, random meander and in some locations of very low probability, drive past.



Map 4: Google Earth image of GPEC and WSA Growth Areas showing the tracks of CFFIS survey.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow.

4.3.2 SPECIES IDENTIFICATION

If a small-leaved *Hibbertia* was located that had macro morphological features resembling that of *Hibbertia fumana* then a specimen would be retained for later microscopic examination. CFFIS has also assessed the likelihood of *Hibbertia puberula* to occur in the GPEC and the WSA. *Hibbertia puberula* co-occurs with *H. fumana* at Moorebank and as both species are small-leaved, diminutive plants it is possible to misidentify *H. fumana* as *H. puberula* or other small-leaved species without careful examination (refer Photo 7). Selected specimens taken as part of the *Hibbertia puberula* assessment were microscopically examined to ensure that *Hibbertia fumana* was not inadvertently collected and dismissed as *Hibbertia puberula* or another small-leaved species. Due to the prevailing drought conditions plants were depauperate, such that any specimens removed consisted of very small fragments (eco-scraps) most only a few cm in length.

Figure 3 drawing depicts *Hibbertia fumana* in bud where those buds appear +/- sessile. During the Moorebank surveys it was purported by a consultant that pedunculate flowers are a key field identification tool even in bud. This is clearly erroneous and should not be used as the sole identifying feature (refer also to photo on the front cover, R.T. Miller and photo of the Isotype in Figure 2).

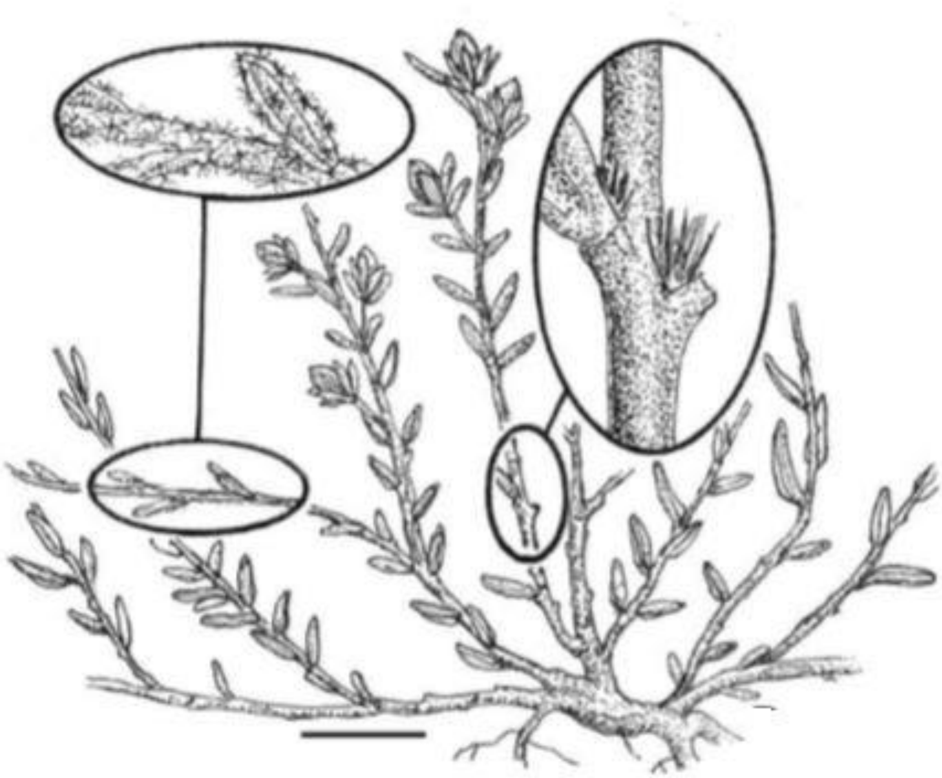


Figure 3: Stem and leaf characteristics of a flowering *Hibbertia fumana* specimen.

F.W. Sieber 147 (MEL 3111616) (Toelken and Miller 2012)

Peduncle elongation is clearly related to and is proportional to the developmental progression from buds to seed formation. Anecdotal observation by Miller suggests peduncle development is also related to environmental conditions such as moisture content of the soil and degree of exposure, for example, extended periods of low soil moisture and /or in combination with exposure appears to reduce peduncle length.

The species profile for *Hibbertia fumana* identifies some of the *Hibbertia* species with which it might be confused: "species with which it may be confused include *Hibbertia aspera* (peduncle of *H. fumana* is shorter, especially in flower, the foliage is more persistently hairy, and there are fewer stamens), *H. empetrifolia* (*H. fumana* is much more prominently stellate-hairy) and *H. riparia* (*H. fumana* has much shorter leaves). *Hibbertia superans* is another possible species for confusion, though *H. fumana* has smaller leaves" (OEH 2018).

It is unlikely that an expert would misidentify large / mature flowering plants of the above species with *Hibbertia fumana*. Confusion / unreliability is likely to arise if a population census is undertaken outside of optimal flowering time and/or the survey site is recovering from fire when a high proportion of the plants will be small and immature, or if depauperate in drought conditions.

There are several other small leaved diminutive Hibbertias that could be confused including *Hibbertia dispar*, *H. pedunculata*, *H. calycina* s.str. and other undescribed taxa.

Relying solely on stem and leaf characteristics in field survey can lead to mis-identification. *Hibbertia fumana*, *H*. *aspera* and *H*. *empetrifolia* have discolorous leaves and using this character alone on non-flowering specimens without a high-resolution microscopic examination could result in dismissing or mis-identifying a plant to be *H*. *fumana*. The discoloration of the under surface of the leaves in both *Hibbertia fumana* and *H*. *aspera* is due to the presence of a usually dense white/silvery tomentum whilst the leaf under surface of *H*. *empetrifolia* lacks dense tomentum but it is of a similar whitish coloration.

Apparent tomentum density and type on the stems and leaves will vary according to the section of branchlet examined and the prior climatic conditions. New growth is likely to have a higher density and a fuller range of hair types present whereas on older growth much of this tomentum will have "worn off" (Toelken), especially the longer simple hairs. Drought condition will see a marked reduction in new growth. *Hibbertia aspera*, like *H. empetrifolia*, shows much variation in different local populations as well as sometimes on the same plant (Toelken).

Hibbertia pedunculata was commonly encountered within suitable habitat. This floriferous species is readily identified in the field provided its flowers are open. It has normally (14-) 18-35 (-43) stamens surrounding the carpels c.f. *H. fumana* which has 5 or 6 (7), subequal stamens, clustered on one side of the ovaries. *Hibbertia fumana* could readily be overlooked as impoverished plants of *H. pedunculata* after petal drop or if surveyed outside the flowering season.

Hibbertia aspera was observed occasionally within potentially suitable habitat for *Hibbertia fumana* during the CFFIS survey but was noted in greater frequency within areas deemed unsuitable habitat such as Shale Plains Woodland.

Microscope photographs of *Hibbertia fumana* characteristic features used for identification during this survey by CFFIS are provided in Appendix 2, and Appendix 3 shows comparison photos of characteristics of *Hibbertia aspera*, *H. dispar, H*. *empetrifolia* and *H*. *pedunculata*.

Photo 7: Five species of Hibbertia, photo taken 30cm above specimens, but which one is which?

Key - A: *Hibbertia fumana* (Moorebank), B: *H. pedunculata* (Wianamatta Regional Park), C: *H. empetrifolia* D: *H. puberula* (Powerline easement), and E: *H*. *aspera* (Wianamatta Regional Park).

4.3.3 SURVEY ASSUMPTIONS

It was not possible to access and survey all the many bushland remnants within the Greater Penrith and Western Sydney Aerotropolis growth areas. As such, the first assumption was:

Assumption 1. *Hibbertia fumana* would not be found growing in bushland that is unlikely to be suitable habitat.

The author is familiar with the species type of habitat at the Moorebank Intermodal and Bankstown sites. Using this knowledge of geology, soil and vegetation type that is the known habitat of the species, areas of bushland that would not be suitable habitat were ruled out of the assessment.

Using this knowledge of habitat requirement, the second assumption was:

Assumption 2. *Hibbertia fumana* is likely to be present in areas that are known to be suitable habitat. While surveys in suitable PCTs since the species was described in 2012 have failed to find *H. fumana*, this is a cryptic plant and the precautionary principal should be applied to the potential for the species to occur in suitable habitat.

The survey was carried out following several years of drought in western Sydney, and many shrubs forbs and grasses were dead. This led to the third assumption:

Assumption 3. In areas of suitable habitat, where *Hibbertia fumana* specimens have not been found, the species could be present in the soil seed bank.

4.3.4 *HIBBERTIA* RECORDED BY THIS SURVEY

Six species of Hibbertia were observed whilst undertaking surveys for this report. They are:

Hibbertia puberula: This species is the subject of a separate report (Strategic assessment for Cumberland Plain Conservation Plan, Aerotropolis and Greater Penrith, *Hibbertia puberula* species group, R. Miller 2018).

Hibbertia pedunculata: Very significant populations of this species were observed in the GPEC within and outside the biodiversity certification areas in the Wianamatta Regional Park, also to the north in the former Air Services Australia Site adjoining the north of the GPEC.

Hibbertia diffusa: Widespread, sometimes locally common inside and outside growth areas. Most commonly observed on shale derived or influenced substrates including river-flat forests.

Hibbertia aspera: Widespread, sometimes locally common inside and outside growth areas. Most commonly observed on shale derived or influenced substrates.

Hibbertia acicularis: Noted in two areas outside the growth areas, at Agnes Banks Nature Reserve and Gulguer Nature Reserve.

Hibbertia fasciculata: Noted in one area outside the growth areas in Agnes Banks Nature Reserve, in Scribbly Gum Woodland.

It is a recommendation of this study that *Hibbertia pedunculata* be listed as a Threatened species or an Endangered Population, and taken into consideration as part of this biodiversity certification process.

Toelken (2013) in his revision of the *Hibbertia vestita* group, including *H. pedunculata* and *H. serpyllifolia*, considers *H. pedunculata* to be confined to NSW. Analysis of the cited specimens reveals that the species has two main areas of distribution the Greater Sydney Metro Area and the lower Hunter.

In the Greater Sydney Metropolitan area, the species has suffered a significant reduction in numbers and extant distribution due to urbanisation. Two cited locales occur within the growth area at St Mary's. The Greater St Mary's – Shane Park vicinity is now the only general vicinity that has long term viable habitat remaining for the species, that is, Wianamatta Regional Park including areas within the former ADI site not gazetted and the Former Air Services Australia site.

Of the twenty specimens cited in the Greater Sydney area six only are known to have extant populations, however all are under severe threat due to small population size and anthropogenic impacts. Nine populations are known or highly likely to be extinct.

4.3.5 INCIDENTAL SIGHTINGS OF SIGNIFICANT FLORA DURING THIS SURVEY

The bushland remnants surveyed were observed to support numerous threatened species including but not limited to *Hibbertia puberula*, *Persoonia nutans*, *Pultenaea parviflora*, *Dillwynia tenuifolia*, *Micromyrtus minutiflora* and *Grevillea juniperina*.

Photo 8: Habitat of threatened species recorded by this survey at Kemps Creek.

4.4 ASSESSMENT OF SPECIES PRESENCE

The previous survey data provided by Biosis and Ecoplanning Consultants was insufficient to assess the probability of occurrence of *Hibbertia fumana* from a desk top study. The species has demonstrated an ability to persist within suitable derived habitat, it was therefore appropriate to undertake specific targeted surveys.

A selection of areas mapped as suitable PCTs for *Hibbertia fumana* habitat were surveyed by CFFIS for the assessment. Areas of potential habitat identified as occurring within or adjacent to the biodiversity certification footprint were prioritised. We also surveyed for habitat appropriate to the species in small areas of potential tertiary sediments across the growth areas and adjacent lands, based on geology, soils and landform maps where access was provided.

4.4.1 LIKELIHOOD OF SPECIES PRESENCE

No specimens of *Hibbertia fumana* were observed whilst undertaking surveys for this report.

Non-detection should not be interpreted as the species not being present, but simply as not seen.

The population numbers of ground layer species at many locales were observed to be depauperate in areas of +/- intact canopy cover. A thick layer of detritus was noted to be suppressing the understorey in many places and particularly so if the site had a long fire interval. This was especially apparent within Wianamatta Regional Park and surrounds, including most of the area under the proposed urban footprint.

Similarly, the bushland remnant to the south of Elizabeth Drive, bounded by Western Avenue, and Cross Street, outside the growth area but used as a surrogate site, had significantly suppressed understorey. This included areas where known threatened species had been observed by Miller previously. Species such as *Grevillea parviflora* and *Dillwynia tenuifolia* had a significant retraction in apparent population numbers at that site.

Hibbertia fumana is known only from very few extant and historic records, this data suggests that *H. fumana* may have a very restricted distribution. The species is known only from a narrow band stretching from South Head, Connell's Point, Condell Park to Moorebank.

It is unknown, however, whether factors such as:

- the species only recently being described,
- being extremely cryptic,
- being easily misidentified and/or overlooked as a depauperate version of other species

may have resulted in populations being overlooked by past surveys.

The presence of this species cannot be dismissed on disturbance factors as the Bankstown Airport population survives in a highly modified environment. Bannerman and Hazelton (1990) in *Soil Landscapes of the Penrith 1:100,000 Sheet* map the entire site as disturbed terrain, although field observation by Miller and others have identified areas to retain the original soil profile. Areas of derived habitat have therefore the same probability of occurrence provided the soil profile is intact and anthropogenic factors have not irreversible change the soil chemistry and soil biota.

Hibbertia fumana is currently assessed as being Critically Endangered. There is limited ecological data available for this species. In this context, a precautionary approach is recommended. Locating and protecting new populations, no matter how small, is significant to the survival of this species.

Potential for *Hibbertia fumana* within the GPEC

The possibility of *Hibbertia fumana* occurring within the GPEC is assessed as low because potential habitat sites found within the biodiversity certification area do not have the same complexity of attributes to known extant sites. It is possible however that the species may exist in small habitat niches found within PCTs of the study area.

There is a moderate potential for *Hibbertia fumana* to occur to the north of the biodiversity certification area, not limited to areas such as the former Air Services Australia site, and the tertiary vegetation stretching from Agnes Banks, Berkshire Park, Castlereagh, Llandilo and Cranebrook vicinities. Many of the remnants in these areas are relatively large and support a complex mosaic of transitional vegetation between the various PCTs.

Photo 9: A complex mosaic of vegetation types occurs in this section of Agnes Banks NR.

The habitat depicted in Photo 9 shows PCT 958 Narrow-leaved Apple - Hard-leaved Scribbly Gum heathy woodland interface as it grades into PCT 1067 Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain (occurring in the background). PCT 725 Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain occurs in close proximity. Such areas have a moderate probability of occurrence for *Hibbertia fumana*. No such areas with this complexity were observed within the GPEC growth area.

Of the sites investigated within the growth areas, no significant occurrences of typical PCT 883 were observed where Scribbly Gum grows on a +/- sandy substrate. Some sites adjoining and on the very northern extremity of the biodiversity certification area were recorded to support stands of *Eucalyptus sclerophylla* though the areas observed were on lateritised clays.

The most likely proximate potential habitat site to the GPEC is within the former Air Services Australia site which is immediately adjacent to the northern boundary of the GPEC (Photo 10). The area is mapped to support PCTs 725,724, 883 and 1067, and in combination provide a moderate likelihood of occurrence.

Photo 10: *Eucalyptus sclerophylla* growing on lateritised clay at the northern extremity of the GPEC.

Eucalyptus sclerophylla was noted to occur sporadically within PCTs 725 and 724 in the Wianamatta Regional Park. As PCTs 725 and 724 exist within the biodiversity certification area of the GPEC and Scribbly Gum is found within these communities, the presence of *H. fumana* cannot be dismissed entirely despite no pre-existing records or non-detection during this current survey. If present, *H. fumana* would be confined to very specific habitat niches.

The Bankstown Airport habitat data records "Soils are grey heavy clay with ironstone fragments present at surface. Other native species observed indicate a derived form of Cooks River / Castlereagh Ironbark forest community."

Lateritised gravel soil and Cooks River / Castlereagh Ironbark forest are common in the northern GPEC, especially within the Wianamatta Regional Park. *Hibbertia puberula* subsp. *puberula* is a co-occurring species at Moorebank and *Hibbertia puberula* subsp. *glabrescens* is proximal (c. 450 m) to the *H. fumana* site at Bankstown. *H. puberula* was located adjacent to the Regional Park by this survey.

It is unknown if Scribbly Gum once occurred as part of the canopy layer at the Bankstown Airport *Hibbertia fumana* site. Remnant Scribbly Gum occurs nearby at the Georges River Golf Course on tertiary sands and a small Scribbly Gum Woodland remnant still exists C. 2.51 km to the south east adjacent Deverall Park.

Photo 11: Lateritised gravel soil substrate within the area of occurrence of *Hibbertia puberula*, east of Ropes Crossing.

No large occurrences of PCT 883 were observed by our survey effort within the Wianamatta Regional Park. The likelihood of the same complexity of habitat found at the Moorebank site to occur within the Regional Park is assessed as negligible. As such a long intergrade between PCT 725 and PCT883 was observed not to exist, however isolated small occurrences of Scribbly Gum were noted. This raises the possibility that localised potential habitat may exist in the area. The discovery of a localised occurrence of *Hibbertia puberula* adjacent to the Regional Park supports this assumption.

Derived habitat areas included in this assessment include the Ropes Creek environs between Ropes Crossing and Oxley Park. Relatively recent BioNet data for the area include records for *Grevillea parviflora* which suggests that potential habitat may exist here despite weed invasion being chronic along the immediate riparian zone and the invasive species *Eragrostis curvula* dominating large swathes of the derived grassland and remnant vegetation.

Large diversity of uncommon and common herbaceous species to the Sydney Metropolitan area including the rarely recorded forb *Murdannia graminea* were noted to be locally common in recently burnt and mown derived grassland under the powerlines. This suggest that other diminutive species such as *Hibbertia fumana* could still persist in the area.

Potential for *Hibbertia fumana* within the WSA

Within the Kemps Creek area of the WSA the likelihood of *H. fumana* occurrence was assessed to range from moderate to low potential adjacent the footprint. Two areas that were adjacent to the footprint and had moderate potential for the species had been mostly cleared in recent times.

The Kemps Creek area is 14 km from known occurrences of *H. fumana* and the complexity of habitat is more appropriate for the species (refer Photo 9). Similarly, a number of co-occurring threatened species have been recorded from the Kemps Creek area including a previously undocumented occurrence of *Hibbertia puberula*. *Grevillea parviflora* subsp. *parviflora* and *Persoonia nutans* are known to be proximate co-occurring species and were recorded by this survey at Kemps Creek.

Only a few remaining areas of remnant bushland exist in the Kemps Creek area. Those that remain are fragmented by development and variously modified and impacted by past and present land use practices. The exact extent of PCT assemblages that occurred in the area is uncertain, however it appears to have been a complex mosaic of various forest types with a diverse assemblage of minor habitat niches within the broader PCT community including heath and open woodland.

Site inspections supports this view with small areas of temporarily wet swales supporting heath/open woodland being observed. These have similarities to the Moorebank site of occurrence.

The Kemps Creek environs is therefore assessed to have potential habitat with a likely occurrence rating ranging from moderately high to low.

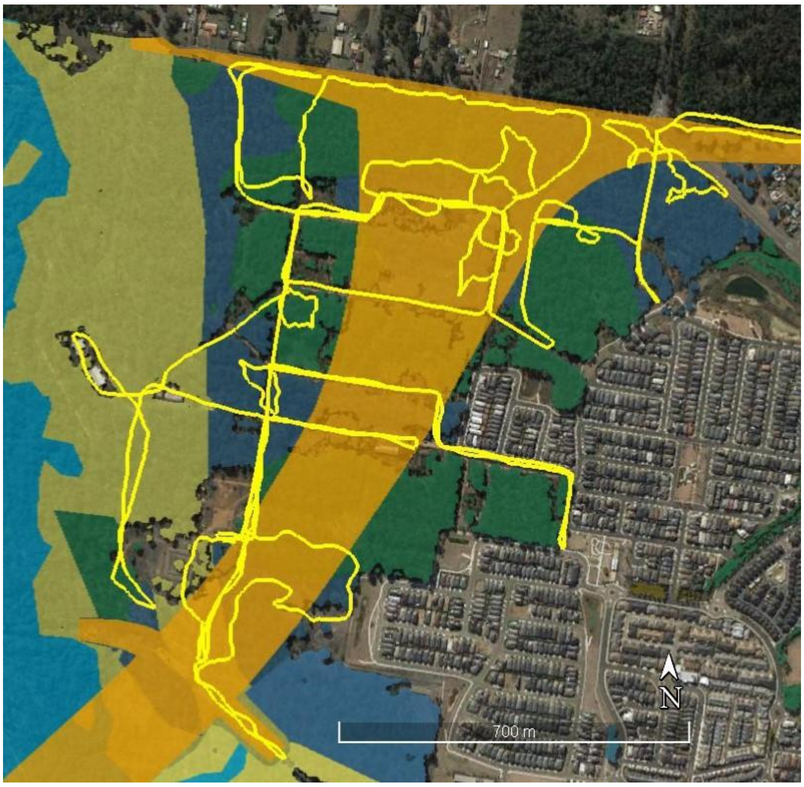
4.4.2 JUSTIFICATION FOR DETERMINATION

The following maps show an overview of areas containing potential habitat of *Hibbertia fumana*, based on vegetation mapping and BioNet records, within the GPEC and WSA. These areas were surveyed by CFFIS for this assessment. Vegetation mapping was provided by DPE.

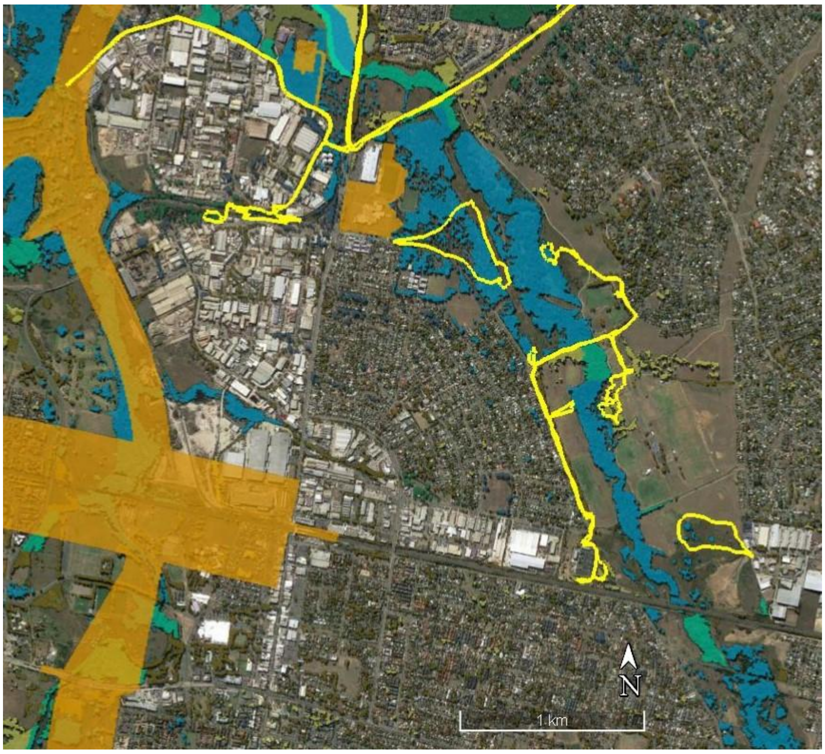
Key to the maps is:

- development footprint – light orange
- CFFIS survey tracks - yellow
- vegetation type PCT 724 – dark blue
- vegetation type PCT 725 - dark green
- vegetation type PCT 835 – light blue
- vegetation type PCT 849 – olive green
- vegetation type PCT 883 – red
- vegetation type PCT 1800 – light green

Map 5: Wianamatta Regional Park south section and powerline easement.



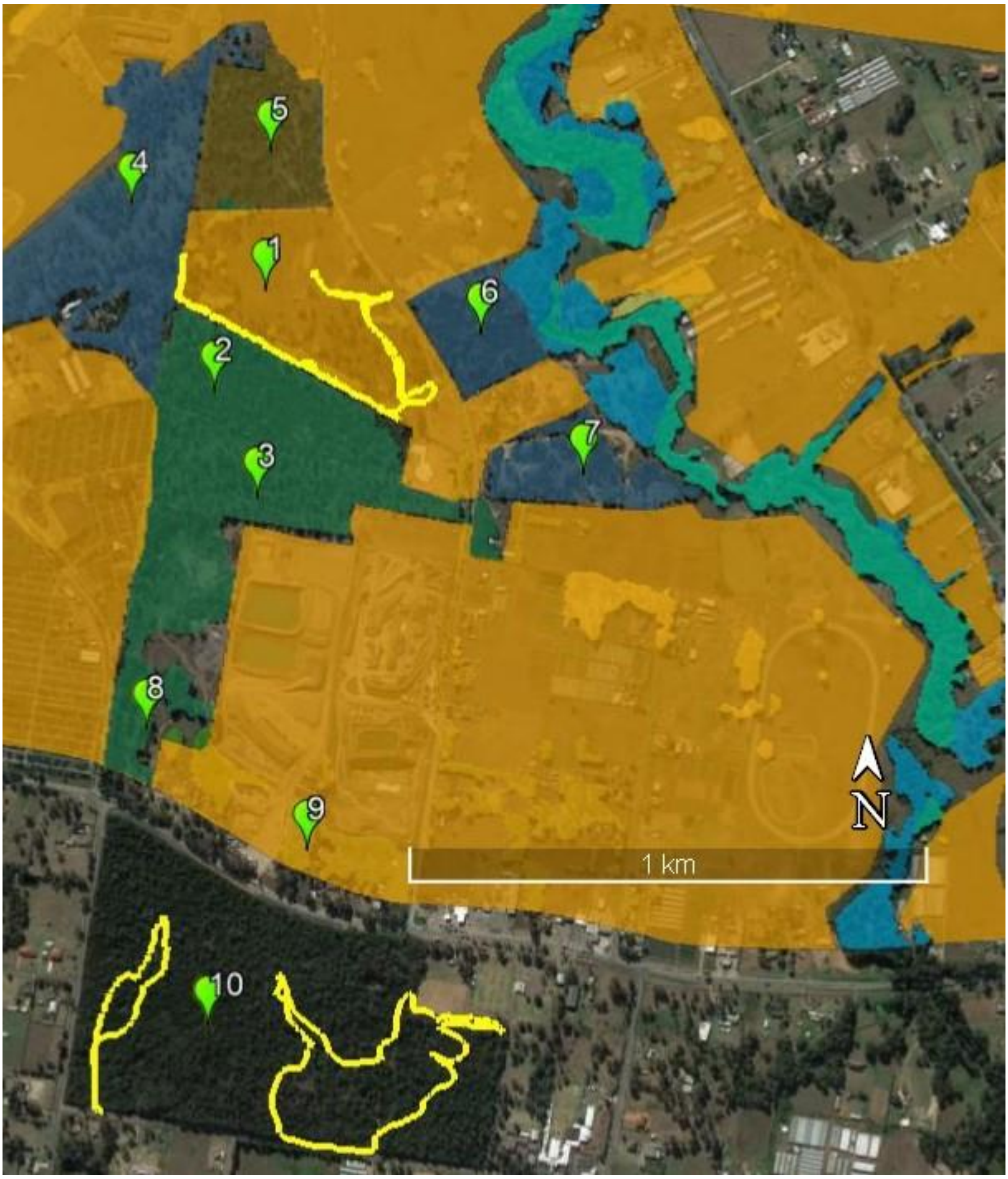
Map 6: Northern section of the Wianamatta Regional Park with road corridor footprint.



Map 7: Ropes Crossing and North St Marys areas of potential habitat, Tregear and Whalan Reserves and development footprint.

Map 8: Boronia Road North St Marys areas of potential habitat.

Map 9: Kemps Creek, south of SUEZ facility, block of land partially cleared.



Map 10: Kemps Creek potential habitat and development footprint.

1. Lot 3 DP812284
2. Lot 2 DP812284
3. Lot 1 DP812284
4. Lot 22 DP60122, Lot 2 DP587135
5. Lot 47 DP734584
6. Lot 6 DP812284
7. Lot 4 DP812284
8. Lot 1 DP716403
9. Lots north of Elizabeth Drive
10. Cross Street bushland

4.5 ASSESSMENT OF SUITABLE HABITAT

4.5.1 SUITABLE HABITAT WITHIN THE GROWTH AREAS

This section provides detail of areas of suitable habitat within the growth areas that have been surveyed by CFFIS, and the outcomes of that survey.

Wianamatta Regional Park area and Outer Sydney Orbital corridor

Within the Regional Park and the Outer Sydney Orbital (OSO) corridor are areas mapped as having PCTs appropriate for *H. fumana* habitat. The potential for the species to occur in these areas is considered to be low.

Survey of the area did not locate the species. Non-detection was not viewed as meaning not present, but rather not observed. The bushland was very dry and had not been burnt for years. It is likely that if the species did occur in the vicinity it's occurrence would be confined to small localised patches that could be easily overlooked. The species is cryptic even in favourable times. Due to the preceding drought conditions the species may have contracted to the soil seed bank.

Hibbertia pedunculata and to a lesser degree *Dillwynia tenuifolia* and *Pultenaea parviflora* were used as surrogate indicator species in determining the likely impact of drought and fire regime on the population densities, within and outside of canopy cover in the assessment of likely occurrence of *Hibbertia fumana*. *Hibbertia pedunculata*, *Dillwynia tenuifolia* and *Pultenaea parviflora* were observed to be locally frequent species within some modified habitat areas.

Photo 12: *Hibbertia pedunculata* within derived habitat away from trees and shrubs.

In areas where these species were noted away from the influence of large trees and shrubs, they were easily discernible, flowering and vigorous. Under the canopy or within the rooting zone of trees and shrubs, flowering was significantly reduced but mostly absent and the apparent population densities low. Visible plants were typically in a late stage of senescence. This was particularly apparent with *Hibbertia pedunculata*.

Other shrub and ground layer species were also noted to be particularly sparse within the areas mapped as PCT 725 and PCT 724 within the Wianamatta Regional Park.

BioNet records the following species for the Regional Park that may indicate localised suitable habitat niches for *Hibbertia fumana*. Species include *Banksia spinulosus*, *Callistemon pinifolius*, *Baeckea diosmifolia*, *Hakea dactyloides*, *Isopogon anemonifolius*, *Leptospermum parvifolium*, *Melaleuca thymifolia*, *Pultenaea tuberculata* and *Xanthorrhoea minor*. The trees *Angophora bakeri*, *Corymbia gummifera*, *E. eugenioides*, *E. parramattensis* and *Eucalyptus sclerophylla* are also listed.

Photo 13: Typical condition of *Hibbertia pedunculata* within “intact” vegetation of the Regional Park.

Note: The *Hibbertia pedunculata* plant is exhibiting extreme water stress and lack of flowers. Detectability of *Hibbertia* in this state is very low.

Many areas were observed to have a particularly high percentage coverage of thick detritus further suppressing the groundcover. BAM plot data for the area records EP GPEC 18 litter cover as 83%, EP GPEC 01 as 93%, EP GPEC 03 as 83%, EP GPEC 12 as 100% and EP GPEC 08 as 72%.

These observations support the conclusion that non-detection of *Hibbertia fumana* within or adjacent to the development footprint (OSO corridor) within the Wianamatta Regional Park is likely to be attributable to a retraction to the soil seed bank rather than non-occurrence.

Photo 14: Typical high levels of detritus under the canopy Wianamatta Regional Park

Photo 15: Many hardy understorey species still show the symptoms of severe drought stress even following recent rains.

Ropes Creek Vicinity

A number of areas were targeted for survey along the Ropes Creek corridor, these were

- Whalan Reserve
- Tregear Reserve
- South of Whalan Reserve
- East of and to the south of St Marys Rugby League Club, Boronia Road North St Marys,
- Electricity Substation vicinity Kurrajong Road and Boronia Road, North St Marys.

The potential habitat sites in the Ropes Creek vicinity were selected based on the PCT mapping, aerial imagery and the following BioNet records:

Grevillea parviflora: 28/01/2015, Ropes Creek, Mt Druitt includes Whalan Reserve and Tregear Reserves, -33.77797 150.80575.

Dillwynia tenuifolia: near corner Roper Rd & Carlisle Ave, Colyton, -33.78435, 150.80540, Ropes Creek, Mt Druitt includes Whalan Reserve and Tregear Reserves -33.78544, 150.80727

Eucalyptus parramattensis subsp. *parramattensis*: Roper Road, St. Marys, -33.78435, 150.80540

Hibbertia pedunculata: Between power station and railway line near Boronia Park, St Marys

Grevillea juniperina: M4 Motorway, Ropes Creek includes Whalan Reserve and Tregear Reserves and near corner Roper Rd & Carlisle Ave, Colyton.

Grevillea parviflora and *Eucalyptus parramattensis* subsp. *parramattensis* are known co-occurring species at Moorebank and at Voyager Point. *Dillwynia tenuifolia* is a known co-occurring species at Kemps Creek and at Ropes Crossing. These species indicate the possibility of potential suitable habitat present in the Ropes Creek vicinity.

The condition of the vegetation and population status of some of the BioNet records remain unknown.

Both *Grevillea parviflora* and *Eucalyptus parramattensis* subsp. *parramattensis* were not located by this survey effort and the GPS points do not align with the descriptors.

The Ropes Creek vicinity was found to be severely impacted by weed invasion displacing most native species in many of the likely potential habitat areas. The majority of the Ropes Creek environs is therefore assessed as unsuitable habitat for *Hibbertia fumana* as no indicative co-occurring habitat species were located within the areas surveyed and these potential habitat areas were acutely degraded.

Further details of the habitat at these sites follows.

Whalan Reserve

Whalan Reserve is primarily developed as a recreational facility including sporting fields, BMX bike jumps, Whalan Model Car Club track, walkway / cycleway and exercise equipment. West of the pathway remnant river-flat forest and supplementary plantings were observed.

In the area surveyed the canopy / subcanopy was variously comprised of *Eucalyptus tereticornis*, *Angophora floribunda*, *Casuarina glauca, Acacia decurrens, A. parramattensis* and *Melaleuca decora*. A stand of Blue Box was noted west of the access road.

Photo 16: Whalan Reserve bushland west of the pathway.

The ground layer was impacted by weeds and dominated by *Eragrostis curvula* in many places. Despite this, numerous areas were observed to support a diverse array of indigenous species including: *Acacia falcata*, *A. elongata*, *Bursaria spinosa*, *Indigofera australis, Ozothamnus diosmifolius*, *Daviesia ulicifolia* var. *stenophylla*, *Tricoryne elatior*, *Phyllanthus virgatus*, *Opercularia diphylla*, *Cyanthillium cinereum*, *Cheilanthes sieberi*, *Glossogyne tannensis*, *Goodenia hederacea*, *G. bellidifolia*, *G. paniculata*, *Brunoniella australis*, *Chorizema parviflora*, *Chrysocephalum apiculatum*, *Centella asiatica*, *Glycine tabacina*, *Desmodium varians*, *Polymeria calycina*, *Zornia dyctiocarpa*, *Dianella longifolia*, *Lomandra longifolia*, *Microlaena stipoides*, *Themeda australis* and *Aristida* *vagans*. *Eucalyptus crebra*, *Melaleuca armillaris*, *Callistemon viminalis*, and *C. salignus* were noted in the plantings.

The river-flat community is atypical of *Hibbertia fumana* habitat as the higher nutrient status of the soils supporting typically a dense grassy /herbaceous layer is unsuitable habitat. However, the presence of minor alluvial terraces in combination with lateritised soil areas with relatively open ground layer provides a low potential for species presence.

Photo 17: Weedy understorey and habitat plantings at Whalan Reserve.

Photo 18: Remnant vegetation at Whalan Reserve severely impacted by *Eragrostis curvula*.

Photo 19: Minor alluvial terrace, potential habitat for *Hibbertia fumana* in Whalan Reserve.

Tregear Reserve

Tregear Reserve is primarily a developed recreational reserve with sporting fields, walkways/ cycleway, exercise facilities and an off-leash dog compound.

Undeveloped portions remain west of the pathway and include riverine remnant vegetation and large areas of unmown exotic grassland / herbland that has predominantly displaced the indigenous vegetation. Habitat enhancement plantings were noted along the bushland verge.

Habitat for *Hibbertia fumana* may have once existed at the interface between the alluvial floodplain and the lateritised rise. The potential habitat is too degraded to now support this species.

In the area surveyed the riparian vegetation was dominated by *Eucalyptus baueriana* with *Casuarina glauca*, *Acacia parramattensis*, *Melaleuca styphelioides*, *Bursaria spinosa* and the native grass *Microlaena stipoides* being relatively common.

Other indicative indigenous species noted included *Carex appressa*, *Scaevola albida*, *Dichondra repens*, *Centella asiatica* and *Alternanthera denticulata*.

The understorey in many locales is heavily weed impacted with species such as: *Eragrostis curvula*, *Chloris gayana*, *Setaria sphacelata*, *Verbena bonariensis*, *Rumex* sp. and *Tradescantia fluminensis*.

Enhancement plantings include: *Eucalyptus crebra*, *Casuarina glauca*, *Melaleuca styphelioides*, *M. decora*, *M. linariifolia* and *Bursaria spinosa*.

Photo 20: Looking across Tregear Reserve to the riparian zone of Ropes Creek

Photo 21: Treagar Reserve chronic weed infestation eliminating potential habitat for the species.

Although very limited in extent, a number of indigenous ground layer species were noted under the canopy of the enhancement plantings and to a lesser degree within the adjoining predominantly exotic weed meadow. Indigenous species noted include: *Wahlenbergia gracilis, W*. *communis, Centella asiatica, Tricoryne elatior, Microlaena stipoides, Phyllanthus virgatus*, *Rubus parviflorus*, *Glycine tabacina*, *Haloragis heterophylla, Cynodon dactylon* and *Glossogyne tannensis*.

The weed meadow adjoining the plantings was dominated by *Eragrostis curvula, Hypochaeris radicata*, *Plantago lanceolata*, *Melilotus albus* and *Paspalum dilatatum*.

The majority of the potential habitat was blanketed by dense weeds, primarily comprised of: *Eragrostis curvula*, *Cirsium vulgare*, *Verbena bonariensis*, *Melilotus albus*, *Foeniculum vulgare*, *Solanum sisymbriifolium*, *Bidens pilosa*, *Lactuca serriola*, *Plantago lanceolata*, *Chloris gayana*, *Nothoscordum gracile*, *Chenopodium album* and *Sorghum halepense*. No indigenous species were noted in this area.

Treagar Reserve vicinity is assessed as having no potential habitat remaining for *Hibbertia fumana*.

South of Whalan Reserve

The generalised geomorphology of the site is summarised by the intersection of the alluvial floodplain deposits of Ropes Creek with low lateritised rises. It is possible that such conditions once provided localised suitable habitat for *Hibbertia fumana*.

The potential habitat in this section of Ropes Creek is severely impacted by weed invasion and the potential for threatened species to now exist is negligible. A large area is being infilled with road ballast.

A small area of a few square metres was observed to support *Themeda australis* and *Wahlenbergia communis* and colonised by invasive species including *Briza subaristata*, *Eragrostis curvula*, *Hypericum perforatum*, *Lactuca serriola*, *Senecio madagascariensis*, *Verbena bonariensis* and *Hypochaeris radicata*. The site is surrounded by dense exotic vegetation now typical of the area.

No suitable habitat exists for *Hibbertia fumana* in this locale.

Photo 22: Eastern side of Ropes Creek south of Whalan Reserve.

Photo 23: *Eragrostis curvula* smothers potential habitat area of lateritised clay.

Photo 24: Only one small area of supporting *Themeda* was noted to remain.

Photo 25: The density of the grass and herbaceous layer precludes the possibility for the area to now support a viable population of *Hibbertia fumana*.

Boronia Road, North St Marys

A diverse herbaceous layer was observed in recently burnt sections of the powerline easement at North St Marys. Most locales including the adjacent wooded areas and containing PCT 724 were heavily infested with dense *Eragrostis curvula* tussocks, and this was smothering the ground layer.

Flowering species noted in one burnt area included *Murdannia graminea*, *Tricoryne elatior*, *Hypoxis hygrometrica* var. *hygrometrica*, *Isotoma fluviatilis*, *Ophioglossum lusitanicum* and *Hibbertia diffusa*. All of these plants were non-discernible under the adjoining tree cover and within the dense *Eragrostis* tussocks.

In the area inspected no indicative co-occurring species or habitat niches were noted that indicate likely potential habitat for *Hibbertia fumana*. Although the survey was very limited in its extent and duration, this area was assessed as unsuitable habitat for *Hibbertia fumana*.

Photo 26: East of and to the south of Boronia Road North St Marys.

Photo 27: North St Marys electricity easement environs.

Electricity Substation vicinity Kurrajong Road and Boronia Road, North St Marys

The selection of the electricity substation in the vicinity of Kurrajong Road and Boronia Road North St Marys is based on the BioNet records previously mentioned in addition to a BioNet record for *Hibbertia pedunculata* and PCT mapping on the Spatial Viewer. The fact that *Hibbertia pedunculata* was noted at the time of the BioNet entry indicates that the ground layer in that area was sufficiently intact to support diminutive species.

Many of the potential habitat zones along Ropes Creek have been significantly modified leaving a narrow band of vegetation along the immediate riparian zone. The modified areas are managed for various uses including in the Boronia Park vicinity sports fields and at the southern end the North St Marys Off leash Dog Park. These areas can no longer be considered potential habitat.

The riparian zone of Ropes Creek was noted to be particularly impacted by stormwater runoff with the understorey seriously degraded in many of the locales inspected. Where not degraded the PCTs were assessed as unsuitable for *Hibbertia fumana* based on current known ecological requirements.

The invasive *Eragrostis curvula* also dominated extensive areas. The potential for *H. fumana* to occur in Ropes Creek area is therefore considered to be low.

Photo 28: Open areas of lateritised clay soil to the east of the substation and north of railway line west of Ropes Creek support *Hibbertia pedunculata* and provide potential habitat for *H*. *fumana*.

Photo 29: Slashed native vegetation within the powerline easement, a potential habitat area for *Hibbertia fumana*.

Photo 30: An indigenous regrowth area between the substation and western railway line is potential habitat for *Hibbertia fumana*.

Kemps Creek area

The vegetation in the immediate vicinity of Lots 1, 2 and 3 DP812284 has been variously described as PCT 883 by Eco Logical Australia (2013), Ecoplanning (2015) and the Vegetation 100km consolidated layer in the Spatial Viewer, and Shale Gravel Transition Forest by Envirotech (2013). It is currently identified on the spatial viewer as PCT 725 on Lots 1, 2 and 3 DP812284 and PCT 724 as occurring to the east and west.

The vegetation in the Kemps Creek area has been dramatically altered with clearing for agriculture and removal of trees for various uses such as fence posts and firewood. The precise abundance of the various *Eucalyptus* species through the area is difficult to ascertain. *Eucalyptus sclerophylla* is obviously a major component within limited areas with stands still occurring south of Elizabeth Drive adjacent to Bill Anderson Park and the adjacent school. Scribbly Gum also appears to have been a major component of the canopy within Lot 3 DP812284 prior to clearance as documented within the Eco Logical 2013 report, refer Photo 31.

Photo 31: Scribbly Gum was an obvious common component of the site (photo Eco Logical 2013).

The presence of both temporary moist swale habitat niches and a transitional vegetation type comprised of Scribbly Gums, Broad-leaved Ironbark, Thin-leaved Stringybark and Woollybutt in combination with lateritised soil provides moderate to high potential of occurrence of *Hibbertia fumana*.

A periodic moist depression occurring on Lot 3 DP812284 provides habitat for species such as *Xanthorrhoea minor* indicating that before disturbance the area was likely to have supported a relative open small moist heath patch within the broader plant community. Such areas are potential habitat for *Hibbertia fumana*.

Lot 1 & 2 DP812284 Clifton Avenue, Kemps Creek in the Penrith local government area

The remnant vegetation is located at the rear portion of Lot 2 and the adjoining Lot 1. No access was granted therefore site assessment was limited to “through the fence” observation made from the adjoining property, Spatial viewer information and literature review of the Envirotech 2013 assessment.

An assessment by Envirotech 2013 noted a relatively intact flora community and that there was a healthy seed bank evidenced by the regeneration of native vegetation in disturbed portions of the property.

Photo 32: *Xanthorrhoea minor* growing in a periodically moist depression (photo S. Douglas).

Envirotech considered the site to have high species diversity including “well-represented herbaceous, understory and canopy layers that were clearly identifiable”. Weeds were confined to the perimeter of the property.

The “through the fence” inspection noted moderate to high potential habitat for *Hibbertia fumana* as species requiring periodic moist soil were easily detected and minor swales were noted. The habitat is +/- contiguous with the remnant remaining on the adjacent block (Lot 3) being separated only by perimeter trails.

Several undocumented threatened species were observed within the site including *Hibbertia puberula*, *Dillwynia tenuifolia* and *Pultenaea parviflora*. It was considered likely that *Grevillea parviflora* would also exist in the area.

Photo 33: Remnant bushland on Lot 2 DP812284, photo taken through fence.

Note: Subtle variation in elevation and possible substrate consistency providing periodic damp conditions supporting range of species e.g. *Xanthorrhoea minor* and potential habitat for threatened plants such as *Grevillea parviflora* and *Hibbertia fumana*.

Lot 22 DP 60122, 1541A Elizabeth Drive Kemps Creek and Lot 2 DP 587135, 146B Clifton Avenue Kemps Creek

Two blocks in the Kemps Creek area (Lot 22 DP60122 and Lot 2 DP 587135) are assessed as having a low to moderate probability of occurrence for *Hibbertia fumana*.

The majority of the understorey on Lot 2 DP 587135 could not be observed. It is included as potential habitat based on its continuity and close proximity to observed potential habitat areas. The area is mapped as PCT 724 thinned on the spatial viewer. Lot 22 DP60122 was assessed by ‘’through the fence’’ inspection. The area is mapped as PCT 724 thinned on the spatial viewer. Much of the observable portions of the site are disturbed with weeds and fill dumping. Small areas were noted to contain an intact ground layer.

Photo 34: Lot 22 DP 60122, photo through fence taken from the adjoining block.

Note: small areas of regenerating native vegetation and intact ground layer occur within Lot 22 DP 60122. These provide potential habitat for threatened taxa.

Photo 35: View from south western corner of Lot 3 DP812284 into Lot 22 DP 60122.

Note: degradation of habitat by fill dumping and invasion of weeds, notably dense swathes of *Eragrostis curvula.*

Photo 36: Evidence of clearing, fill dumping and weed invasion degrading the habitat potential for threatened species Lot 22 DP 60122.

Lot 47 DP 734584 Kemps Creek

This block of land on Clifton Avenue is cleared and under investigation. It is most likely that similar moist habitat niches also occurred on this block. If so, they may have supported populations of *H. fumana* prior to clearing. From the most recent 31/10/2018 Google Earth imagery no habitat now remains on Lot 47. A narrow strip of very low potential habitat remains roadside.

Photo 37: Street view Google earth November 2016 of block to the north of Lot 3 DP812284.

Photo 38: Street view Google earth November 2016 of block to the north of Lot 3 DP812284.

Photo 39: Location of Lot 47 DP 734584, Lot 3 DP812284, Lot 2 DP587135 and Lot 22 DP601022.

Bushland Remnants Lot 4 DP812284 373 381 Clifton Road and Lot 6 DP812284, 316 Clifton Road, Kemps Creek

There are two blocks on the east side of Clifton Road that both have suitable habitat type although they are disturbed. These blocks have low to moderate probability for the species to occur.

The assessment was made from data shown in the Spatial Viewer from two BAM plots located on Lot 6. Species recorded include:

BIO WSAN 13: *Eucalyptus fibrosa* 15% coverage, *Eucalyptus globoidea* 1%, *Melaleuca decora* 2% and *Melaleuca nodosa* with a 15% coverage. Other species recorded each with a 1% coverage include: *Ozothamnus diosmifolius*, *Dillwynia sieberi*, *Dodonaea viscosa*, *Bursaria spinosa*, *Exocarpos cupressiformis*, *Aristida vagans*, *Lomandra gracilis*, *Daviesia ulicifolia*, *Dillwynia parvifolia*, *Pultenaea microphylla*, *Einadia hastata*, *Phyllanthus hirtellus*, *Pratia purpurascens*, *Eragrostis leptostachya*, *Entolasia stricta*, *Lepidosperma gunnii*, *Lepidosperma laterale*, *Cyathochaeta diandra*, *Lomandra longifolia*, and *L. multiflora*.

The only weed recorded in the BAM data is *Eragrostis curvula* with a 2% coverage.

BIO WSAN 14: *Eucalyptus globoidea* 30%, *Melaleuca decora* 2%, *Bursaria spinosa* 1% and *Cassinia uncata* 1% coverage. Ground layer species recorded cover 45% of the ground layer. They include: *Einadia hastata*, *Lomandra multiflora*, *Entolasia stricta*, *Eragrostis brownii*, *Cynodon dactylon*, *Dichelachne micrantha* and with *Microlaena stipoides* a 40% coverage.

Weeds in total had an 8% coverage, species recorded are: *Axonopus affinis*, *Sporobolus creber*, *Hypochaeris radicata*, *Sida rhombifolia*, *Eragrostis curvula* 1%, *Senecio madagascariensis*, and *Setaria parviflora*.

Photo 40: Google Earth image of Lot 6 DP812284 viewed from Clifton Road.

Remnant Vegetation North of Elizabeth Drive, Kemps Creek

The following Lots contain potential habitat for *Hibbertia fumana*: Lot 1 DP747285 1521 – 1539 Elizabeth Drive, Lot 1 DP1212980 1503 Elizabeth Drive, Lot 10 DP 1087346 1495 Elizabeth Drive Lot 16 DP2566 1491 Elizabeth Drive and Lot 1 DP 1o90754 1481-1489 Elizabeth Drive.

The two vegetation remnants north of Elizabeth Drive and south of Lot 2 DP812284 of land were assessed by ʻʻover the fenceʼʼ and ʻʻdrive-byʼʼ observation as access was not granted at the time of survey. Both sites were noted to have potential habitat from information contained within the spatial viewer, field observation revealed the small observable areas to be in poor condition and with low habitat suitability. Most of the vegetation was not able to be seen from the roadside.

The majority of the largest remnant Lot 1 DP747285 was not visible from the road. It is a large block extending northward from the road and adjoining the intact remnant on Lot 2 DP812284. Google Earth imagery provides evidence of potential moist swales to be present on the site. There is no BAM Plot data available for this site. The spatial viewer maps two vegetation types PCT 1067 thinned and PCT 725 thinned on the site providing potential likely habitat for the species. The remnant is bordered by a wholesale nursery in the west and a quarry to the east. Numerous site disturbances such as large areas of fill emplacement are observable on Google Earth Imagery providing evidence of degradation of habitat across much of the site.

The smaller remnant is bordered by the quarry on two sides and rural residential properties on Elizabeth Drive, consequently the impact of edge effects is likely to be high. Two BAM plots are located in this remnant and the Spatial viewer maps the site as PCT 725. The information provides some insight into the habitat.

BIO WSAN 10: *Angophora subvelutina* 15%, *Eucalyptus tereticornis* 5%, *Allocasuarina littoralis*, *Acacia decurrens*, *Ozothamnus diosmifolius*, *Acacia elongata*, *Cryptandra spinescens*, *Eragrostis brownii*, *Themeda australis*, *Glycine clandestina*, *Solanum prinophyllum*, *Hibbertia aspera*, *Microlaena stipoides* 50%, *Panicum simile*, *Eragrostis brownii*, *Cynodon dactylon, Lomandra multiflora*, *Juncus usitatus*, *Dichondra repens* and *Lepidosperma laterale*.

Weeds recorded in the BAM Plot include: *Ligustrum lucidum*, *Verbena bonariensis*, *Setaria parviflora*, *Bidens pilosa*, *Sonchus oleraceus*, *Eragrostis curvula*, *Senecio madagascariensis*, *Cyperus eragrostis*, *Ehrharta erecta*, *Anagallis arvensis*, *Araujia sericifera*, *Passiflora subpeltata*, *Chloris gayana*, *Axonopus compressus*, *Conyza* sp., *Sida rhombifolia*, and *Asparagus asparagoides*.

BIO WSAN 9: *Angophora floribunda*, *Eucalyptus tereticornis*, *Melaleuca decora, Acacia decurrens*, *Ozothamnus diosmifolius*, *Bursaria spinosa*, *Dillwynia sieberi*, *Themeda triandra*, *Glycine tabacina*, *Einadia trigonos*, *Opercularia diphylla*, *Brunoniella australis*, *Centella asiatica*, *Pratia puberula*, *Polymeria calycina*, *Microlaena stipoides*, *Aristida vagans*, *Entolasia marginata*, *E. stricta*, *Paspalidium distans*, *Dichelachne crinita*, *Echinopogon caespitosus*, *Cynodon dactylon*, *Lomandra multiflora*, *Carex inversa*, *Dichondra repens*, *Lepidosperma laterale*, *Lomandra filiformis* and *Cheilanthes sieberi*.

Weeds recorded in the BAM Plot include: *Senecio madagascariensis*, *Ehrharta erecta*, *Asparagus asparagoides*, *Cirsium vulgaris*, *Pennisetum clandestina*, *Cuscuta campestris*, *Sida rhombifolia*, *Opuntia stricta*, *Plantago lanceolata*, *Tradescantia fluminensis* and *Hypochaeris radicata*.

The representativeness of the habitat information contained within the BAM plot data is unknown. It is also unknown whether or not localised habitat niches prevail within the broader vegetation type as observed at other locales at Kemps Creek. Accordingly, the presence of *Hibbertia fumana* could not be ruled out though the likelihood of occurrence was assessed as low.

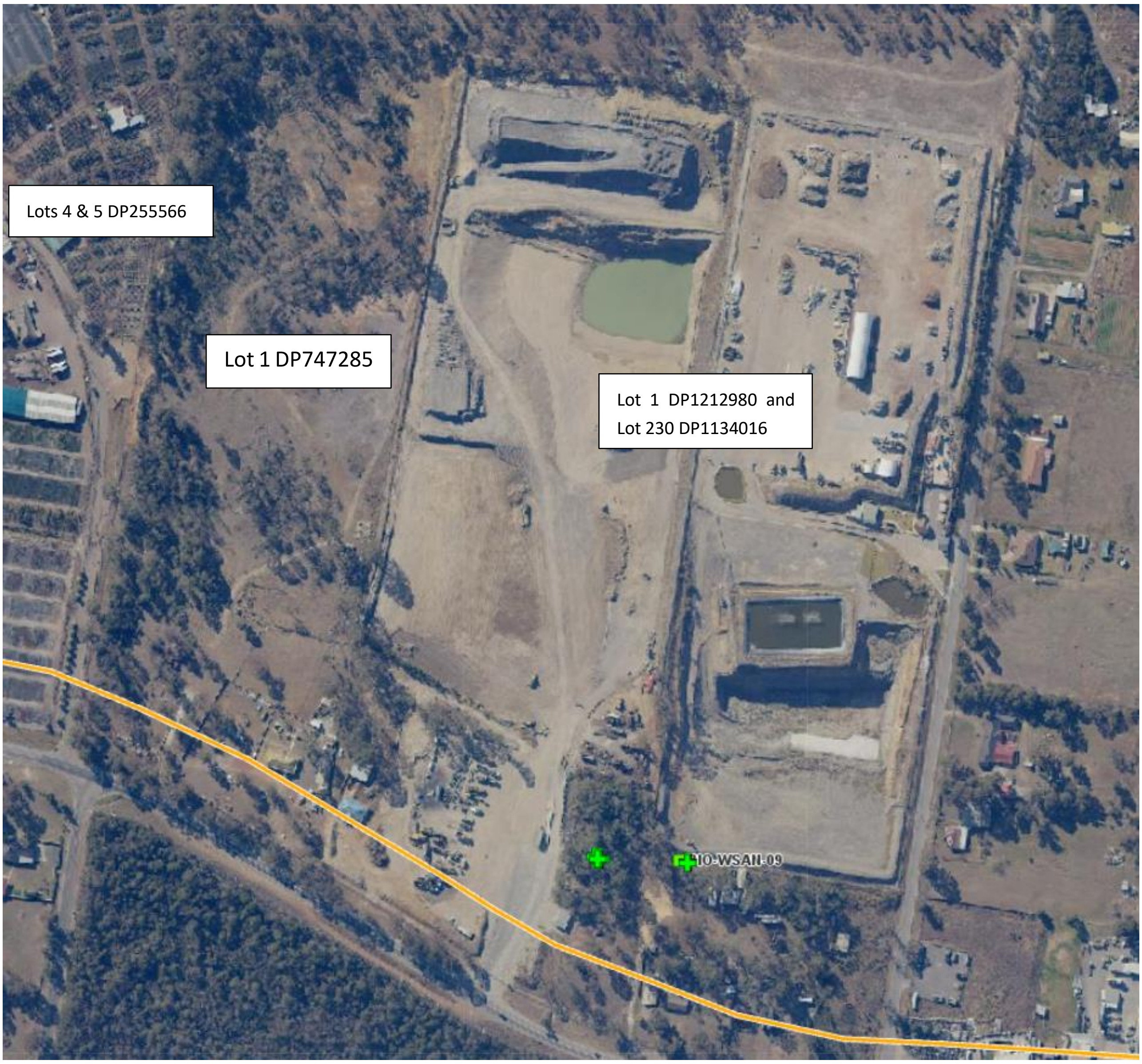


Photo 41: Location of BAM plots BIO WSAN 9 and BIOWSAN 10.

Note: Labels show the location of Lot 1 DP716403, Lots 4 and 5 DP255566, Lot 1 DP1212980 and Lot 230 DP1134016.

Photo 42: Land use practices have impacted upon the biological integrity of the site.

South of the SUEZ landfill site

Lot 4 DP860456, Elizabeth Drive, Kemps Creek.

Inspection of Lot 4 DP860456 was not granted. The area will not be certified due to pending investigation into clearing.

The determination of potential habitat occurring on Lot 4 DP860456 was therefore based on the information contained within the spatial viewer and google earth imagery. Drive by inspection was also constrained by the high volume of trucks entering and exiting the site and the adjoining Suez approved facility. There is a moderate probability that the species occurred in Lot 4 DP860456, as the spatial viewer identifies the area to have contained both PCT 725 and 724. The Google Earth imagery (Photo 43) shows a distinct change in vegetation and two farm dams (the larger on the adjoining property) indicating the presence of a moist depression. Periodically moist depressions in such habitats in the Kemps Creek area are known to support Threatened Species such as *Grevillea parviflora* e.g. at the bushland adjacent Bill Anderson Reserve. *Grevillea parviflora* is a co-occurring species with *Hibbertia fumana* at Moorebank.

Lot 4 is now mostly cleared and under investigation, with high volumes of fill emplacement being observe adjacent Elizabeth drive and the Suez facility 1. A linear band of vegetation remains in the central portion of the site.

Photo 43: Lot 4 DP860456 showing moist swale in the central portion of image prior to clearance and fill emplacement.

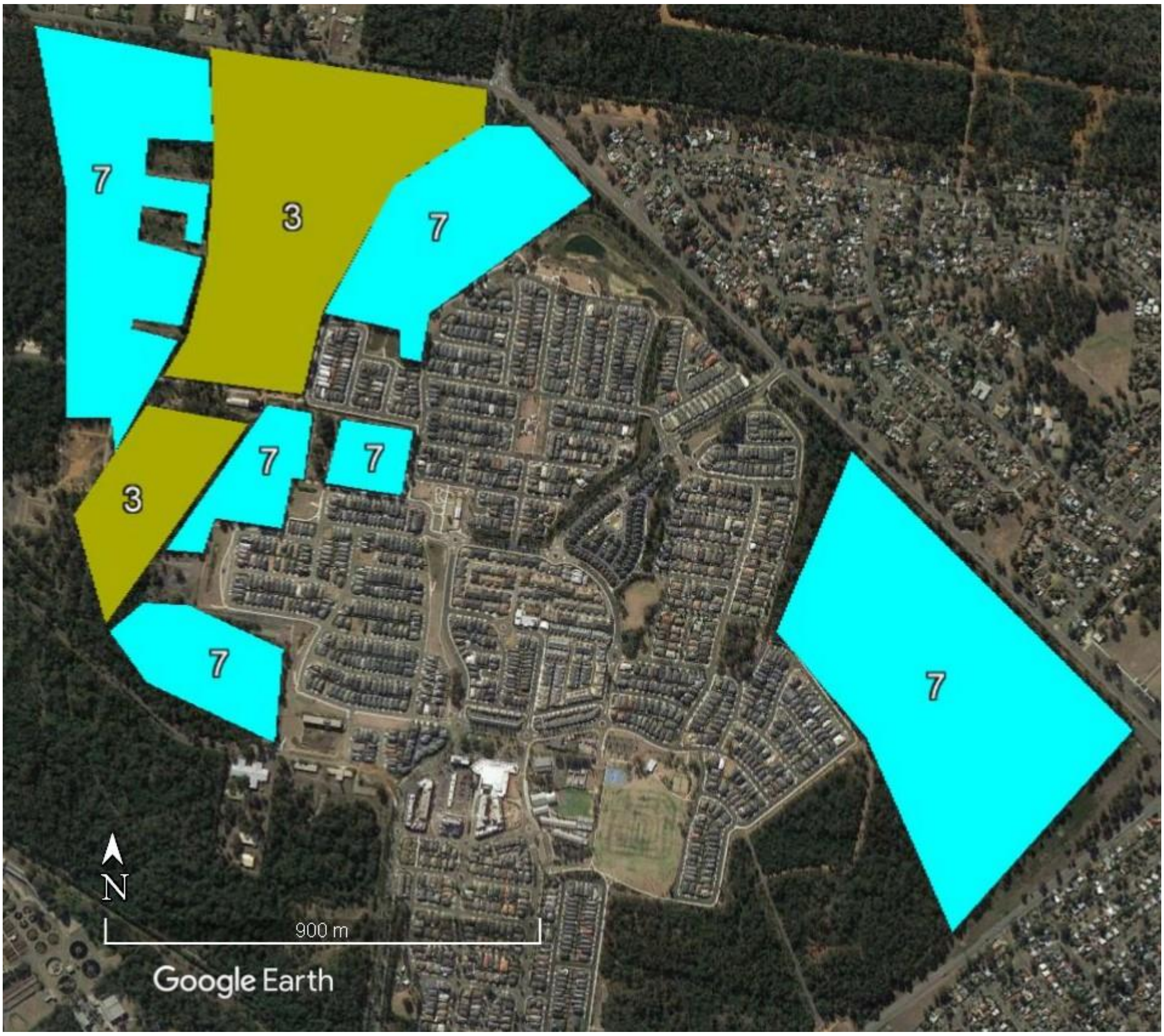
Photo 44: Google Earth Imagery 31/10/2018 Lot 4 DP860456 showing high volume of fill emplacement across most of the site. A small area remains providing some habitat potential.

Photo 45: Fill batter at northern end of Lot DP860456, South of SUEZ facility.

Note: This area is identified as not to be certified on the spatial viewer. Photo taken through fence from the adjoining SUEZ facility.

4.5.2 DETERMINATION OF SPECIES POLYGONS

Based on the available vegetation mapping, site survey and knowledge of the species habitat requirements, the following maps show the polygons of likely habitat and the estimated probability for the species to occur.



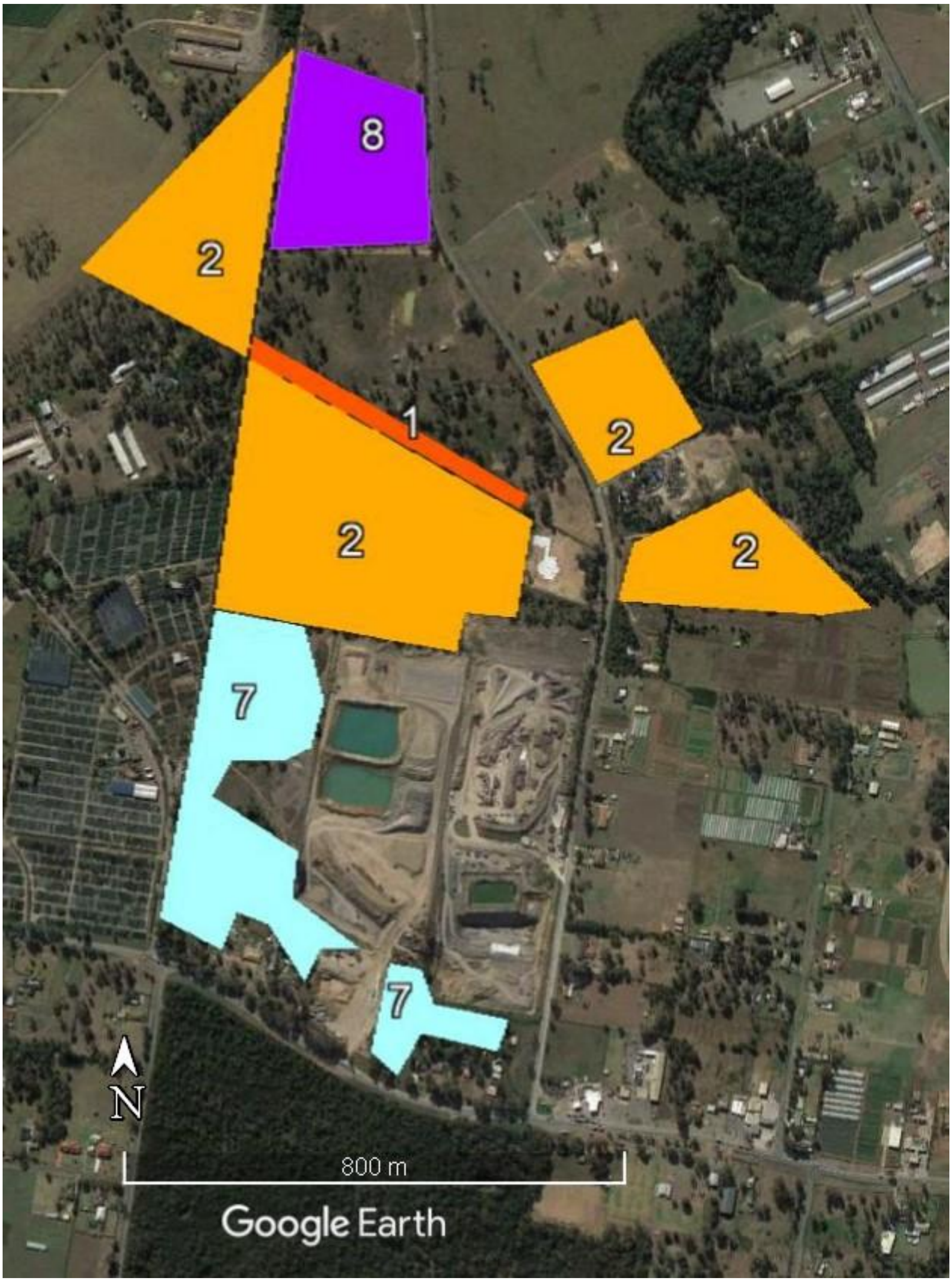
Map 11: Wianamatta Regional Park potential habitat sites.

Key: Within footprint, low probability, olive green - 3.

Proximate to footprint, low probability, light blue - 7

Map 12: Ropes Creek area potential habitat sites.

Key: Outside footprint, low probability, peach - 5



Map 13: Potential habitat sites in the Kemps Creek area

Key to map:

Removed from certification area, moderate probability for the species – dark orange - 1

Adjacent footprint, moderate probability for the species – pale orange - 2

Adjacent footprint, low probability for the species – pale blue - 7

Adjacent footprint, moderate probability for the species prior to clearing – purple - 8

Map 14: Former habitat site south of the SUEZ landfill site.

Key: Adjacent footprint, former moderate probability, purple - 8

4.5.3 ESTIMATE OF AREA OF HABITAT

The following are estimates of the potential habitat for the species. Note that the habitat could be small niches within these areas.

Greater Penrith to Eastern Creek Urban Release Investigation Area

Wianamatta Regional Park

In footprint, low probability, 32 ha.

Adjacent to the footprint, low probability, 77 ha

Ropes Creek vicinity

Adjacent footprint, low probability, 5 ha.

Western Sydney Aerotropolis Growth Area

Kemps Creek area

Removed from certification area, moderate probability, 1.47 ha

Adjacent footprint, moderate to high probability, 14.4 ha

Adjacent footprint, moderate to low probability, 15.6

Adjacent footprint, low probability, 10.25 ha

Adjacent footprint, moderate probability, cleared, 6.25 ha.

South of SUEZ landfill

Adjacent footprint, moderate probability, cleared, 4.4 ha.

In summary, 32ha of habitat with a low probability of the species occurring are within the development footprint, and more than 100 ha of habitat with moderate to low probability of species occurrence are outside the footprint but are likely to suffer from anthropogenic impacts caused by the development. More than 10 ha with moderate potential have recently been partly cleared.

5. Information used in the assessment

Information used in this assessment includes taxonomic papers, BioNet and ALA records of the target species, Critically Endangered Listing, online Threatened Species profile and associated documents, personal observations and site inspections, and the spatial viewer including the layers: survey access and coverage, (BAM plots, polygons and transects), PGA layer and geology and soils. Reference was made to Flora Appendix 2 & 3 of Western Sydney Biodiversity Survey NPWS 1997 for records of *Hibbertia species* observed in that study.

6. References

Bannerman S.M. and Hazelton P.A., 1990, *Soil Landscapes of the Penrith 1:100,000 Sheet map and report*, Soil Conservation Service of NSW.

Duretto, M., Orme, A., Rodd, J., Stables M. and Toelken, H. 2017. *Hibbertia fumana* (Dilleniaceae), a species presumed to be extinct rediscovered in the Sydney region, Australia. *Telopea* 20: 143–146 and available at https://openjournals.library.sydney.edu.au/index.php/TEL/article/view/11684/11653

Eco Logical Australia, 2013. *Lot 3, No 90-145 Clifton Avenue Kemps Creek – Flora and Fauna Impact Assessment,* prepared for Sydney Metro Tree Services Pty. Ltd.

Eco Logical, 2015. *Inspection and review of the Hibbertia sp. Bankstown Population at Bankstown Airport*, report for Bankstown Airport Limited, available at http://www.environment.nsw.gov.au/resources/threatenedspecies/s91ands95/Site_Assessment_ReportA06600-2016.pdf

Ecoplanning, 2015. *Flora and Fauna Assessment and Vegetation Management Plan – 90-145 Clifton Road Kemps Creek NSW,* prepared for TreeServe.

Envirotech (2002). *Flora and Fauna Assessment, 81-83 Clifton Avenue, Kemps Creek,* prepared for the Muhammadi Welfare Association.

Hills District Council website, https://webcache.googleusercontent.com/search?q=cache:-vpeh8rPRVEJ:https://www.thehills.nsw.gov.au/files/assets/public/library-documents/local-studies/aborigines-in-the-hills-district.pdf+&cd=3&hl=en&ct=clnk&gl=au

National Parks and Wildlife Service. 2002. *The Native Vegetation of the Cumberland Plain Final Edition*. NSW National Parks and Wildlife Service, Hurstville, available at http://www.environment.nsw.gov.au/resources/nature/cumbPlainMappingInterpguidelines.pdf

NSW Department of Environment, Climate Change and Water, 2010. *Cumberland Plain Recovery Plan*, available at http://www.environment.nsw.gov.au/research-and-publications/publications-search/cumberland-plain-recovery-plan

OEH website *Hibbertia fumana* - Sydney Basin: Distribution and vegetation associations, last updated: 29 May 2018, available at https://www.environment.nsw.gov.au/threatenedspeciesapp/profileData.aspx?id=20323&cmaName=Sydney+Basin

Orchard A.E. 1999. A History of Systematic Botany in Australia, in *Flora of Australia Vol.1*, 2nd ed., ABRS.

Toelken, H. R. and Miller, R. T., 2012. Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in *Journal of Adelaide Botanic Gardens* 25 (2012) 71–96 and available at https://data.environment.sa.gov.au/Content/Publications/JABG25P071_Toelken.pdf

Toelken, H.R., 2013. Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia,* in *Journal of Adelaide Botanic Gardens* 26 (2013) 31-69 and available at https://www.jstor.org/stable/23874401?seq=1#page_scan_tab_contents

James, T., 1997. *Urban Bushland Biodiversity Survey, Stage 1 Western Sydney, Native Flora of Western Sydney, Appendices 2 & 3,* published by NSW National Parks and Wildlife Service, Hurstville NSW.

7. Appendices

Appendix 1. Curriculum Vitae

Robert Miller *Curriculum Vitae*

Contact Details:

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	0410 244 865
Email	janrob02@gmail.com

Current Position:

Principal of Cumberland Flora & Fauna Interpretive Services

Qualifications:

Associate Diploma Horticulture from the University of Western Sydney (formerly Hawkesbury Agricultural College), conferred on 17 April 1982

Journal Articles

H.R. Toelken & R.T. Miller **2012** Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in Journal of the Adelaide Botanic Gardens, Vol. 25.

Miller J and Miller R **2005** Aquatic macroinvertebrates of headwater streams in the south east forests – diversity and conservation management issues, Wetlands (Australia) 23 (1).

Employment Record

1993 – present

Cumberland Flora and Fauna Interpretive Services

Principal - flora surveys, plant identifications, vegetation assessment, project impact assessment, bush regeneration, rehabilitation, habitat enhancement, seed collection and propagation services.

1990 - 1997

Sylvan Grove Native Gardens

Curator of gardens and adjoining bushland - maintenance of and improvement to the plant collection, training and supervision of staff, liaison with other botanic gardens, guided tours, technical advice.

1982 - 1990

Sylvan Grove Native Gardens

Horticulturist Specialising in Australian Flora - collection, propagation, identification, and growing of native plants.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES INFORMATION AND RELEVANT EXPERIENCE

Cumberland Flora and Fauna Interpretive Services have provided technical expertise since 1993 to numerous clients including Local Government, NSW Roads and Maritime, NSW Office Environment Heritage NPWS and community groups.   Following is a list of some of our projects and clients:

REPORT	CLIENT
Expert advice for Conservation Assessment of *Solanum celatum* Eren Delgado 16/04/2018, Science Division, NSW Office of Environment and Heritage	OEH
Saving our Species (SoS) project for *Pomaderris adnata* a post fire population census Grid D 2018	OEH
Provision of expert advice to update the current ecological data for southern NSW threatened flora species, as part of the review of biodiversity assessments under the Biodiversity Conservation Act 2016.	OEH

REPORT	**CLIENT**
Expert witness in botany Residents Against Intermodal Development Moorebank Incorporated v NSW Minister for Planning and Anor – NSW Land & Environment Court Class 1 Proceedings No. 2017/81889. Review of project documentation, in particular the various biodiversity assessments including the BAM assessment for the project and Individual Expert Witness report of Dr David Robertson 15 October 2017; Site inspections to identify the location of and/or potential habitat for *Hibbertia fumana*, *Hibbertia puberula*, *Grevillea parviflora*, *Persoonia nutans*, *Acacia bynoeana*, provision of an expert report in accordance with Division 2 of Part 31 of the UCPR; confer with the other parties experts at a joint conference and produce a joint expert report; and f appear at the section 34 conciliation conference	EDO
Saving our Species (SoS) project for *Pomaderris adnata* a population census 2017	OEH
Central Coast Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Great Lakes Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2015 – Vegetation Consultant	OEH
Clarence Colliery Discharge Investigation April 2015	OEH
Vegetation Assessment as part of the Lachlan Wetlands Condition Assessment Project October 2013 – May 2014	Lachlan Catchment Management Authority
Field expertise and guidance in the Sydney basin to PhD candidate Karen Muscat studying the molecular phylogenetics and morphology of the genus Dianella with close scrutiny of the variation in the D. *caerulea* group of species in eastern Australia	Volunteer to University of Melbourne
Survey for *Pomaderris adnata* to determine population size, structure, occupancy and threats 2014	NPWS Illawarra Region
Survey of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats. Collection of voucher herbarium material for taxonomic review June 2014	OEH
Survey of the southern populations of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats May 2014	OEH
Investigation of works within the Sublime point precinct Illawarra Escarpment State Conservation Area February 2014.	NPWS Illawarra Region
Identification of Hibbertia species in proposed control burn sites Victoria Road precinct Dharawal National Park.	NPWS Illawarra Region
Assessment of impact of infrastructure upgrade Victoria Road, Dharawal National Park – location of threatened species.	NPWS Illawarra Region
APPEAL IN RESPECT OF PROPERTY AT Lot 1 and 2 DP 224431 Site 2 Sturdee Avenue, Bulli	Roy 'Dootch' Kennedy

REPORT	CLIENT
Expert Witness Report Relating to Some Environmental Issues Land & Environment Court of New South Wales PROCEEDINGS NO 10982 of 2012	Roy 'Dootch' Kennedy
Field surveys, collection, pressing, curation of botanical specimens and contributions of notes in association with the manuscript "Notes on Hibbertia subgen. Hemistemma (Dilleniaceae) 7. Eight new species, a new combination and four new subspecies from mainly central New South Wales H.R. Toelken & R.T. Miller 2006 - 10 July 2012	Volunteer to Adelaide Botanic Gardens
Vegetation Surveys and assessments & input into the preparation of REF for proposed car-park and amenities Victoria Road Precinct Dharawal National Park November 12.	NPWS Illawarra Region
Office of Environment and Heritage – Priority Action Statement Expert Consultant Interviews June 2012 – January 2013	OEH
Vegetation Surveys and assessments & input into the preparation of REF for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking tracks in Dharawal National Park input into conservation risk assessments 2011 – 12.	NPWS Illawarra Region
Nomination to list Prostanthera saxicola R. Br. S. Str. as an Endangered Species under the NSW TSC Act September 2011	
Field surveys, collection, pressing and curation of botanical specimens of undescribed Kunzea to assist in the taxonomic circumscription of previously presumed extinct, rare and/or poorly known taxa for Dr. H.R. Toelken Honorary Research Associate State Herbarium Science Resource Centre Department of Environment and Natural Resources SA 2011	Volunteer to Adelaide Botanic Gardens
Significant Plant Survey – Maddens Plains Forest Path to Mount Mitchell Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Significant Plant Survey – Wongawillii Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Kembla State Forest Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Site Inspections and Vegetation Survey of Proposed Minor Track Re-Alignments: Forest Path to Woodward Track & Sublime Point to Austinmer Track Maddens Plains To Sublime Point Precinct Illawarra Escarpment State Conservation Area August 2010	NPWS Illawarra Region

REPORT	CLIENT
Sandon Point Aboriginal Place and Kuradji Lands Vegetation Management Plan April 2010	Illawarra Aboriginal Land Council, Wollongong Council, Southern Rivers Catchment Management Authority.
Forest Path to Woodward Track Precinct Track-head Realignment Maddens Plains IESCA Vegetation Survey April 2010.	NPWS Illawarra Region
Bushland Conservation Project 95 Glendiver Road, The Oaks 2008	A & S Fitzsimmons / Hawkesbury Nepean Catchment Management Authority
Significant Plant Survey – Maddens Plains Forest Path to Woodward Track Precinct Illawarra Escarpment State Conservation Area June 2007	NPWS Illawarra Region
Nomination of Hibbertia "Bankstown Airport" (R.T. Miller & C.P. Gibson s.n. 18/10/2006) as Critically Endangered under the Environment Protection and Biodiversity Conservation Act	Bankstown Bushland Society
Proposal to Demolish A Derelict Amenities Block at Deepwater Park Webster Street Milperra Environmental Assessment of Impacts	Bankstown City Council
Significant Plant Survey – Sublime Point to Panorama House Precinct Illawarra Escarpment Conservation Area August – September 2006	NPWS Illawarra Region
A Consultant for Priority Action Statement Workshop July 2005	NPWS
PHD research assistance – 'The Benefits of Riparian Vegetation in Maintaining Water Quality as Assessed Using Biological Indicators".	UNSW
Plan of Management for Part Lot 11 Dp 1049307 Kurrajong Road Prestons January 2005	Sule College
Preliminary Investigation & Vegetation Survey of Lands At Prestons Bounded By Maxwells Creek, Kurrajong Road, Ash Road & The Western Sydney Orbital December 2003	Sule College
Supply and collection of seed for a research project entitled: Factors Affecting Seed Germination and Microrrihzal Development of the Epacrid: *Woolsia pungens* (2001-2003)	UNSW
Compensatory Habitat Assessment Western Sydney Orbital March 2004	RTA
Compensatory Habitat Assessment Western Sydney Orbital July 2002	RTA
Compensatory Habitat Assessment of Flora at Rouse Hill, Doonside, Cecil Hills & Kemps Creek for The Western Sydney Orbital March 2002	RTA
Compensatory Habitat Assessment Western Sydney Orbital November 2001	RTA
Preliminary Vegetation Survey Between Lawson Rd & Alfords Point Rd, Menai as Part of The Proposed Bangor Bypass 2001	RTA
8-Part Tests for The Proposed Bangor Bypass 2000	RTA
Preliminary Vegetation Survey for The Proposed Bangor Bypass 2000	RTA
Species Impact Statement for the Western Sydney Orbital 2000	Sinclair Knight Mertz

REPORT	CLIENT
Review of Environmental Assessments – Proposed Cricket Ground - Louisa Reserve, The Crest of Bankstown 2000	Bankstown Bushland Society
Review of Environmental Assessments – Proposed Olympic Criterium Circuit the Crest Statement of Environmental Effects	Bankstown Bushland Society
Vegetation Survey – 60 Yanderra Road, Yanderra 1999	Mr. Brian Timmis
Review and Comments on Environmental Assessment – Bankstown City Council - Proposed Cricket Ground – 8 – Part Test- The Crest 1999	Bankstown Bushland Society
Vegetation Survey and Review of Proposed Sand Mining Restoration Works – Howard Park, Lansvale 1999	Chipping Norton Lakes Authority
Rare Species Survey – Blue Mountains & Central Western Slopes 1999	National Parks & Wildlife Service
Vegetation Survey - Kookaburra Road and Camden Valley Way Intersection 1999	Roads & Traffic Authority
Chullora Detention Basin Wetlands Habitat Enhancement 1998	Business Land Group DUAP
Vegetation Study Maxwells Creek Trunk Drainage Stage 1 Vegetation Assessment 1998	Bewsher Consulting
Vegetation Study Prestons Urban Release Area Part 3 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 2 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 1 1998	Liverpool City Council
Survey of Remnant Flora for Proposed Nth Liverpool Rd to Edensor Rd Interim Transitway 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management Discussion Paper 1998	Roads & Traffic Authority
Eastern and Western Alignments WSO Cecil Hills Flora Study 1998	Roads & Traffic Authority
Valmay Road Development Vegetation Study 1998	LesryK Pty Ltd
Western Sydney Orbital Prestons To West Baulkham Hills Descriptive Inventory of Remnant Bushland 1998	Roads & Traffic Authority
Vegetation Survey River Road M5 East 1998	Roads & Traffic Authority
Tree Survey, Great Western Highway, Faulconbridge 1998	Roads & Traffic Authority
Eve & Marsh Street Wetlands M5 East 1997	Roads & Traffic Authority
Beverley Grove Bush M5 East 1997	Roads & Traffic Authority
Vegetation Survey - Salt Pan Creek Bridge Duplication M5 East 1997	Roads & Traffic Authority

REPORT	**CLIENT**
Survey of Flora: Trees and Shrubs, Princes Highway Interchange M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Adjacent to Proposed Exhaust Stack Henderson Avenue, M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Illoura Reserve, Adjacent to Air Intake Vent M5 East 1997	Roads & Traffic Authority
Lansdowne Reserve Survey of Remnant Flora 1997	Bankstown City Council
Villawood Drain Vertebrate Fauna Survey 1997	Bankstown City Council
Kelso Wetlands Survey of Remnant Flora 1997	Bankstown City Council
Deverall Park Survey of Remnant Flora 1997	Bankstown City Council
Louisa & McClean Reserves Bass Hill Survey of Remnant Flora 1997	Bankstown City Council
The Crest of Bankstown Survey of Remnant Flora 1997	Bankstown City Council
Lawson Bridge Roadworks Survey of Remnant Flora 1997	Roads & Traffic Authority
Davidson Street Scrub Survey of Remnant Flora 1997	Strathfield Council
Freshwater Creek Bushland Survey of Remnant Flora 1996	Bankstown Bushland Society for the EPA
Vegetation Survey Forest Lawn Cemetery Roadworks, Leppington 1996	Roads & Traffic Authority
Vegetation Survey Catherine Fields Road Intersection, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Springfields Road Intersection and Camden Valley Way, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Deepfields Road Intersection Camden Valley Way, Catherine Fields 1996	Roads & Traffic Authority
Picnic Point Reserve Vegetation Survey 1996	Bankstown City Council
East Hills Park Vegetation Survey 1996	Bankstown City Council
Monash Reserve Vegetation Survey 1995	Bankstown City Council
Vegetation Consultant on Plan of Management for Cox's Creek for the Endangered Green and Gold Bell Frog 1995	Urban Bushland Management
Smith Park Vegetation Survey 1995	Bankstown City Council
Flora and Fauna Survey, Villawood Stormwater Channel 1995	Bankstown City Council
Virginius Reserve Vegetation Survey 1994	Bankstown City Council
Carysfield Park Vegetation Survey 1993	Bankstown City Council

Ongoing research projects:

Private taxonomic research into the Australian plant genera Prostanthera, Westringia, Dianella, Thelionema, Viola and Hibbertia.

Private research into the invertebrate fauna of the Illawarra with particular emphasis on the Mayfly genus *Atalophlebia*

Flora of Bankstown" a botanical inventory

Botanical inventories of the Sublime Point and Maddens Plains precincts in the Illawarra Escarpment State Conservation Area

Other Publications & Reports

Miller, R.T. (1984 to 2006) numerous papers for the Prostanthera and Westringia Study Group Newsletters.

Miller, R.T. (1991) Vegetation Consultant on Eloura Nature Reserve Vegetation Survey: Report to Liverpool City Council, Greening Australia.

Miller, R.T. Vegetation Consultant on Salt Pan Creek Stage 1 Vegetation Survey: Report to Bankstown City Council, Ian Olsen.

Gibson, C.P. & Miller, R.T. Plant Species List for Bankstown's Natural Heritage: McLaughlin, L., BCC.

Gibson, C.P. & Miller, R.T. Flora of Bankstown Scientific Inventory of Botanical Heritage: Report to Australian National Parks and Wildlife Service, Gibson, C.P. and Miller, R.T. (in preparation).

Nomination of Prostanthera saxicola R. Br. s. str. As an Endangered Species under the NSW TSC Act November 2011

Special Projects

- "Flora of Bankstown" a botanical inventory
- Founder & Convener Cookson's Landcare Group Bulli (2003 – 2007)
- President, Society for Growing Australian Plants, East Hills Region, 1987-1995.

- Vice President, Society for Growing Australian Plants, East Hills Region, 1996.
- Plant Steward, Society for Growing Australian Plants, East Hills Region, 1987-1996.
- Leader of the Prostanthera Study Group Australian Plant Society, 1992 - 2010.
- Editor and publisher of Prostanthera & Westringia Study Group's Newsletter *The National Mint* and the Study Groups' Journal – *Lasianthos*.
- Vice President and Founding Member, Bankstown Bushland Society.
- Coordinator Grants Application, Bankstown Bushland Society.
- Bushland Regeneration Grants Project Manager, Bankstown Bushland Society:
  - Deverall Park Restoration and Rehabilitation Swamp Woodland ($17,880).
  - The Crest of Bankstown Restoration and Rehabilitation ($27,850).
  - Airport and Ashford Reserves Restoration and Rehabilitation Swamp Woodland ($45,000).
- Co-recipient of Save the Bush grant for Flora of Bankstown by Hon. Ross Kelly, Minister for Arts, Sports and Environment, 1992-93 ($11,050).
- Founding Member of Illawarra Grevillea Park, Bulli.
- Curator, Lamiaceae collection, Illawarra Grevillea Park, Bulli.
- Former Bankstown City Council's Bushfire Taskforce Community Representative.
- Former presenter of an adult education course in gardening at Bankstown Evening College.
- Development and curation of a private regional herbarium.
- Expert Witness for NSW Police murder trial
- Former appointee as Trustee of the Georges River State Recreational Trust by the Minister for the Environment (the Hon. Tim Moore).

Appendix 2. Taxonomic details for identification of *Hibbertia fumana*

Photo 46: *Hibbertia fumana* indumentum of axillary shoot and +/- sessile flower bud (R.T. Miller)

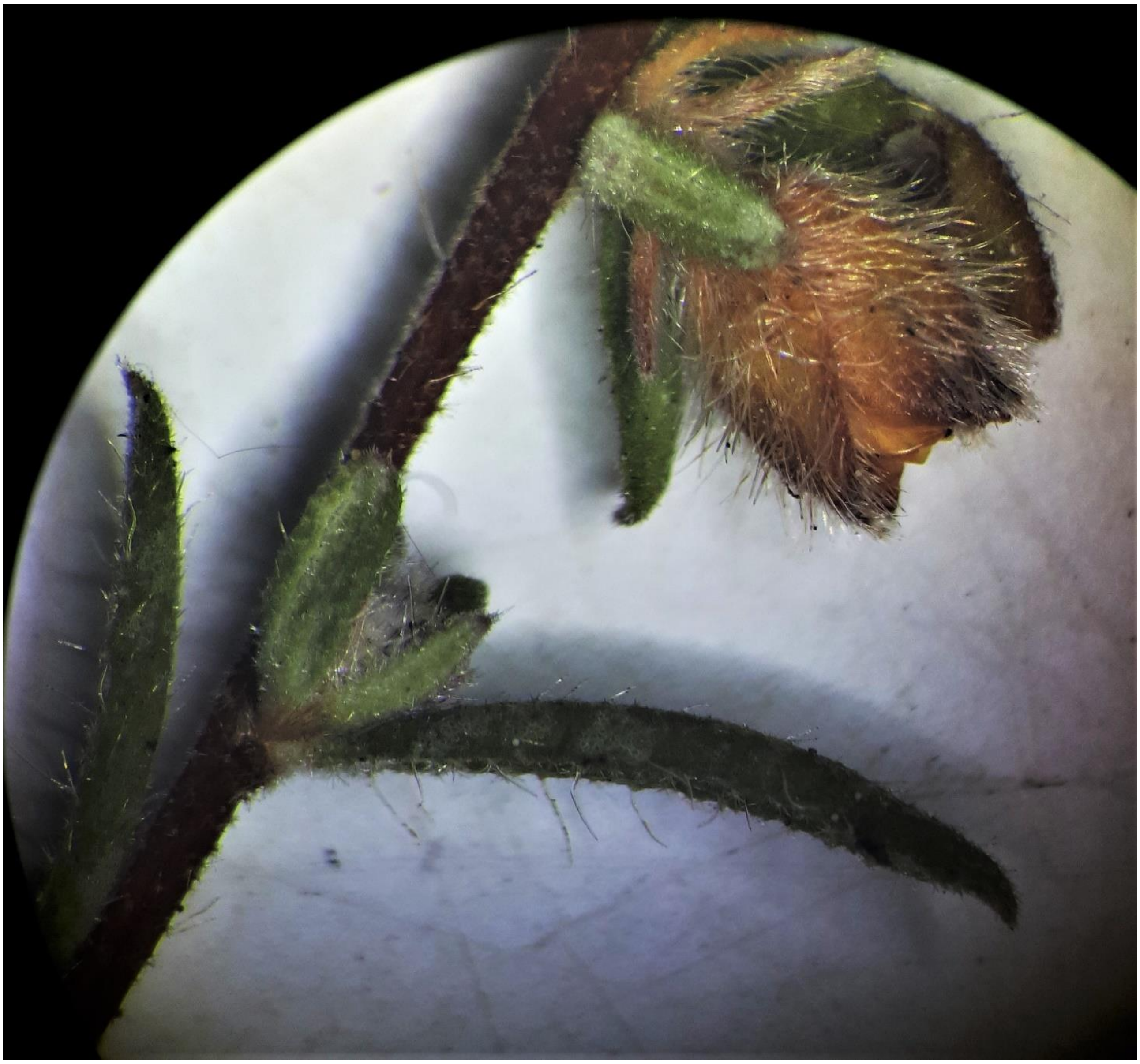


Photo 47: *Hibbertia fumana* indumentum of leaf, axillary shoots and flower buds (R.T. Miller).

Photo 48: *Hibbertia fumana* elongated flower peduncle after petal dehiscence on terminal shoots and indumentum characteristics of leaf undersurface and calyxes. (R.T. Miller).

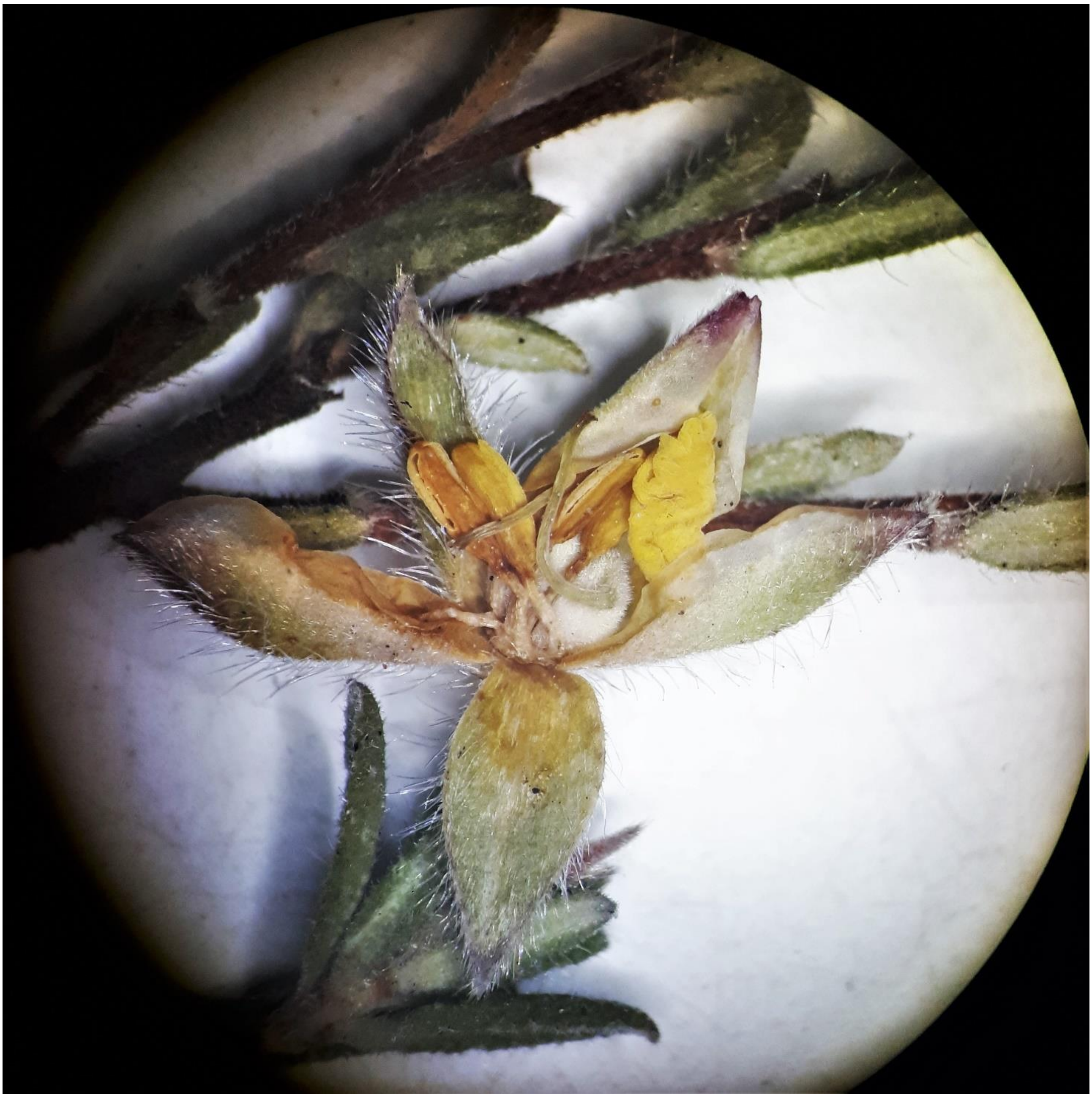


Photo 49: *Hibbertia fumana* flower morphology (R.T. Miller).

Photo 50: *Hibbertia fumana* interpetiolar tuffs in leaf axils and short subequal multiangulate fascicled hairs characters of the branchlets (Robert T. Miller)

Photo 51: Tomentum characteristics of *Hibbertia fumana* approximate 5 cm from shoot apex. (R.T. Miller)

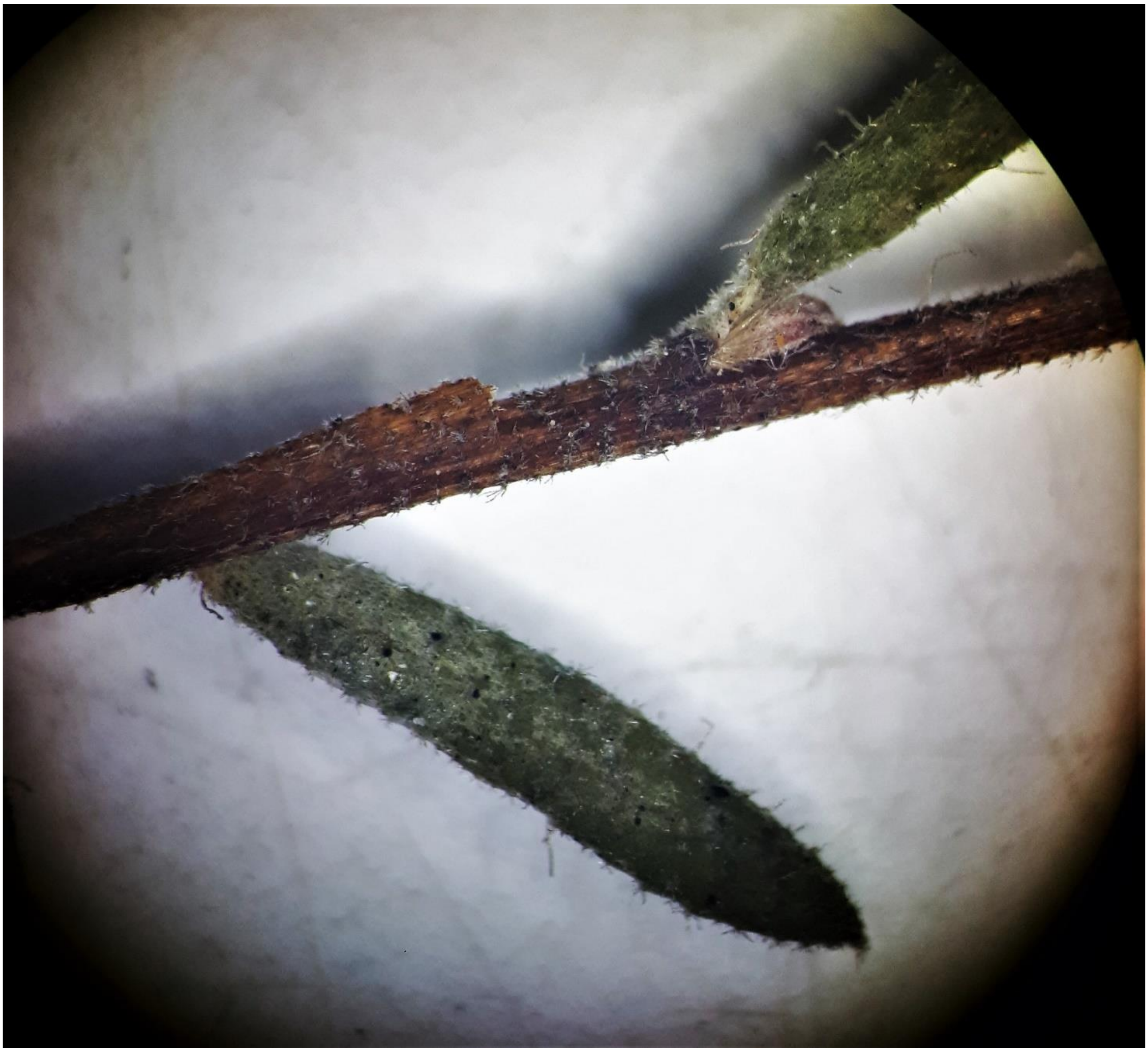


Photo 52: Leaf upper surface showing a reduction in tomentum.

Note: Leaf sample is approximately 12cm from tip (R.T. Miller).

Appendix 3. Comparison of taxonomic details for *Hibbertia* species

Photo 53: *Hibbertia pedunculata*: growing under an electricity easement.

A mature well-developed plant of *Hibbertia pedunculata* free of competition is particularly floriferous and unlikely to be misidentified as *Hibbertia fumana*

Photo 54: *Hibbertia pedunculata* showing flower characteristics noting the 3 styles and large number of anthers surrounding and obscuring the ovaries

Photo 55: *Hibbertia pedunculata* showing leaf, peduncle and calyx characteristics.

Photo 56: Plant of *Hibbertia empetrifolia* (R.T. Miller).

Photo 57: Closeup of leaf undersurface of *Hibbertia empetrifolia* (R.T. Miller).

Photo 58: *Hibbertia aspera* mature plant showing flower, leaf characters and a propensity to have woody branches

Photo 59: *Hibbertia aspera* flower showing distinct arrangement of anthers bent over the ovaries

Photo 60: *Hibbertia aspera* (R.T. Miller).

Photo 61: *Hibbertia aspera* showing tomentum on suckering new growth (R.T. Miller)

Photo 62: *Hibbertia dispar* showing procumbent growth habit, small-leaves and pedunculate flowers (R.T. Miller).

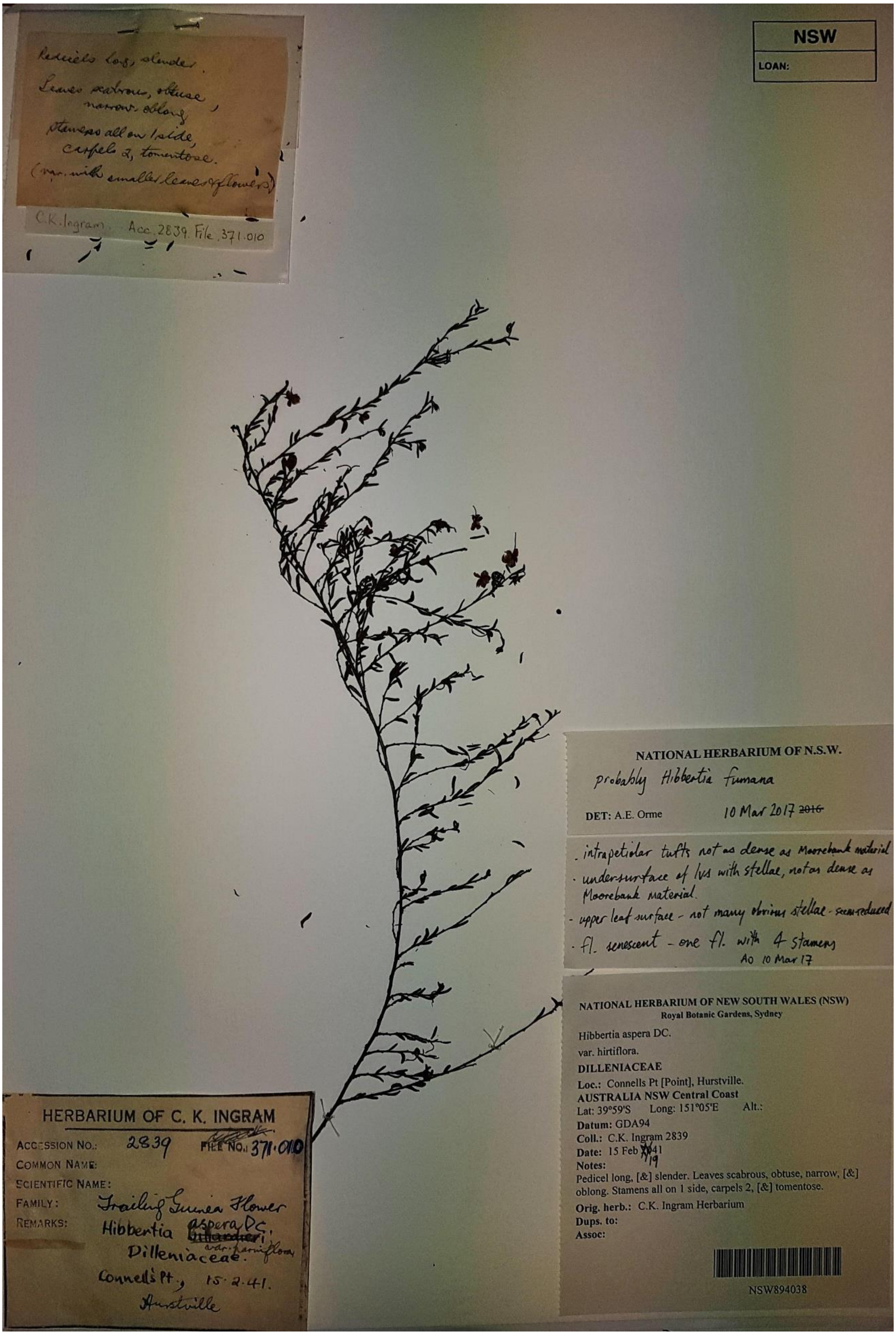
Photo 63: *Hibbertia dispar* showing apparent glabrous leaves and stems and +/- glabrescent floral parts of older growth in which much of the tomentum has “worn off”.

Photo 64: *Hibbertia dispar*: closeup of new growth showing tomentum characteristic

Photo 65: *Hibbertia dispar* showing much of the tomentum of the calyxes being “worn off”.

Photo 66: *Hibbertia dispar* showing the tomentum of the calyxes before being “worn off”.

Appendix 4. Specimen of *Hibbertia fumana* from Connells Point 1941



Expert report – *Hibbertia puberula*

Hibbertia puberula species group – Wilton and GMAC, Robert Miller, August 2018

Hibbertia puberula species group – WSA and GPEC, Robert Miller, December 2018

Strategic assessment for Cumberland Plain Conservation Plan

Hibbertia puberula species group

Hibbertia puberula subsp. *glabrescens* at Bankstown Airport

Report prepared for Department of Planning and Environment

By

Cumberland Flora & Fauna Interpretive Services

Robert Miller - August 2018

Executive Summary

Hibbertia puberula subsp. *extensa* and subsp. *puberula* are listed as an Endangered Species under the *Biodiversity Conservation Act 2016*. *Hibbertia puberula* subsp. *glabrescens* is listed as a Critically Endangered Species, being known from only one population at Bankstown. The species group is assessed as data-poor.

Survey for this report was limited by time constraints, lack of access to private property, survey outside the species' flowering season and years of preceding drought conditions. Assessment of potential habitat area relied on the expected presence of likely habitat, based on habitat of extant populations.

Specific habitat niches of potential occurrence include upper drainage lines, seepages especially those associated with exposed sandstone bedrock or slabs, margins of hanging swamps / wet heath, exposed sandstone rock plates, and large and small occurrences of colluvial or alluvial deposits.

Positive identification to species and subspecies requires flowers, which were not available, so *Hibbertia* that had leaf and stem characteristics consistent with *H. puberula* were considered to be that species. Despite the limitations, survey located three new populations of *Hibbertia* that had leaf and stem characteristics consistent with *H. puberula* within the growth areas and adjacent to the footprint.

H. puberula is a small shrub that could be severely affected by anthropogenic impacts resulting from development edge effects, particularly in areas downhill of development.

The assessment identified:

- Likely habitat for *Hibbertia puberula* subsp. *extensa* occurs within the footprint in the southern part of the WGA, habitat would be small seepages or wet heath within an area of 23ha.
- A further 278ha of land that could contain habitat niches for *H. puberula* subsp. *extensa* is adjacent to the footprint in the southern section of the WGA and the eastern side of the GMGA between Appin and Wedderburn.
- Likely habitat for *Hibbertia puberula* subsp. *glabrescens* occurs at Menangle Park. An area of approximately 92ha could contain likely habitat niches within the growth area footprint, and a further 31 ha of land containing likely habitat niches adjacent to the footprint.
- Likely habitat for *Hibbertia puberula* subsp. *puberula* occurs outside the development footprint at Milton Park, Kayess Park and in the vicinity of Bunbury Curran Creek reserve.
- Likely habitat for subspecies *puberula* within the development footprint occurs at Menangle Park (92ha), Gilead and Appin areas (8ha) and WGA (65ha).
- Likely and known habitat for subspecies *puberula* adjacent to the development footprint occurs at Menangle Park (31ha), Gilead and Appin areas (380ha) and WGA (680ha).

Survey during the flowering period is recommended, to identify the subspecies of *H. puberula* and to locate further populations within and adjacent the growth areas.

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Abbreviations

ALA	Atlas of Living Australia
AVH	The Australasian Virtual Herbarium
BAM	Biodiversity Assessment Method
BC Act	Biodiversity Conservation Act 2016
CFFIS	Cumberland Flora & Fauna Interpretive Services
DPE	NSW Department of Planning and Environment
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
GMGA	Greater Macarthur Growth Area
IBRA	Interim Biogeographic Regionalisation for Australia
OEH	NSW Office of Environment and Heritage
PCT	Plant Community Type
sp./spp.	species (species singular / plural)
s. str.	sensu stricto – in the narrow sense
subsp.	subspecies
WGA	Wilton Growth Area

1. Introduction

1.1 PURPOSE

The purpose of this expert report is to determine the potential for future urban development in identified growth areas of Western Sydney to impact on *Hibbertia puberula*, the subspecies of which are listed as an Endangered or Critically Endangered Species under the *Biodiversity Conservation Act 2016*. This report forms part of the Cumberland Plain Conservation Plan, which will be assessed under the:

- Biodiversity certification under the *Biodiversity Conservation Act 2016* (BC Act)
- Strategic assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Biodiversity Assessment Method (BAM) sets out the framework and methods to be used for assessment of impacts to biodiversity to provide preferred conservation outcomes while also supporting the development approval process. Under the BAM an expert report can be used when adequate survey is not possible. An expert report can only be used for species to which species credits apply.

The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report. The report must set out whether the subject species is likely to be present at the development site, and if present then the report must estimate, in the case of a species such as *Hibbertia puberula*, the area of habitat where the species is likely to be impacted, as well as areas from which it is known to occur in which it will be impacted.

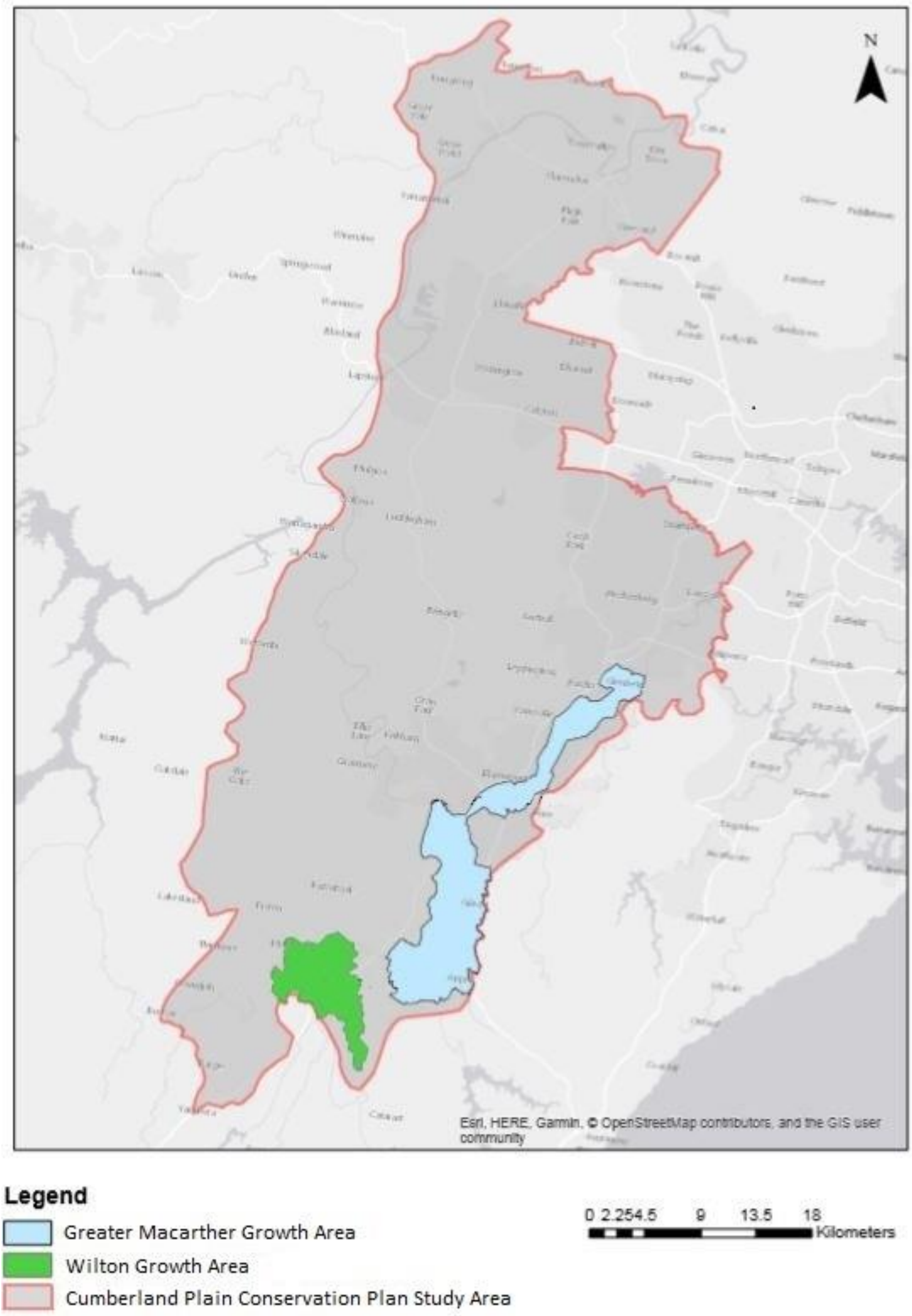
1.2 PROJECT CONTEXT

The NSW Government is planning for future urban development in Western Sydney. Four growth areas have been identified, these are Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These growth areas are all located within the Cumberland Subregion in version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) (2016).

As part of the planning for this future development, the Department of Planning and Environment (DPE) is preparing the Cumberland Plain Conservation Plan. This is a strategic regional assessment that will lead to the identification of preferred conservation outcomes for the Cumberland subregion.

1.3 STUDY AREA

Map 1 shows the Cumberland Plain Conservation Plan Study Area and the two growth areas of Greater Macarthur (GMGA) and Wilton (WGA).



Map 1: Cumberland Plain Conservation Study Area and Growth Areas

Map source: NSW Department of Planning and Environment.

1.4 SPECIES SURVEYS

<u>Survey timing</u>

Survey for species such as *Hibbertia puberula* are usually carried out during the flowering period of October to December because the plant is a small shrub which can be quite cryptic. The bright yellow flowers, although small c. 10 – 20mm are readily discernible in bushland environs. Surveying in the flowering period makes species counts more reliable and relatively easy. Without flowers the tiny green leaves can hide amongst leaf litter, grasses and other ground covers making species counts near impossible and extremely unreliable.

The survey for this expert report was initially required to be completed within the month of June, when the species is not in flower. Further, the survey follows several very dry years which has caused high levels of leaf fall from trees and retraction of many shrubs to ground level. The following two photos show a close-up view of a *Hibbertia puberula* and the same plant from 2m away. These photos demonstrate the difficult task of finding *Hibbertia puberula* in the field when it is not in flower.

Photo 1: *Hibbertia puberula* plant at Smith's Creek Reserve at Campbelltown.

Photo on the left shows a *Hibbertia puberula* plant, the photo on the right shows the same plant from 2m distance. Scale: individual *Hibbertia* leaves are c.5mm. The photo depicts the largest and most obvious plant found.

Survey methods

To compensate for some of these difficulties the survey for this report followed the following steps:

- Visit known localities of the species, locate some *Hibbertia puberula* plants, and take particular note of the habitat characteristics, plant habit, co-occurring species and population density in the context of the protracted rainfall deficit and;
- Examine the Plant Community Type maps provided by the Department of Planning and Environment;
- Locate potential habitat sites based on the mapping and expert knowledge of the plant habitat requirements;
- Visit as many of these potential habitat sites as possible, considering time and access constraints; and
- Survey these potential habitat sites for the species.

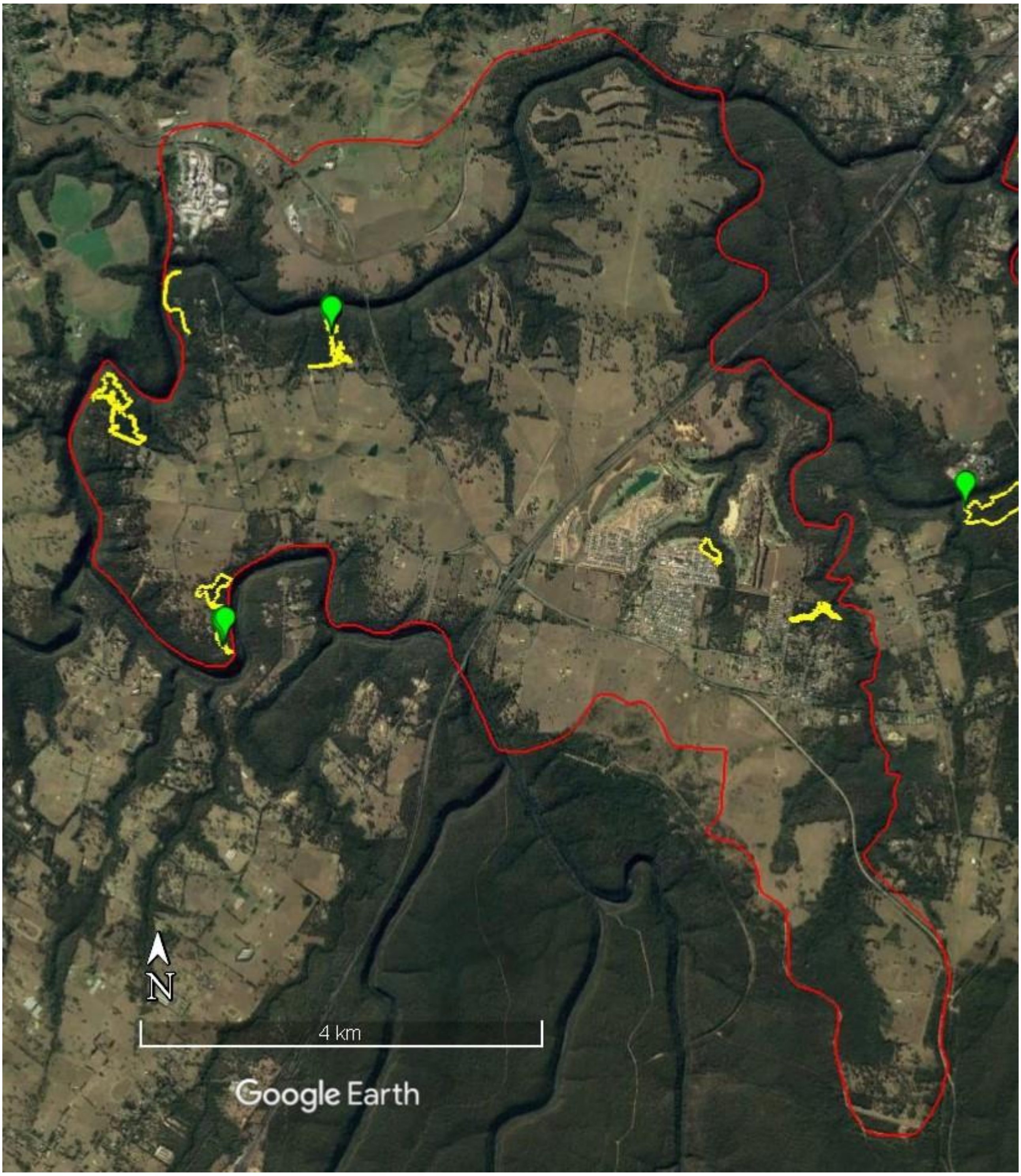
Surveys for the biodiversity assessment informing the development of the biocertification were constrained by private lands access issues, time and the overall size of the biocertification area.

Surveys undertaken by Ecoplanning and Biosis consultancies since 2017 have largely been confined to the deemed "development footprint" and have been undertaken predominantly to comply with the BAM protocols for vegetation sampling for assessment purposes with little survey for threatened species. As such, no new occurrences of threatened *Hibbertia* species including *Hibbertia puberula* were recorded by Biosis or Ecoplanning through their survey efforts.

Access to a spatial viewer was provided by DPE to assist in the expert assessment. Whilst this tool has been useful in gaining a general overview, the information presented is limited and is acknowledged to "have been acquired and developed from numerous sources of differing dates, accuracy and completeness and may include errors in extent and content". CFFIS are not aware of any surveys performed specifically for *Hibbertia puberula* by DPE, Ecoplanning or Biosis Consultancies in the context of this project. The broadscale mapping of plant community types (PCTs) that was provided to assist with this assessment cannot identify the habitat niches that may be present on a localised scale.

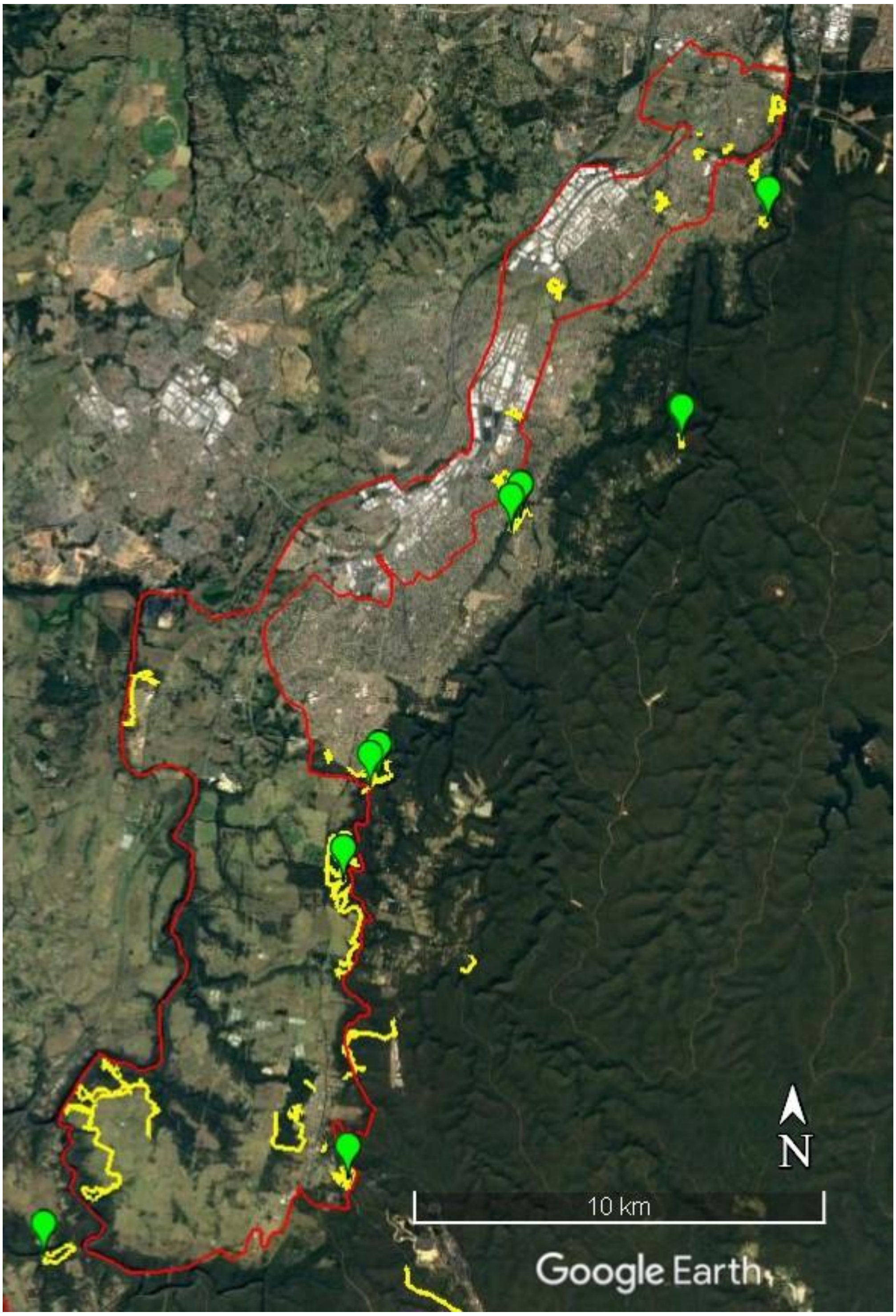
The surveys undertaken by CFFIS as part of this expert report relied on assessment of known habitat traits of extant sites. PCT mapping and aerial digitised photography were used to select potential habitat areas for targeted surveys.

Map 2 and Map 3 show the sites that were surveyed for this assessment.



Map 2: Google Earth map of Wilton Growth Area showing the tracks of CFFIS survey.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow, location of small leaved *Hibbertia* sp. with vegetative morphology +/- consistent with *H*. *puberula* marked in green.



Map 3: Google Earth map showing Greater Macarthur Growth Area and CFFIS survey tracks.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow, location of a small leaved *Hibbertia* sp. with vegetative features consistent with *H. puberula* marked in green.

NOTE: The absence of green dots along the survey route does not equate to the species not being present in that locale, only to the fact that it was not observed.

<u>Species identification</u>

When we located a small-leaved *Hibbertia* specimen that had macro morphological features resembling that of *Hibbertia puberula,* a specimen was retained for later microscopic examination. Selected specimens were taken according to protocols. Due to the time of the year and prevailing drought conditions plants were not in flower and depauperate, such that any specimens removed consisted of very small fragments (eco-scraps) most only a few cm in length.

This is far from ideal, the challenge was to then identify the eco-scraps to species using only stem and leaf characteristics, as shown in the drawing below (Toelken 2000). The small branchlets of each specimen was compared to voucher material of *Hibbertia puberula* under a dissecting microscope. Note that positive identification of the species requires flowering parts, however, some species of *Hibbertia* can be ruled out based on stem and leaf characteristics.

Microscope photographs of *H. puberula* characteristic features used during this survey by CFFIS are provided in Appendix 3.

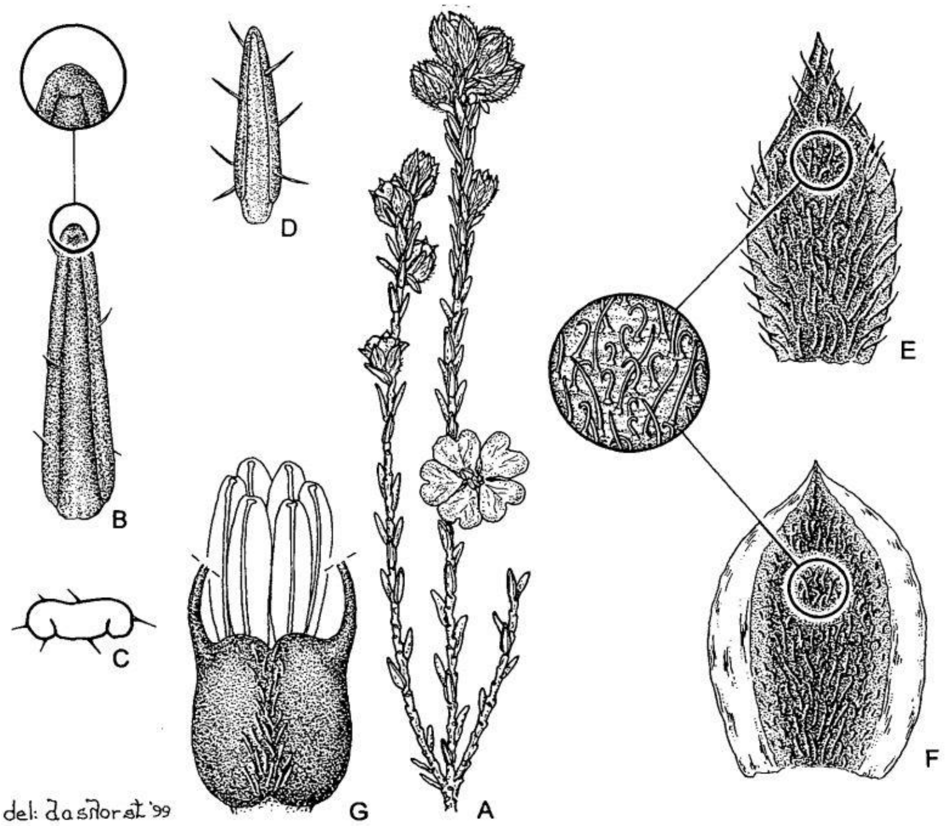


Fig. 7. ***H. puberula*.** **A**, Flowering branch; **B**, cauline leaf; **C**, tranverse section; **D**. bract; **E**, outer calyx lobe; **F**, inner calyx lobe; **G**, two glabrescent ovaries. (**A–G**, *J.M.Lindale NSW 101952*; **A** ×1; **B**, **D** ×10; **C** ×15; **E**, **F** ×6; **G** ×20).

Figure 1: Line drawing of *Hibbertia puberula* distinguishing characteristics.

All small narrow leaved *Hibbertia* specimens found during the survey were examined under the microscope to determine if the stem and leaf characteristics matched those of *Hibbertia puberula.* Essential characters considered include leaf dimensions and shape, the leaf undersurface having revolute margins and recessed to bulging broader central vein obscuring the leaf undersurface, and branchlets having interpetiolar tuffs of hairs. Some of these characters are shown on Figure 1Figure 2. Where the majority of characters were a match, the species could not be ruled out of consideration and so was assumed to be the subject species. It should be noted that these characters vary slightly between sub-species, as shown in Figure 2 below, and confident identification to sub-species requires flower characteristics.

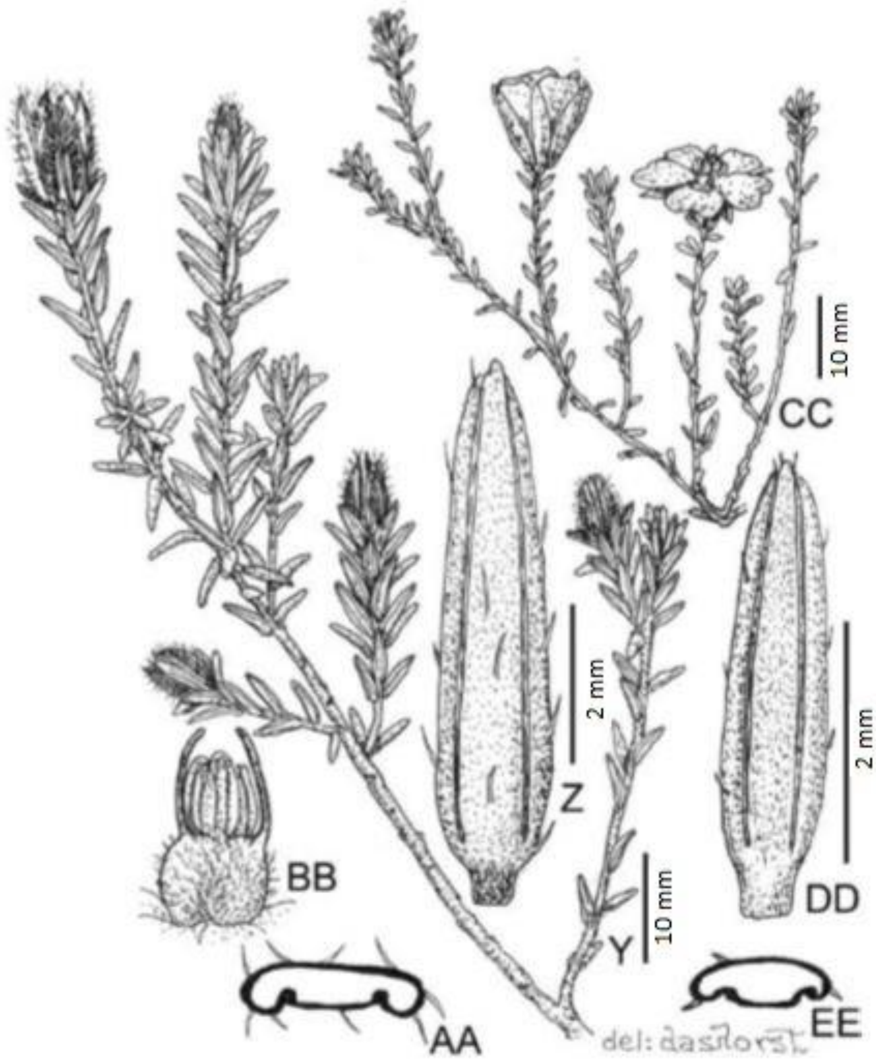


Figure 2: Line drawing of *H. puberula* subs. *extensa* and subsp. *glabrescens*.

Key: *H. puberula* subs. *extensa* Y flowering branch; Z leaf from below; AA transverse section through mid-leaf; BB flowers with petals and calyx removed. *H. puberula* subs. *glabrescens*: CC flowering branch; DD leaf from below; EE transverse section through mid-leaf.

A requisite taxonomic feature is hair types and the specific arrangement on leaf and branchlets. The persistence of the hairs on various parts of *Hibbertia* is variable according to the species. In many species such as *Hibbertia puberula,* hairs on the leaves and stem are notoriously non-persistent and "soon wear off" (Toelken pers. comm.). The full range hair expression is best observed on new and recent growth (Miller pers. obs.). The lack of new or recent growth is a significant limiting factor in the determination of the specimens as at all sites the vegetation was in severe drought stress.

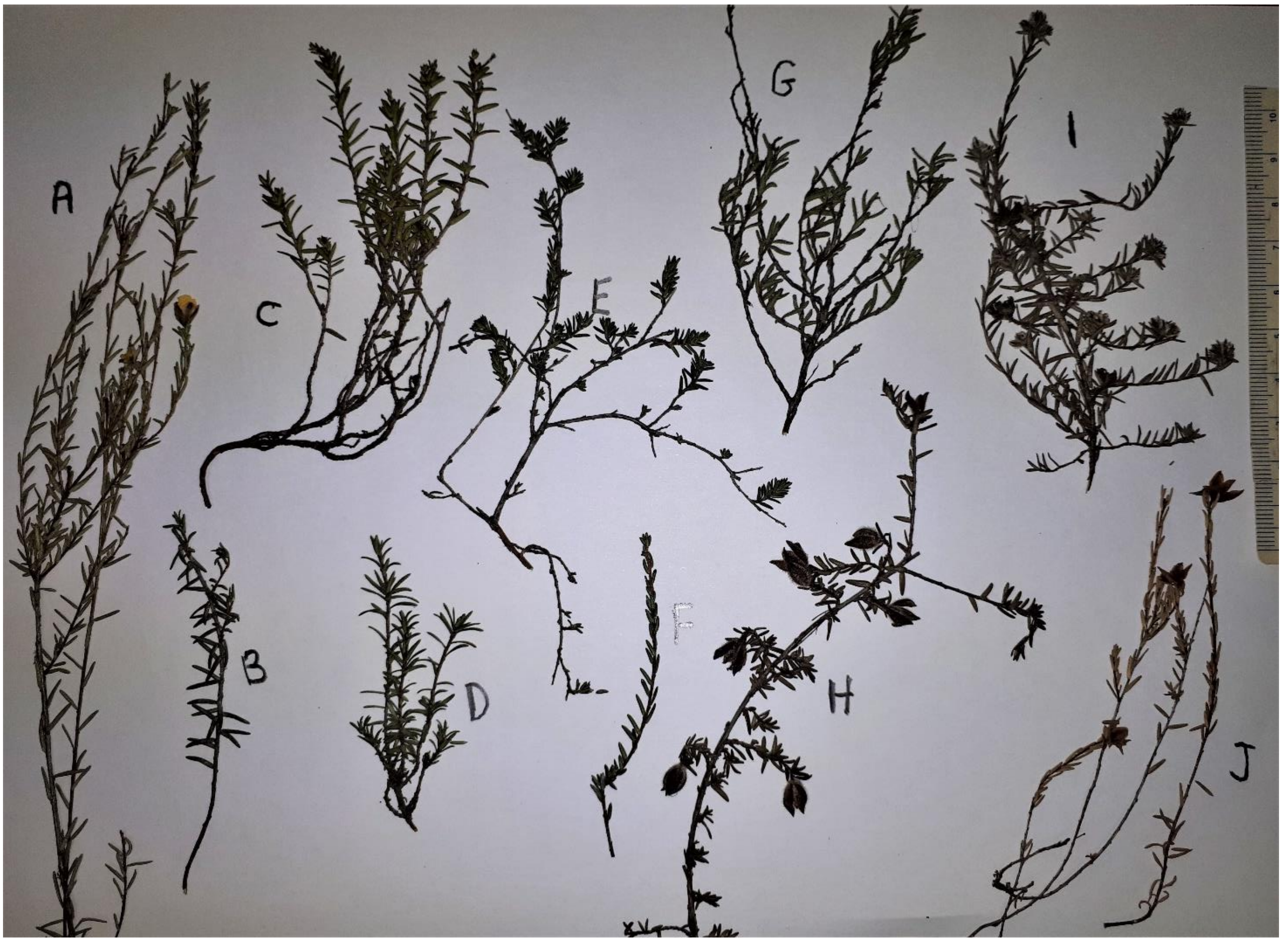


Photo 2: A selection of *Hibbertia* voucher specimens, photo from c. 30cm away.

Key - A: *H. puberula* subsp. *puberula* Moorebank; B: *H. puberula* subsp. *puberula* Smiths Creek Reserve; C: *H.* sp. *puberula?* Round Hill Road, Wilton; D: *H.* sp. *puberula?* Shingle Hill, Wilton; E: *H. puberula*? FT SH1.4 Gilead; F: *H. puberula* subsp. *extensa* juvenile growth, south of Appin Road; G: *H. empetrifolia* Appin; H: *H. puberula* subsp. *extensa* Bonnum Pic vicinity; I: *H. puberula* subsp. *puberula* Lucas Heights and J: *Hibbertia puberula* subsp. *glabrescens*. (Photo by R.T. Miller August 2018). Morphological features are difficult to ascertain without microscopic examination.

Hibbertia sp. *puberula?* is a small leaved *Hibbertia* sp. with vegetative morphology +/- consistent with *H. puberula*.

Survey assumptions

The survey was carried out in June to August, during the non-flowering period, and it was not feasible to survey all the many bushland remnants within the Wilton and Greater Macarthur growth areas. As such, the first assumption was:

Assumption 1. *Hibbertia puberula* would not be found growing in bushland that is not its known habitat.

The author is familiar with the species' types of habitat at Bankstown Airport, the Moorebank Intermodal site, and locations such as Smiths Creek Reserve and Simmo's Beach Reserve. Using this knowledge of geology, soil and vegetation type that is the known habitat of the species, areas of bushland that would not be suitable habitat were ruled out of the assessment.

Using this knowledge of habitat requirement, the second assumption was:

Assumption 2. *Hibbertia puberula* is likely to be present in areas that are known to be suitable habitat.

Although there are occasions where the plant occurs in higher densities, the most common occurrences are rare and scattered throughout suitable habitat or low populations numbers localised to a small habitat niche. Areas of suitable habitat were surveyed using the random meander method. When only one or no individual specimens were located using this method, it was deemed likely that the species would occur scattered throughout these areas of suitable habitat.

The survey was carried out following several years of drought in western Sydney, and many shrubs forbs and grasses were dead. This led to the third assumption:

Assumption 3. In areas of suitable habitat, where *Hibbertia puberula* specimens have not been found, the species could be present in the soil seed bank.

There was a high amount of leaf fall in most locations and most locations have not recently been burnt. In these areas the species is likely to be present in the soil seed bank. An example is the Basin Reserve (outside the growth areas), where the species was previously scattered throughout suitable habitat within the reserve. Since the drought and control burning, the species appears to be very rare at this site but is likely to be still present in the soil seed bank in some of the unburnt habitat.

Identification to species of the *Hibbertia* relies on characters of the flowers. The survey was carried out in the non-flowering period which led to the fourth assumption:

Assumption 4. That specimens matching the stem and leaf characteristics of *Hibbertia puberula* could most likely be that species.

1.5 JUSTIFICATION FOR USE OF EXPERT REPORT

The BAM allows for situations where an expert report will be required to replace or complement survey effort at a development site. While there has been some field survey for the Strategic Biocertification assessment, the area covered by the proposed GMGA and WGA are extensive and there have been issues with gaining access to some of the private properties.

An expert report is required to assess potential impact to *Hibbertia puberula* for the following reasons:

<u>Insufficient survey</u>

A large extent of the identified growth areas could not be surveyed because it was on private property and could not be accessed within the project timeframe. Expertise was required to identify and survey potential species habitat and propose additional habitat based on extant populations and prior knowledge of the species.

<u>Survey out of flowering season</u>

Survey during June and July is at the non-flowering period for the species, so finding cryptic species of *Hibbertia* in the field is difficult even for an expert and more so for someone who is not an expert (refer Photo 13).

<u>Survey during drought</u>

The Western Sydney region has been experiencing dry conditions for several years, which means that the *Hibbertia puberula* plants are likely to be under severe drought stress and partially defoliated making this small and cryptic species more difficult to locate. It requires an expert in the species to locate and identify rare *Hibbertia* under these conditions.

Found in bushland at the end of Roundhill Road, Wilton, this plant shown on the left has vegetative morphological characters +/- consistent with *H*. *puberula*.

Scale reference: leaves are approximately 5mm in length.

Photo 3: A severely drought stressed plant of *Hibbertia* species.

Photo 3 shows the largest specimen of *Hibbertia* species with vegetative features consistent with *H*. *puberula* that was found within the Wilton growth area.

The plant is severely drought stressed, and it is likely that other plants in the area have succumbed to drought. The area had not been burnt for some years, so it is likely that the species apparent population has retracted and survives in numbers in the soil seed bank.

<u>Reliable species identification</u>

Identification of the genus *Hibbertia* to species level requires examination of flower parts in combination with stem and leaf characters, especially tomentum type and density. It is not practical nor reliable to identify small leaved species in the field as many of these morphological features require microscopic examination and comparison to known voucher specimens. This needs to be carried out by an expert in *Hibbertia*.

The use of an expert report to complement survey of the growth areas avoids the problems associated with *Hibbertia* misidentifications. *Hibbertia* species can be misidentified in vegetation assessments, frequently being dismissed as "common" species.

The misidentification of both *Hibbertia puberula* and presumably *Hibbertia fumana as Hibbertia riparia* during past surveys raises the possibility that other records of *Hibbertia riparia* may in fact be *Hibbertia puberula*. Searches of the databases revealed prior surveys undertaken for various projects have recorded *Hibbertia riparia* to occur at a number of locales within and adjacent to the GMGA and WGA (refer Appendix 5).

The *Hibbertia riparia / H. calycina / H. hirsuta* groups are currently under further detailed evaluation (Toelken pers. com.). *Hibbertia riparia* R.Br. s. str. occurs in Tasmania (Toelken) and is unlikely to occur in NSW, the name being misapplied (pers. com. Toelken). It was therefore anticipated that the identifications of *Hibbertia riparia* would be found to be incorrect.

Two recorded *H. riparia* sites were inspected for this assessment, one at Douglas Park (12 June 2018) and one at Wilton (17 August 2018). A third Site at Appin was not surveyed due to access constraints.

The *Hibbertia* sp. observed off Douglas Park Drive was found to have vegetative features consistent with *H. puberula*. The Wilton locale was inspected in August and it was found that the severity of impact to the bushland from drought had markedly increased. The site was extremely dry following the years of drought, the ground was covered with a thick layer of leaf litter, and many plants were dead including large numbers of *Hibbertia aspera*. No plants resembling *H. riparia* were found at the location, so the correct identification of the species could not be ascertained.

It is considered likely that this species is the same taxon as the proximate occurrence off Douglas Park Drive which has vegetative features consistent with *H. puberula*.

1.6 CREDENTIALS OF EXPERT

Robert Miller has over 30 years' experience in field botany. Over this time Robert has identified many rare and endangered plant species and has contributed to the scientific knowledge of native flora distribution and habitat in NSW.

Robert has worked with Hellmut Toelken of the State Herbarium of South Australian, locating, collecting and identifying undescribed or rare species of *Hibbertia*. Some of these taxa were known only from historic records with non-precise locality details and depauperate or non-existent habitat information. Many of the specimens have been used for the taxonomic revision of the genus and are cited in various taxonomic publications including "Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*" published in the Journal of the Adelaide Botanic Gardens 26 (2013). Examples of the cited specimens include: *Hibbertia ericifolia* subsp. *acutifolia* Toelken, subsp. nov. Type: New South Wales, Sarahs Knob, R. & J. Miller s.n., 21.x.2006 (holo.: AD; iso.: BRI, CANB, NSW, PERTH) and *Hibbertia dispar* R.T. Miller s.n., 0.5 km S of Penrose Rest area, along western boundary track, Penrose State Forest, 12.x.2010 (AD, NSW).

Robert and Hellmut's paper "Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales", was published in the Journal of the Adelaide Botanic Gardens in 2012. The paper describes 13 new taxa including *Hibbertia fumana* Toelken and *Hibbertia puberula* subsp. *puberula,* – subsp. extensa *R.T.Mill.* and – subsp. *glabrescens Toelken.*

In 2017 Robert was called as an expert to identify the species of *Hibbertia* on the Moorebank bushland site that is the subject of the Intermodal development proposal.

Robert is also a recognised expert for other threatened taxa including *Pomaderris adnata*, *Solanum celatum*, *Epacris purpurascens* var. *purpurascens*, and the genus *Prostanthera* including the threatened taxa *Prostanthera discolor*, *P. stricta*, *P. densa*, *P. junonis* and has provided expertise to the OEH Saving our Species programs.

2. Species information

2.1 SPECIES DESCRIPTION

There are 3 sub-species of *Hibbertia puberula*. The following descriptions are taken directly from the Toelken and Miller 2012 paper "Notes on Hibbertia (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. Hemistemma, mainly from the central coast of New South Wales".

***Hibbertia puberula* Toelken**

Typus: New South Wales, Yowie Bay, A.A.Hamilton s.n., 14.xi.1908

Description: Shrublets up to 0.25 m tall, decumbent or rarely suberect, much to sparsely branched or spreading; branches wiry to stiff from a woody stem or base, with decurrent leaf bases more or less flanged, pubescent to hirsute mainly between flanges, rarely glabrescent or glabrous. Vestiture often not persistent, with spreading longer over shorter simple hairs on all parts of the plant; on branches with few to many (rarely glabrous) mainly longer hairs (but varying very much in actual length) over much shorter ones, often predominantly in the grooves between flanges of the leaf bases, becoming appressed and wearing off soon; on leaves above with scattered spreading antrorse simple hairs becoming longer towards the margins, often wearing off; on leaves below with few scattered hairs as above on the revolute margins but not on the central vein, wearing off; on bracts with finer but similar hairs to leaves; on outer calyx lobes outside moderate to dense, with erect short hooked hairs overtopped by longer tubercled straight hairs up to 1.3 mm long, often becoming bristle-like particularly on the margins and the base and receptacle, persisting, inside dense, with fine, often silky appressed antrorse hairs; on inner calyx lobes outside and inside usually similar to the outer lobes, but hairs finer and decreasing in number and size towards the glabrous, membranous margins. Leaves usually with dense intrapetiolar tuft spilling over into grooves between flanges; petiole 0–0.6 mm long, ± flattened; lamina linear-lanceolate to oblong-lanceolate or oblong-elliptic, (1.2–) 2.8–5 (–7.6) × (0.5–) 0.7–1 (–1.2) mm, ± abruptly constricted into petiole, acute and usually with a terminal tuft of hairs wearing off soon, often becoming obtuse, above ± flat and sparsely pilose to glabrescent, below revolute margins and recessed to bulging broader central vein obscuring the undersurface, sparsely pilose to glabrous on the margins. Flowers single and terminal, rarely in clusters of up to three from subtending axils; pedicel 0–3 mm long; bracts linear-elliptic to elliptic-lanceolate, (2.9–) 3.2–3.8 (–4.2) × (0.4–) 0.6–0.8 (–0.9) mm, leaf-like but flatted with central vein ± visible, short pilose, rarely glabrous. Calyx distinctly accrescent; outer calyx lobes lanceolate to ovate, (5.3–) 6–8 (–11.7) × (1.6–) 2–3 (–4.2) mm, frequently longer than inner lobes, acute to beaked, usually with raised ridge and recurved distal margins, hirsute, strigose, rarely pubescent to glabrescent; inner calyx lobes oblong-ovate to oblong-elliptic, (4.6–) 5–8 (–11.6) × (2.1–) 2.5–3.5 (–3.7) mm, acute to cuspidate and with lateral membranous margins rarely up to the apex when obtuse and mucronate, hirsute to finely pilose, decreasing towards the margins. Petals broadly obovate to oblanceolate, or rarely oblong-oblanceolate, 5.5–10.6 mm long, ± bilobed. Stamens (4–) 10–14 (–18); filaments (0.6–) 1.4–1.7 (–1.9) mm long, up to one-third connate basally;

anthers obloid, (0.8–) 1.4–1.8 (–2.1) mm long, subequal, rarely unequal, abruptly constricted above and below. Pistils 2; ovaries erect-obloid and usually horizontally truncate, (4–) 6 (–8) ovules, puberulous, rarely shortly pubescent, with style attached apically, rarely laterally, then curved back- and upwards on either side of the anthers with style well above or rarely at the apex of anthers. Fruit puberulous to glabrescent with simple hairs. Seeds oblong-obovoid to almost obloid, 1.6–1.8 × (1.2–) 1.3–1.4 mm, brown; aril with fleshy base surmounted by one-sided membranous cup covering one-third to half of seed.

Notes: The extra specimens now available introduced a much wider range of variation in the *H. puberula* complex. Specimens from the Central Coast can frequently be recognized by almost sessile leaves, broadly ovoid to ellipsoidal buds with apices of the calyx erect to incurved, and often more than one flower is born terminally on branches, while plants from more inland localities have usually petiolate leaves, slender ovoid to ellipsoidal buds with more or less recurved apices of the calyx and a single terminal flower on branches. None of these characters can be decisively used to distinguish these forms. The terminal flower clusters are formed by axillary growth from one or two leaves below the bract of the terminal flower and, in keeping with other species of the H. sericea group with fascicled hairs, immediately develop a terminal flower after usually two nodes with distinct internodes between, so that it becomes a more or less corymbiform cluster. (This is also a distinction from *H. stricta* s.l., which has usually spikiform (pyramidal) terminal clusters). Similar, but loosely branched cymbiform terminal inflorescences have been observed on only one collection (Turpentine Road, Flat Rock Creek, R.T. & J.Miller 22/30.x.2010). The most southern population of *H. puberula*, as represented by this and other mass collections, as well as R.D.Hoogland 11702 and E.Gauba NBG4784, is a particularly interesting extension of the species, as most of the flowers, though large, show a distinct reduction of hairs on the calyx and, more significantly, the styles tend to be laterally attached to the ovaries, similar to those of *H. cistiflora* in the *H. stricta* group. However, this phenomenon, indicative of a convergent development, can be observed in different stages on different plants, varying from an apically attached style curving down- and backwards to being attached laterally. The calyx lobes of most of the specimens identified as belonging to the *H. puberula* complex are hirsute to strigose on the outer surface, but in a few specimens both the shorter hooked hairs as well as the straight overtopping longer ones are very short or absent on plants from a few different localities (cf. variation under subsp. *glabrescens*). Among these, the plants from Bankstown Airport are smaller with thread-like branches and have consistently smaller calyx lobes, which are up to 2.7 mm broad, so that they are here described as subsp. *glabrescens*. The calyx of some flowers of subsp. *puberula* from Voyager Point (R.T.Miller & C.P.Gibson 52/20.x.2006) are of similar size, but hirsute and with a distinct terminal ridge on the outer calyx lobes. Furthermore, the flowering calyx of one plant must always be compared with other specimens at a similar stage, as the calyx (accrescent) elongates after flowering. Specimens from Lucas Heights are an extreme example, as the outer calyx lobes of a flower are 7.2 mm long and those of a fruit on the same specimen (R.T.Miller 3/16.x.2007) are 11.6 mm long. Of all the variation observed, *H. puberula* subsp. *extensa* is very unusual, as its androecium of commonly six stamens was previously unknown in *H. puberula*, which has ten or more stamens. There is a distinct gap between the two types of stamen numbers, as, unlike specimens of the typical subspecies from Simmos Beach Recreation Reserve (R.T.Miller 24–32/2.xi.2007), which has a range of stamens from 15–18, no specimen has as yet been recorded to complete the range from (4–) 6 or 7 stamens of the subsp. *extensa*. However, the wide variation recorded for the typical subspecies suggests this new form should be recognized at subspecific level. The anthers of subsp. *extensa* also tend to be smaller like those of the subsp. *glabrescens*, and their cuneate base into the filaments is rarely observed in the other subspecies.

Key to subspecies of the *H. puberula* complex

1. Stamens (4–) 6 or 7; lateral branches usually spreading up to about right angles to the main axis
…………………………………………………………………………………………………… *H. puberula* subsp. *extensa*

1: Stamens (9) 10–14 (–18); irregularly and commonly untidily branched

2. Anthers (1.3–) 1.4–2.1 mm long; outer calyx lobes distinctly ridged toward the apex, strigose to hirsute or if pubescent to glabrescent then (2.5–) 2.6–3.0 (–3.8) mm broad when flowering .... ………………………………………………………… *H. puberula* subsp. *puberula*

2: Anthers 0.9–1.3 mm long; outer calyx lobes 1.6–2.1 mm broad when flowering, scarcely ridged towards the apex, puberulous to glabrescent

………………………………………………………………………………………………… *H. puberula* subsp. *glabrescens*

Hibbertia *puberula* subsp. *puberula*

Description: Branches wiry to stiff-woody from woody stems. Leaf lamina mainly lanceolate. Outer calyx lobes lanceolate to ovate, (7.3–) 7.8–9.3 (–11.6) × (2.5–) 2.6– 3.0 (–3.8) mm, acute to beaked with strongly recurved margins and distinctly raised central ridge towards the apex, strigose or hirsute to rarely puberulous; inner calyx lobes broadly elliptic to oblong-ovate, (6.9–) 7.3– 7.8 (–10.1) × (2.8–) 3.15–3.3 (–3.7) mm, with innermost two acute to ± cuspidate above broad membranous margins, hirsute to strigose, rarely pubescent along the central ridge becoming smaller to glabrous towards the margins. Stamens (9–) 10–14 (–18); anthers (1.3–) 1.4– 2.1 mm long. Flowering: October–December (January).

Variation: The few previous collections available have been disconcertingly variable, but mass collections from a few localities revealed that individual populations are often very variable in the size and number of hairs on various organs. Buds vary from almost spherical to narrow-ellipsoidal to -ovoid with lanceolate to ovate outer calyx lobes, each with an incurved, erect or recurved apex and more or less densely covered with spreading, straight and smaller hooked hairs of varying length. Flowers have usually 12–14 stamens in this subspecies, but the number varies locally from 9 or 10 at Wollemi National Park to 18 in one specimen from Yeramba Lagoon (C.P.Gibson & R.T.Miller 50/14.x.1993). Specimens from Simmos Beach Recreation Reserve show a few flowers with 15 to 17 stamens, while other flowers of similar plants of the same population have 12 to 14 (R.T.Miller 24–32/2. xi.2007). The filaments are up to one-third basally connate. Usually the anthers are described as subequal and forming a range from the slightly smaller to larger ones, but occasionally one or two distinctly larger ones were observed. The typical obloid ovaries are surmounted by a horizontal style base and, while the style is usually attached at the apex, it is sometimes more or less dipping to a lateral position in a number of populations, mainly from Morton National Park. This must not be confused with fruiting specimens, where the bulging developing seeds often displace the position of the style attachment. While the ovaries are usually puberulous, they may vary from pubescent (R.T.Miller 111–113/20.xi.2007) to almost glabrous (R.T.Miller 33–43/12.x.2007).

Hibbertia *puberula* subsp. *extensa* R.T.Mill., subsp. nov.

Typus: New South Wales, south of Appin Road, upper George River catchment, R.T.Miller 102 & A.Henderson, 8.x.2007 (holo.: AD; iso.: NSW).

Description: Branches stiff-woody and lateral ones spreading up to about right angles. Leaf lamina mainly lanceolate. Outer calyx lobes ovate, (6.1–) 66–72 (–7.9) × 3.1–3.5 (–3.8) mm, acute to beaked with ± strongly recurved margins and distinctly raised ridge towards the apex, strigose to hirsute; inner calyx lobes elliptic rarely oblong-ovate, (4.2–) 4.5–4.8 (–5) × 2.9–3.2 (–3.4) mm, with innermost two abruptly constricted into minute terminal point continuous with broad membranous margins, hirsute to strigose with hairs becoming smaller towards the margins. Stamens (4–) 6 (7); anthers 0.8–1.2 mm long. Flowering: October, November (March, April). Fig. 2Y–BB.

Variation: In spite of their often isolated occurrence very little variation was observed in the material examined. The specimens from south of Appin had usually 6 stamens, whereas several flowers from the Wanganderry Tableland had 7. The subspecies has generally very long straight hairs on the calyx and some of them are up to 1.3 mm long. Not only are the stamens shorter in this subspecies, but also the styles are short and robust and often just reach the apex of the anthers. These robust specimens are easily distinguished from superficially very similar plants with spreading branches of the typical subspecies from Lucas Heights (R.T.Miller 111– 113/20.xi.2007) by the number and size of the anthers. While most of the specimens of this subspecies occur in a restricted area from Appin to Wedderburn, a collection from Sackville Road (R.T.Miller 81/23.x.2008) seems to indicate that the taxon has a much wider geographic range. This preceding specimen exhibits in addition to six stamens also the robust spreading branching of the plants from the southern localities in spite of records of more slender forms of the typical subspecies nearby. Etymology. The epithet ‘extensa’, Latin, ‘stretched out, extended’ refers to the impression created by the lateral branches spreading at about right angles to the main branches.

Hibbertia puberula* subsp. *glabrescens Toelken, subsp. nov.

Typus: New South Wales, Bankstown Airport, G.M. Cunningham s.n., 13.xii.2006 (holo.: AD200524; iso.: CANB, K, MEL, NSW). Hibbertia sp. Bankstown (R.T. Miller & C.P. Gibson s.n. 18.x.2006) N.S.W. Herbarium in Australian Plant Census database (2011). Hibbertia sp. nov. (Bankstown Airport) C.P. Gibson, Bushland Bulletin 59: 4, 6 (2009).

Description: Branches thread-like wiry from short stiff-woody stems. Leaf lamina mainly elliptic-oblong. Outer calyx lobes linear-lanceolate, (5.3–) 5.5–6.1 (–6.3) × 1.6–2.1 mm, not beaked and with scarcely recurved margins and faint central ridge towards the apex, glabrescent or sparsely pubescent; inner calyx lobes narrowly oblongovate, (4.6–) 4.8–5.2 (–5.6) × 2.1–2.3 (–2.7) mm, innermost two abruptly constricted into minute terminal mucro continuous with broad membranous margins, glabrous or glabrescent along central ridge. Stamens 12–14; anthers 0.9–1.3 mm long. Flowering: October, November (December).

Variation: The plants at Bankstown Airport are comparatively uniform, as one would expect for such a small and extremely localized population. However, the plants and especially also the calyx lobes are rarely entirely glabrous. Although specimens of some plants of the typical subspecies, especially from nearby Simmos Beach Reserve (R.T. Miller 24–32/2.xi.2007), as well as those from the much further south population along Turpentine Road near Sassafras (e.g. R.T. & J. Miller AD15A–M), show a variation from a hirsute or strigose through to glabrescent tomentum of the calyx lobes, they are always more robust plants and in particular, the calyx lobes are larger and especially broader. Some specimens of the mass collection R.T. Miller 1622/12.x.2007 are very similar to subsp. glabrescens, but can be distinguished by the shape of the calyx or by their strigose to hirsute calyx (C.P. Gibson & R.T. Miller 27/23.x.1990). Furthermore specimens from Bankstown Airport collected in subsequent years (since 2006) have not shown any significant change in morphology. Thus we must assume that a taxon has established itself here that is suited to the unusual ecological conditions artificially maintained by the Bankstown Airport management since about 1940. Etymology. Since all organs of this subspecies have very few small and delicate hairs which usually wear off soon, the epithet 'glabrescens', Latin, 'glabrescent' seemed appropriate.

2.2 LIFE CYCLE

Peak flowering time is October to December and sometimes into January, and seed is set during this period. Anecdotal evidence (Miller pers. obs.) suggests time of flowering and time to petal dehiscence is variable across subspecies and appears also to be influenced by prevailing climatic conditions. Very limited observations of the flowering times of *Hibbertia puberula* subsp. *extensa* suggest this subspecies has a very short period of flowering each day. Total petal dehiscence has been noted to occur before 1 pm on two occasions in the largest population south of Appin Road. It is not known at what time petal expansion commenced. The subspecies is virtually invisible when not in flower.

Hibbertia puberula and *H. diffusa* at Moorebank were noted to have a window of daily peak flowering (albeit in September, outside its normal recognised peak flower period) being not apparent in early mid-morning and petal senescing by early afternoon. This phenomenon has been observed with several *Hibbertia* species, whilst others appear to have protracted flowering across the day e.g. *Hibbertia dentata*.

Photo 4: *Hibbertia puberula* subsp. *puberula* at Moorebank.

The plants in photos 4 and 5 were not flowering at 8.40 am, the pictures show near total petal dehiscence by early afternoon. (Miller Friday, 29 September 2017 12:05 PM).

Further research is needed to ascertain daily flowering ranges particularly for threatened taxa as this has significant implications for threatened species assessments regarding the reliability of detection.

Flowering time of day may explain, in part, the non-detection of the significant and widespread population of *Hibbertia puberula* at West Menai in the environmental assessment (refer Appendix 4 Indicative distribution of *Hibbertia puberula* at West Menai).

Photo 5: *Hibbertia diffusa* plant at Moorebank.

Plant was not in flower on the way into the site c. 8.40 am, flowered and shed petals by 12.14 pm.

No systematic fire response studies have been undertaken on *Hibbertia puberula*. Anecdotal observations and inferred information from similar species suggest *H. puberula* subsp. *puberula* is killed by fire. In certain circumstances the species may be capable of re-sprouting from near or just below the soil surface as noted at the Keith Longhurst Reserve (formerly the Basin Reserve) in 2007 (R. Miller pers. obs.). At the same site Miller noted in June 2018 the species appears to have mostly been killed by a recent control burn, with limited recruitment from the soil seed bank observed. It is unknown to what degree the protracted dry period has impacted apparent recruitment, but it is thought that the combined impact of fire and drought has been significant.

Since its discovery there has not been a fire in the habitat of *Hibbertia puberula* subsp. *glabrescens*.

The impact of fire upon *Hibbertia puberula* subsp. *extensa* is also poorly known, with only observation by Miller providing a limited insight. The two occurrences south of Appin Road have recently been control burnt. Price *et. al.* (2016) state that “The first fire was 52 ha, lit at 09:45 on 22 August 2015, and targeted patches of forest within the scout camp. The second was 700 ha, lit at 10:15 on 9 October 2015 and burnt the area surrounding the camp in an arc from north through west to south”. All pre-existing plants appear to have been killed. Only three tiny plants presumably seedlings were apparent at one site and no plants were detectable at the other.

2.3 DISTRIBUTION AND ABUNDANCE

Limited systematic population surveys have been undertaken for *Hibbertia puberula* s. lat.. The most comprehensive population survey undertaken is for *Hibbertia puberula* subsp. *glabrescens* at Bankstown Airport environs (refer to that subsp.). The population of *Hibbertia puberula* subsp. *puberula* occurring at the Moorebank Intermodal Terminal was, in part, assessed in the environmental assessment for the project.

Hibbertia puberula* subsp. *puberula

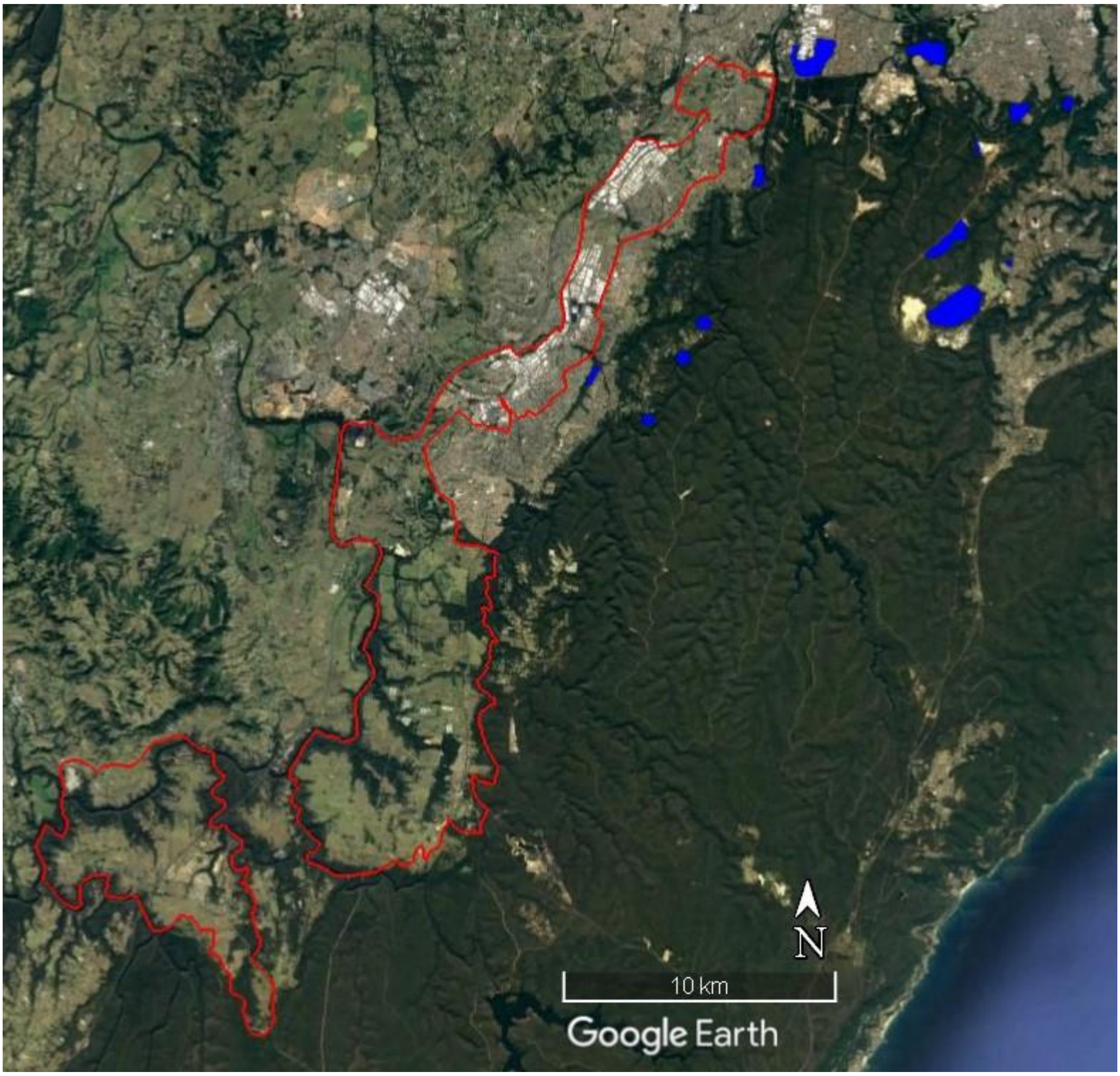
This sub species is known in New South Wales mainly from near Sydney (CC), but also from Wollemi National Park and near Morton National Park (SC, ST).

Of relevance to this study are those sites close to the Wilton and Greater Macarthur growth areas. The sub species has been collected from Smiths Creek Reserve, Moorebank Intermodal site, Simmos Beach Recreation Reserve, Peter Meadows Reserve, the Keith Longhurst Reserve (formerly the Basin Reserve), Kentlyn, Freres Crossing Reserve, Kentlyn, Old Kent Road, Kentlyn, and Lucas Heights. Map 4 shows the areas from which the sub species had been collected prior to this study.

Environmental assessment surveys for the Moorebank Intermodal Terminal have provided some population data on *Hibbertia puberula* subsp. *puberula*. The population data derived cannot be inferred to reflect population density at all recorded sites of its distribution and specifically not within the GMGA or the WGA. The predominant vegetation communities found at the Moorebank Intermodal Terminal where surveys were undertaken are Castlereagh Scribbly Gum Woodland and Cooks River/Castlereagh Ironbark Forest with Shale-Gravel Transition Forest and Castlereagh

Swamp Woodland being recorded in close proximity. Extant examples of these communities in combination are not known to occur in the GMGA or WGA.

The majority of records in proximity to GMGA and WGA occur as small populations in a variety of habitats at the edge of sandstone shale transition or in transition with or in the lower elements of the Mittagong formation. Appendix 4 shows the indicative distribution of *H. puberula* at West Menai, where the species was found to occur as small subpopulations in suitable micro-habitats.



Map 4: Generalised location of *Hibbertia puberula* subsp. *puberula* collections.

Key – Areas of *H. puberula* subsp. *puberula* collections (blue) in relation to the growth areas (red) from surveys prior to this BAM assessment.

A selection of habitat and occurrence notes compiled by Miller in 2007 as herbarium specimen notes are provided below:

- At Lucas Heights the population at a site in Open Woodland / heath – Canopy: *Eucalyptus haemastoma*? and Stringybark species is described as: “Abundance: extremely localised, rare < 12 plants noted”.
- At Lucas Heights Little Forest the population is described as Localised in narrow zone in upper drainage line.
- At Simmos Beach Reserve in Open Woodland of *Eucalyptus sclerophylla*?, *E. punctata, Angophora bakeri* one sub-population is described as “Very localised but locally common c. 20 plants noted”
- At Barden Ridge one population is described as scattered through sedges - relatively rare at edge of wet heath/swamp.

Further details of herbarium specimen collections from Western Sydney in 2007 are provided in Appendix 2.

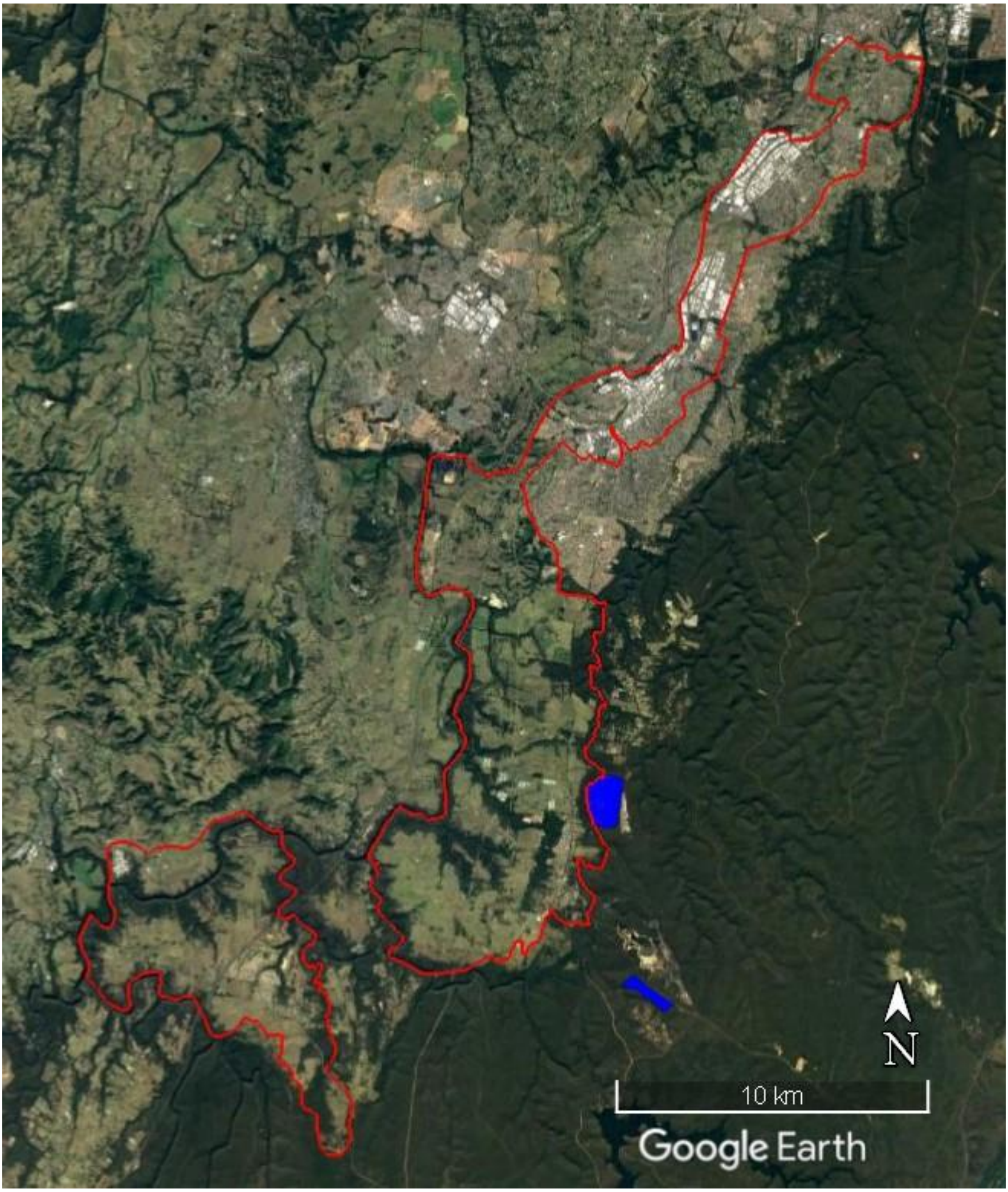
Hibbertia puberula* subsp. *extensa

This subspecies grows with heath on upper headwaters of the Georges River and in rock plate heath on the Wanganderry Tableland, New South Wales (CC).

Collection sites located in the vicinity of the Wilton and Greater Macarthur growth areas are c. 3.5–4 km SE of Appin township, South of Appin Road and Wedderburn, NSW Sports & Aircraft Club, walking tracks, Lysaghts Road vicinity. Map 5 shows the locations of collection sites.

No systematic population surveys have been undertaken for this subspecies. All known populations are thought to be small with most observations noting only a few individuals. One location south of Appin Road was the only population noted as having more than 10 plants. The sightings at Woronora Dam vicinity, Sackville North, the two recorded Wedderburn locations and the Bonnum Pic vicinity all recorded a few individuals only. The known Sackville North occurrence has subsequently been severely impacted by hazard reduction measures and is possibly now extinct at the known site. Similarly, the known occurrence west of Wedderburn Aerodrome has been impacted by grading and fill emplacement and only one specimen could be relocated (Miller pers. obs. July 2018).

A small population of a *Hibbertia* species with vegetative features consistent with *H*. *puberula* subsp. *extensa* was observed to occur on the verge of a fire trail within the Dharawal National Park at Wedderburn. Only six plants were noted. Positive determination can only be ascertained in combination with floral characters.



Map 5: Generalised location of *Hibbertia puberula* subsp. *extensa* collections.

Key – Areas of past *H. puberula* subsp. *extensa* collections (blue) in relation to the growth areas (red).

Hibbertia puberula **subsp.** ***glabrescens***

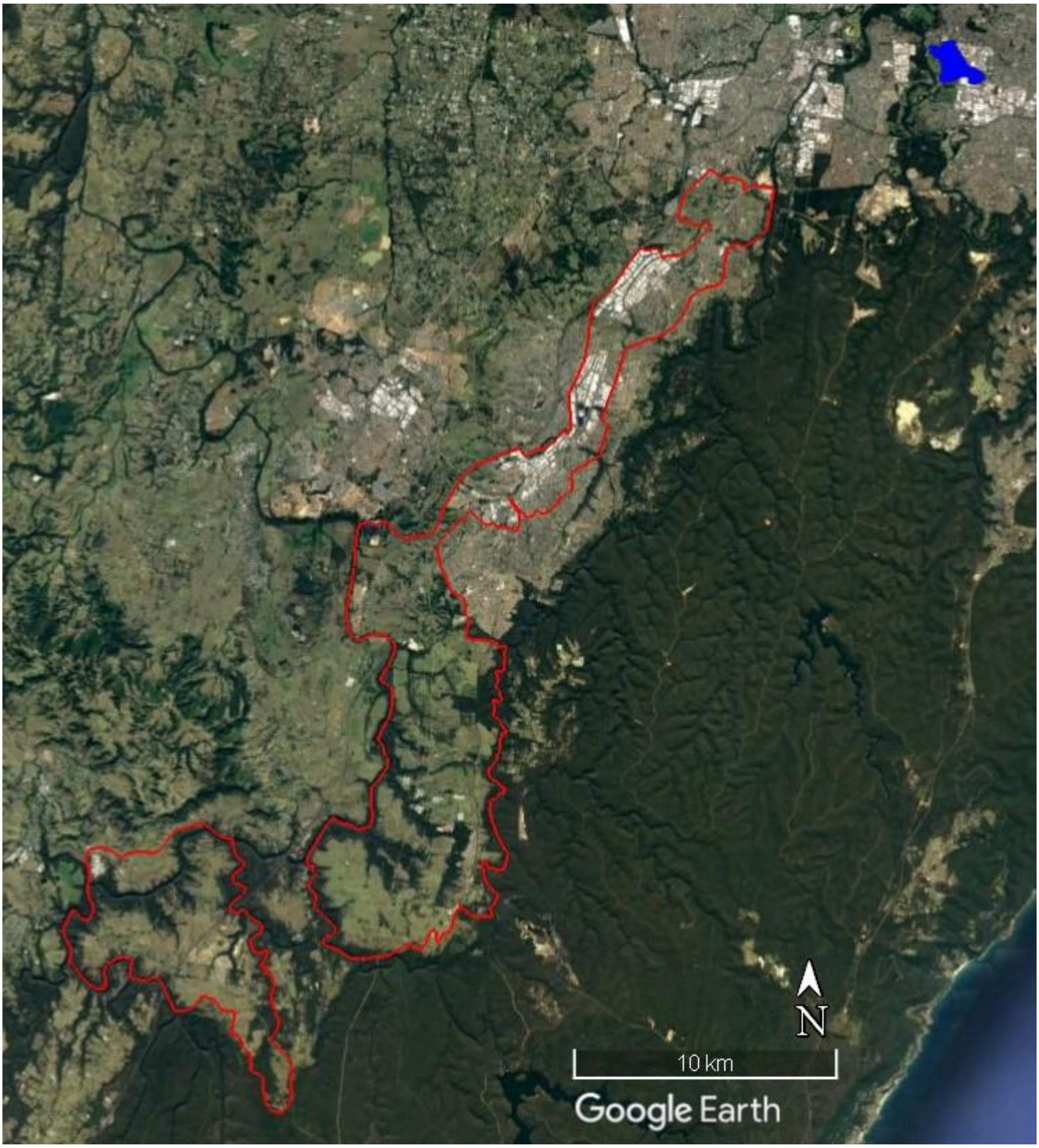
Subspecies *glabrescens* is known only from Bankstown Airport. Map 6 shows the general area where this species has been collected. The population contains between 50 and 100 individuals. Survey by Eco Logical in 2015 could not differentiate individual plants and recorded area of plants only.

The species has a limited area of occupancy. Most of the extant plants are known from one small area to the north of a modified drainage line colloquially referred to as Airport Creek. It was previously recorded by Gibson and Gibson & Miller to occur to the south of Airport Creek. Development and maintenance measures have negatively impacted upon those known occurrences and it had not been observed there again until October 2017 when one plant was observed (Gibson pers. obs.).

Photo 6: *Hibbertia puberula* subsp. *glabrescens* growing in a slashed area of Bankstown Airport.

Top: measure of slashing height, bottom: Airport Area 5. Photos taken by R. Miller 8 October 2014.

Both photographs clearly show the bright yellow flowers of *Hibbertia puberula* subsp. *glabrescens* while vegetative features such as leaves and stems are not discernible. These photographs illustrate the importance of undertaking surveys for small Hibbertia species within the flowering period.



Map 6: Generalised location of past *Hibbertia puberula* subsp. *glabrescens* collections.

Key – Area of *H. puberula* subsp. *glabrescens* collections (blue) and the growth areas (red).

2.4 HABITAT REQUIREMENTS

Hibbertia puberula **subsp.** ***puberula***

Occurs in a wide range of habitats, but usually low heath, on sandy soil or rarely in clay, with or without rocks underneath (Toelken 2000). Proximate populations have been recorded from habitats associated with the Mittagong formation, shale sandstone transitional vegetation and tertiary alluvial deposits. Associated canopy species may include, but not limited to, in combination or isolation: Scribbly Gum spp., Grey Gum (*Eucalyptus punctata*), Scaly Bark (*Eucalyptus squamosa*), Ironbark spp., Narrow-leaved Apple (*Angophora bakeri*), Dwarf Apple (*A. hispida*), and Stringybark spp.

Hibbertia puberula **subsp.** ***extensa***

The habitat requirements of *Hibbertia puberula* subsp. *extensa* are poorly known. The subspecies has only been recorded from five localities: south of Appin Road, Wedderburn vicinity, Woronora Dam vicinity, Sackville North vicinity and Bonnum Pic vicinity Wanganderry Tablelands.

This subspecies appears to have highly specific micro-habitat requirements. The largest known population occurs south of Appin Road, where less than 30 plants of *Hibbertia puberula* subsp. *extensa* have been recorded. Its area of occupancy is small, being noted to occur in a narrow band within a small upland swamp amongst wet heath vegetation. In a larger nearby wet heath site a few specimens of the subspecies were recorded to occur on skeletal soil, in the downslope seepage zone, where the underlying sandstone substrate outcrops. The subspecies has not yet been observed in superficially similar nearby wet heath habitats but as it is very cryptic it may be present. The Woronora, Sackville North and one of the two Wedderburn populations grow in seepage zones of sandstone outcropping in skeletal soil downslope of heathland. In the Bonnum Pic vicinity a few plants were noted growing on rock plate heath.

Hibbertia puberula **subsp.** ***glabrescens***

Subspecies *glabrescens* is known only from Tertiary alluvial soil along Airport Creek on Bankstown Airport and not from areas where subsequent fill has been deposited in between (pers. com. Gibson). The plant assemblage is attributable to "Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion".

The airport site is very heavily modified from the natural state, lacks canopy species and is currently a low grass/shrub association with many pasture grasses and other introduced herbaceous weeds.

Soil at the site is a sandy (Tertiary) alluvium with a high silt content.

The remnant at the site and soil type are consistent with an inferred pre-settlement cover of Castlereagh Ironbark Forest although some remnant vegetation at and near the site (along the channel in particular) suggests Castlereagh Scribbly Gum Woodland is equally valid.

Hibbertia sp. Bankstown has been observed to flower from October to December, with seed setting from October to January. Most Hibbertia species are primarily pollinated by bees, but many have specialised mechanisms requiring particular bee species, beetles or syrphid flies (OEH Threatened Species Profile).

2.5 ANTHROPOGENIC THREATS TO THE HABITAT

Threats to the habitat of *Hibbertia puberula* that are relevant to sites within or adjacent to urban development include:

- Loss of habitat.
- Damage to habitat by trailbikes, 4WDs and mountain bikes.
- High densities of weeds and invasive grasses occur at the top of ridgelines; there is significant potential for encroachment into areas where the species occurs.
- Altered fire regime, either too frequent or too seldom.
- Potential for widening of major roads to affect populations of the species.
- Road maintenance and slashing works.
- Clearing for fire protection zones.
- One of the subspecies (subsp. *extensa*) occurs in areas subject to underground mining and is known from rock shelves and upland swamps. One site has been destroyed the rock outcropping utilised as a turning circle for hazard reduction purposes and another the habitat has been impacted by fire trail widening and spoil placement.

Photo 7: Smith’s Creek Reserve, clearing and weed invasion adjacent housing.

Field inspection of bushland remnants in the heavily urbanised sectors of GMGA provide irrefutable proof of severe degradation arising from a range of anthropogenic impacts and urbanisation. Without exception, all creeks and many of the remnants were heavily weed infested caused by a range of factors not limited to altered hydrology as well as nutrification and stormwater discharge, garden refuse and fill dumping and exotic seed dispersal by various vectors.

Photo 8: Bunbury Curran Park adjacent Harrow Road Canterbury Road intersection.

The photo shows garden refuse dumping and fire trail maintenance impacting upon the small remnant of potential habitat.

Damage to zones adjacent urban development can also be caused by clearing for fire hazard reduction, control burning frequently, and recreation activities such as 4WD vehicle access, mountain bikes and kids' cubby house building. Changes to hydrology, nutrification, stormwater discharge are of particular concern to this species group as many habitat niches are associated with seepages.

Photo 9: Severe weed infestation at Bunbury Curran Creek vicinity south of Harrow Road.

Photo 10: Severe impact of fire on bushland adjacent Bunbury Curran Creek, potential habitat.

Photo 11: Severe weed degradation of habitat, Pembroke Park, Minto.

Photo 12: Recreational impacts upon habitat, Pembroke Park, Minto.

3. Description of the study area

3.1 LAND USE HISTORY

The Cumberland subregion was first occupied by the Aboriginal peoples, who enjoyed a plentiful supply of fresh water and foods including fruit, tubers, fish, animals, birds and honey (Hills District Council website).

With the arrival of Europeans land use changed to timber gathering and agriculture, permanently altering the landscape. Particularly since the end of the second world war urban settlement and industry have expanded west from Sydney into the Cumberland subregion. Over the last 40 years many rural properties have been subdivided as lifestyle and hobby farm properties.

Currently there is great pressure for further residential development to the west of Sydney in the Cumberland subregion.

3.2 LANDSCAPE CONTEXT

The changes in land use have caused the clearing of a large proportion of the natural bushland of the Cumberland subregion. In 2011 the Cumberland Plain Recovery Plan stated "Only 13% of the pre-1750 extent of the region's vegetation remains as intact bushland, with an additional 12% occurring as scattered trees in disturbed areas (NPWS 2002 in DECCW 2011). Consequently, much of the region's biodiversity is listed as threatened under State and/or Commonwealth legislation."

Widespread clearing of the remaining habitat has continued with much of the extant vegetation now being assessed as Critically Endangered. This widespread clearing has resulted in loss of habitat for endangered species such as *Hibbertia puberula*.

3.3 NATIVE VEGETATION

Since 2011 there has been further clearing, there are now 15 Plant Community Types that are listed as Critically Endangered, Endangered or Vulnerable in the Cumberland subregion.

The Cumberland Plain Recovery Plan states that "there are seven threatened species, four endangered populations and nine threatened ecological communities listed on the NSW *Threatened Species Conservation Act* 1995 that are found only on the Cumberland Plain. Seven of these are also listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999." The remaining bushland is highly fragmented and much of it occurs on private lands.

Within the GMGA and the WGA eleven Plant Community Types (PCTs) are mapped (mapping provided by the NSW Department of Planning and Environment). The PCTs are:

- Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion, PCT 830

- Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, PCT 835
- Grey – Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion. PCT 849
- Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion. PCT 850
- Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion. PCT 877
- Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 883
- Red Bloodwood – Grey Gum woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 1081
- Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateau of the Sydney Basin Bioregion. PCT 1083
- Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion. PCT 1181
- Water Gum- Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion. PCT 1292
- Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion. PCT 1395

3.4 POTENTIAL HABITAT

Hibbertia puberula has the potential to occur within five Plant Community Types (PCTs) mapped as occurring within the GMGA and the WGA. These community types are:

- Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 883
- Red Bloodwood – Grey Gum woodland of the Cumberland Plain, Sydney Basin Bioregion. PCT 1081
- Red Bloodwood – Scribbly Gum heathy woodland on sandstone plateau of the Sydney Basin Bioregion. PCT 1083
- Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion. PCT 1181
- Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion. PCT 1395

With the exception of PCT 883 at Moorebank, *Hibbertia puberula* has not been recorded to occur uniformly or in substantive numbers across any of the above listed communities. In general, it is usually confined to a variety of specific habitat niches within these regional mapping units. The area of occupancy within and/or the area of the specific habitat niches at any locale may be as small as a few square metres.

Specific habitat niches of potential occurrence may include upper drainage lines, seepages especially those associated with exposed sandstone bedrock or slabs, margins of hanging swamps / wet heath, exposed sandstone rock plates, and large and small occurrences of colluvial or alluvial deposits.

At most locales presence or absence can only be positively determined by intensive targeted surveys that investigate such habitat niches thoroughly within the peak flowering period. Refer to Photo 6 of *Hibbertia puberula* subsp. *glabrescens* that clearly shows the importance of surveying in the flowering period.

Photo 13: *Hibbertia puberula* habitat at Smiths Creek Reserve.

Note that the *Hibbertia* is not discernible. Refer also to the conspicuousness of flowering *Hibbertia puberula* subsp. *glabrescens* in Photo 6.

4. Assessment of species presence and suitable habitat

4.1 SPECIES RECORDS AND HABITAT ASSESSMENTS

Hibbertia puberula including its subspecies are poorly known and assessed as data poor. Apart from Miller (June – August 2018), there have been no other specific targeted surveys for *Hibbertia puberula* within the study area. General vegetation assessments undertaken for various purposes appear also not to have found *Hibbertia puberula* as there are no prior database records of the species within the proposed growth areas.

<u>Prior Records of *Hibbertia puberula*</u>

The nearest known populations of *Hibbertia puberula* subsp. *puberula* to the GMGA boundary are 850m away in West Moorebank and 990m away in Smiths Creek Reserve.

The nearest known population of *Hibbertia puberula* subsp. *puberula* to the northern boundary of WGA is approximately 22km away at Old Kent Road, Kentlyn.

The closest known population of *Hibbertia puberula* subsp. *extensa* occurs just 30 m from the GMGA boundary east of the Georges River Appin. The closest known population to the WGA boundary is c. 7.5km away south of Appin Road.

Hibbertia puberula subsp. *glabrescens* is only known from Bankstown Airport which is situated 9km from the northern boundary of GMGA and approximately 41km from WGA.

Searches of the databases revealed records of *Hibbertia riparia* at a number of locales including a Biobanking site at Douglas Park, just to the north of WGA (refer Appendix 5 *Hibbertia riparia* records in or adjacent GMGA and WGA). The name *Hibbertia riparia* is consider by Toelken to be misapplied to NSW taxa. Miller has observed that *Hibbertia puberula* is sometimes misidentified as *Hibbertia riparia*.

4.2 PRIOR SPECIES SURVEYS

From the information provided, no prior dedicated targeted searches have been undertaken for this species as part of the biocertification process.

4.3 ASSESSMENT OF SPECIES PRESENCE

The previous survey data provided by Biosis and Ecoplanning Consultants was insufficient to assess the probability of occurrence of *Hibbertia puberula* from a desk top study. CFFIS undertook targeted survey of suitable habitat where access was granted.

4.3.1 LIKELIHOOD OF SPECIES PRESENCE

Hibbertia puberula subsp. *extensa*

It is unlikely that suitable habitat for the subspecies occurs within the footprint of the growth areas, with the exception of the area at the southern extent of the WGA where the landscape may contain areas of wet heath or small localised seepages.

It is highly probable that this subspecies occurs within the GMGA and WGA boundaries adjacent to the footprints. Any occurrences would be confined to small populations restricted to very localised habitat niches. Potential habitat areas adjacent to the footprint would be highly susceptible to significant indirect impacts from a range of anthropogenic influences arising from the increase in urbanisation.

Hibbertia puberula subsp. *glabrescens*

Within the GMGA footprint the only location that supports potential habitat for the subspecies is the Menangle Park area. The subspecies may have once existed at Milton Park and Kayess Park vicinities, however, it is now unlikely to occur at those parks. Targeted surveys are recommended within the flowering period at these locales.

The likelihood of occurrence within or adjacent to the WGA is assessed as negligible. From known occurrence data the subspecies does not have the capacity to exist in habitats that occur within the proposed WGA development footprint. No further, specific targeted surveys are warranted for this subspecies in the WGA.

In the unlikely event that this subspecies was to occur it would be picked up in the targeted surveys for the other subspecies.

Hibbertia puberula subsp. *puberula*

Within the development footprint the subspecies is likely to occur at Menangle Park area, Milton Park and Kayess Parks, as well as in areas fringing and adjacent to the footprints (see maps 7 to 9).

From CFFIS limited field surveys, a small-leaved *Hibbertia* sp. has been observed to occur at three sites within the GMGA and WGA boundaries adjacent to the development footprint. Plants were also observed outside but proximate to the GMGA and WGA boundaries. These plants have vegetative morphological features +/- consistent with *Hibbertia puberula*.

It is highly probable that this subspecies occurs at many other locales within the GMGA and WGA boundaries. Any occurrences are likely to be confined to small populations restricted to very localised habitat niches. Potential habitat areas adjacent to the footprint would be highly susceptible to significant indirect impacts from a range of anthropogenic influences arising from the increase in urbanisation.

4.3.2 JUSTIFICATION FOR DETERMINATION

Hibbertia puberula subsp. *extensa*

Occurs in very close proximity to GMGA eastern boundary approximately 30m upslope from the Georges River in seepage zones associated with sandstone outcroppings. Similar outcropping formations were observed within GMGA and WGA that have the potential to support the subspecies. Within the development footprint the only area that may have suitable habitat is at the southern section of the WGA.

No extensive areas of wet heath/swamp areas were noted to occur in the limited sites inspected. Small localised areas supporting species associated with periodically damp soil were observed. There is potential for small localised areas of heath/swamp to occur within WGA in a number of areas where access was not granted.

Hibbertia puberula subsp. *glabrescens*

Sand deposits are noted in the Nepean River floodplain at Menangle Park as evidenced by past and present sand extraction. The alluvial sand deposits may provide suitable habitat.

Hibbertia puberula subsp. *puberula*

Shale – Sandstone geology is widespread around the periphery of both the GMGA and WGA, within this it has been demonstrated from limited field validation that habitat and potential habitat exist. Within the development footprint this habitat occurs at Menangle Park, Kayess Park and Milton Park. Sand deposits are noted in the Nepean River floodplain at Menangle Park as evidenced by past and present sand extraction. The alluvial sand deposits may provide suitable habitat.

4.4 ASSESSMENT OF SUITABLE HABITAT

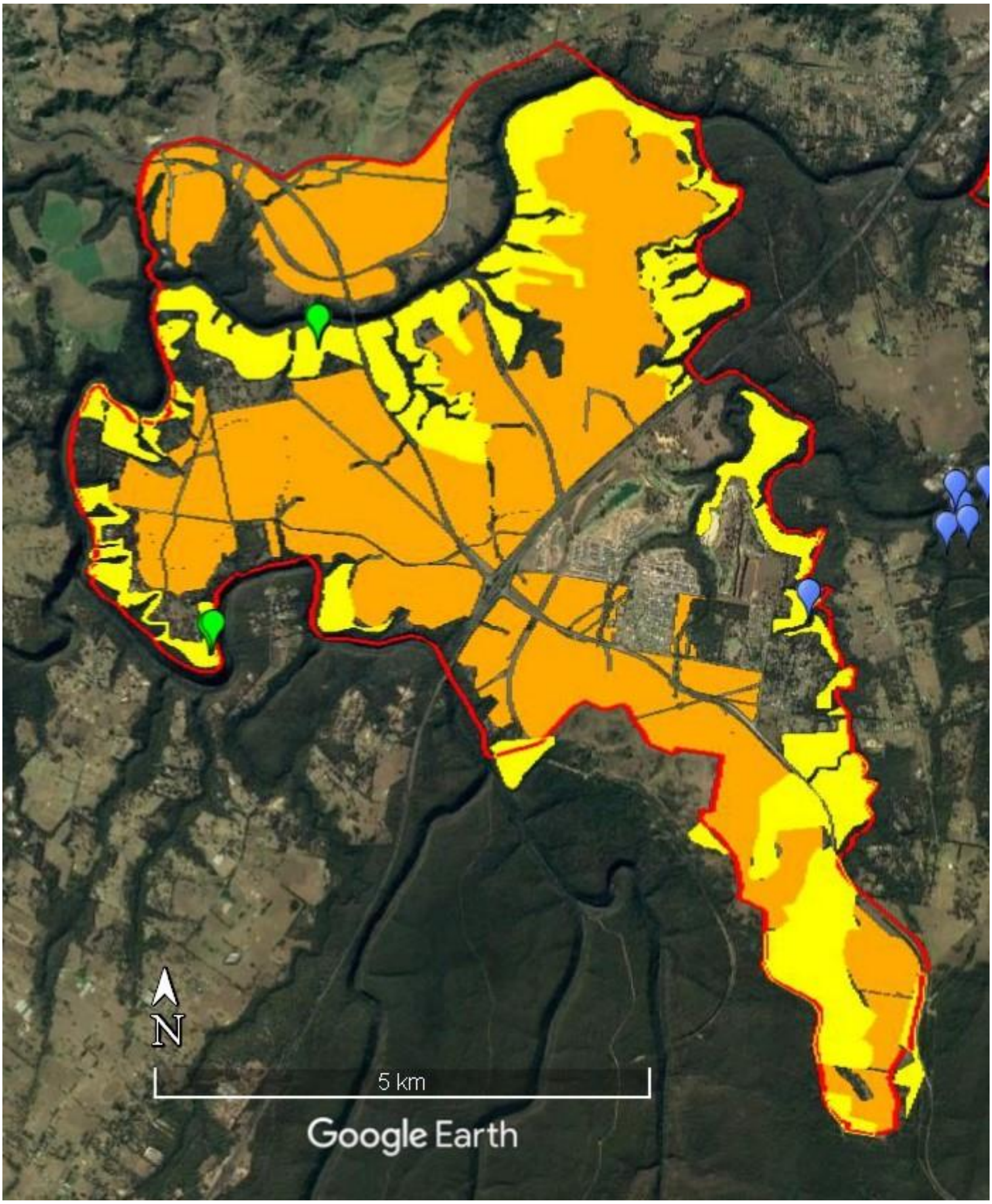
The assessment of suitable habitat has been described in section 4.3, assessment of species presence, because the survey during the non-flowering period required the presumption that if suitable habitat were present then the species could also be present.

The species group could be present in areas of alluvial / colluvial deposition especially adjacent shale and shale / sandstone transition. Within the WGA and GMGA occurrences within and shale / sandstone transition communities are most likely to occur in microhabitats such as seepage zones below or above sandstone outcrops or minor sandy colluvial deposits. Broad scale vegetation survey and mapping do not identify habitats at this scale. Survey during the flowering season is recommended.

4.4.1 DETERMINATION OF SPECIES POLYGONS

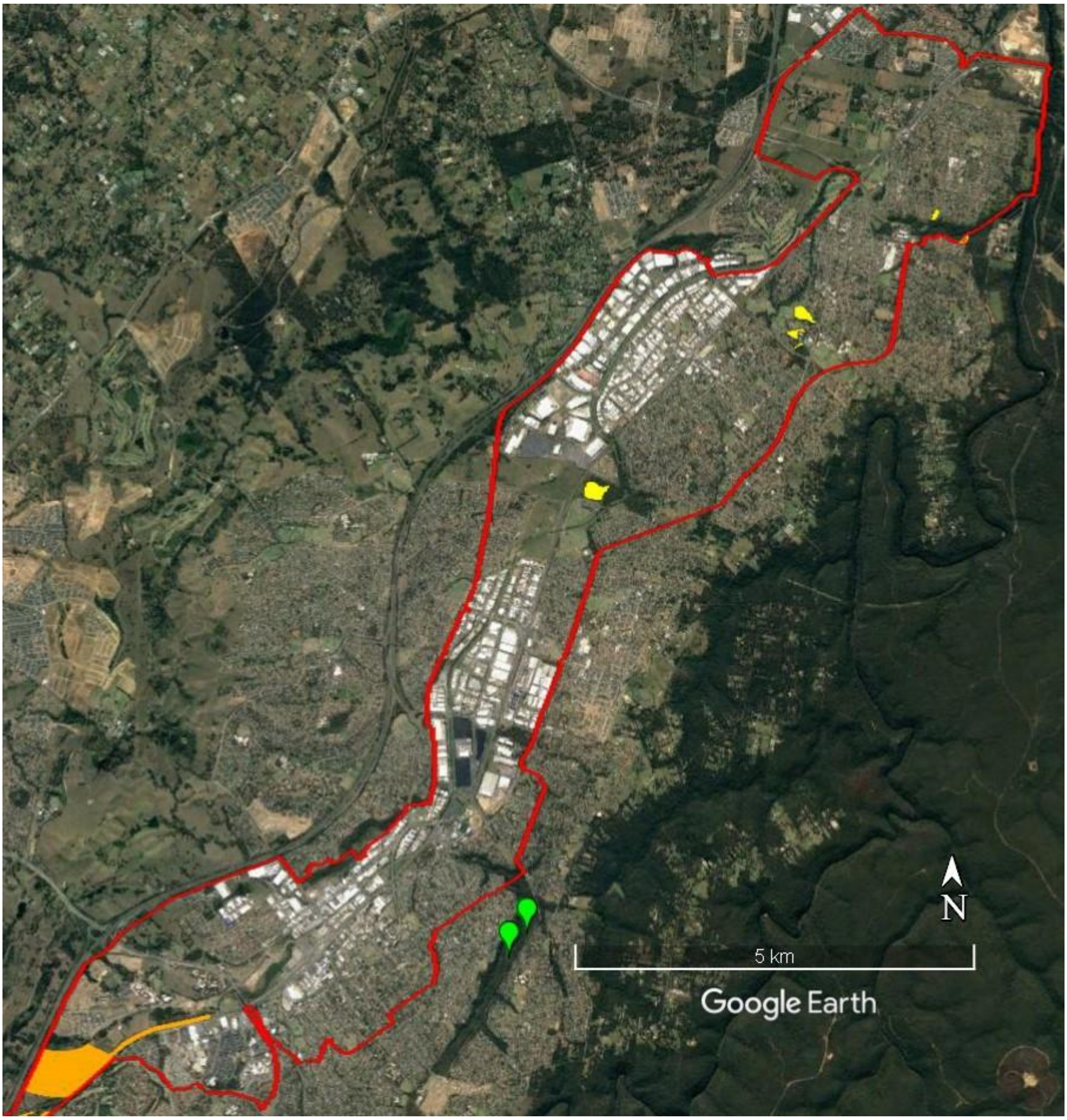
Determination of potential habitat for *Hibbertia puberula* includes areas identified outside the deemed biocertification area. Anthropogenic impacts are well documented to adversely affect vegetation well beyond the direct urban footprint.

The following maps show an overview of areas containing potential habitat of *Hibbertia puberula* group within the GMGA and WGA.



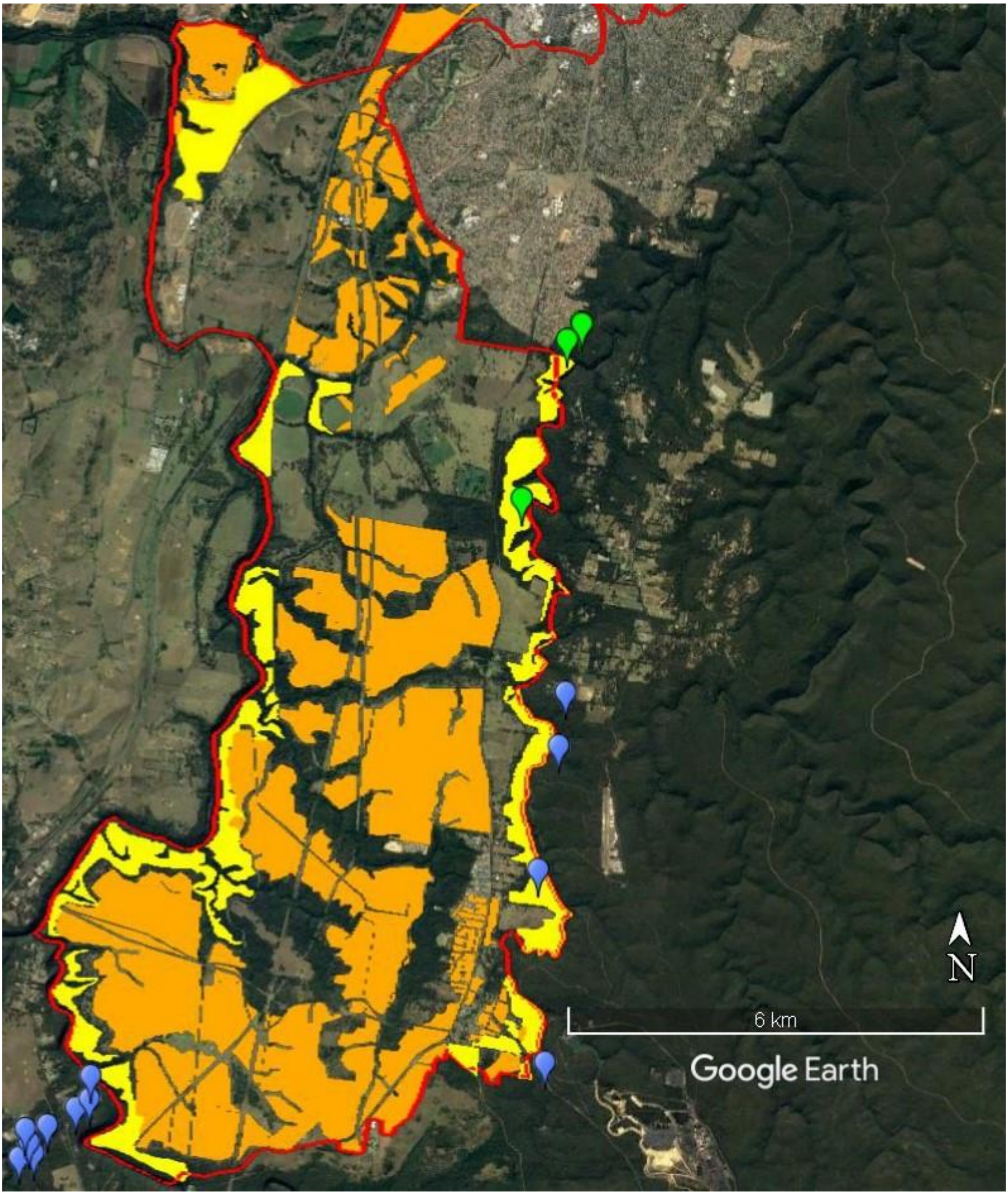
Map 7: Polygons of areas containing potential and known *H. puberula* habitat, WGA.

Key: Red - growth area boundary, orange – growth area footprints, yellow – areas containing known and likely habitat niches, green markers - location of a small leaved *Hibbertia* sp. with vegetative features consistent with *H. puberula*, purple markers – locations of *H. riparia* records.



Map 8: Polygons of areas containing potential *H. puberula* habitat, GMGA northern section.

Key: Red - growth area boundary, orange – growth area footprint, yellow - habitats assessed as having attributes similar to known extant populations, green markers - location of a small leaved *Hibbertia* sp. with vegetative features consistent with *H. puberula*.



Map 9: Polygons of areas containing potential *H. puberula* habitat, GMGA southern section.

Key: Red - growth area boundary, orange – growth area footprint, yellow - habitats assessed as having attributes similar to known populations, green markers - location of a small leaved *Hibbertia* sp. with vegetative features consistent with *H. puberula*, purple markers – location of *H. riparia* records.

4.4.2 JUSTIFICATION FOR DETERMINATION

The species potential habitat polygons for Milton Park, Kayess Park, Bunbury Curran Creek and Menangle Park in the GMGA are based on limited field inspections undertaken in adverse environmental conditions outside the flowering period. Therefore, the polygons are indicative only. The *Hibbertia puberula* group has been recorded from similar habitats.

The majority of potential habitat polygons for the WGA are based on regional mapping data provided by DPE as access issues limited field validation. Similar access issues arose with other potential habitat areas within the southern and central portions of the GMGA. Unless indicated potential habitat polygons for the southern and central portions of the GMGA are also based on regional mapping data.

The *Hibbertia puberula* group has been frequently recorded from Shale /Sandstone transition environs. The polygons are also an extrapolation of habitat characteristics where a small leaved *Hibbertia* sp. was located within or adjacent to the growth areas during survey for this assessment.

4.5 ESTIMATE OF AREA OF HABITAT OR NUMBER OF INDIVIDUALS

4.5.1 ESTIMATES

The assessment provides the following estimates:

- Likely habitat for *Hibbertia puberula* subsp. *extensa* occurs within the footprint in the southern part of the WGA, habitat would be small seepages within an area of 23ha.
- A further 278ha of land that could contain habitat niches for *H. puberula* subsp. *extensa* is adjacent to the footprint in the southern section of the WGA and the eastern side of the GMGA between Appin and Wedderburn.
- Likely habitat for *Hibbertia puberula* subsp. *glabrescens* occurs at Menangle Park. An area of approximately 92ha could contain likely habitat niches within the growth area footprint, and a further 31 ha of land containing likely habitat niches adjacent to the footprint.
- Likely habitat for *Hibbertia puberula* subsp. *puberula* occurs outside the development footprint at Milton Park, Kayess Park and in the vicinity of Bunbury Curran Creek reserve.
- Likely habitat for subspecies *puberula* within the development footprint occurs at Menangle Park (92ha), Gilead and Appin areas (8ha) and WGA (65ha).
- Likely and known habitat for subspecies *puberula* adjacent to the development footprint occurs at Menangle Park (31ha), Gilead and Appin areas (380ha) and WGA (680ha).

4.5.2 JUSTIFICATION FOR ESTIMATES

Assessment relied on personal knowledge of the species habitat for known populations, combined with vegetation mapping and soil and landscape features, to determine likely habitat locations within and adjacent the growth areas footprints.

It was not possible to provide accurate habitat areas or counts due to the following:

- Access was not granted to the majority of development footprint.
- Positive determination of the small leaved Hibbertias found as part of this expert report is not possible even though the vegetative morphological features are assessed to be +/- consistent with *Hibbertia puberula*. Floral characters in combination with vegetative features are essential to confirm identification of many *Hibbertia* species.
- The region has undergone a period of protracted drought and small diminutive species, forbs and even many of the larger resilient shrubs were observed to be in severe drought stress or dead. At all locations only a few *Hibbertia* sp. attributable to *H*. *puberula* were found, most almost dead. It is well documented that the above ground populations of many genera including *Hibbertia* species fluctuate widely in response to various conditions such as rainfall and time since last fire.
- Most sites inspected within the WGA and many within GMGA were noted to have senescing or dead shrubs, high levels of leaf, bark and branch fall and dead understorey, an indication of both a long fire interval and severe drought. Apparent diversity and population numbers of many species significantly decline, retreating to the soil seedbank under such conditions. It is inconclusive to undertake population census or estimates of occupied area under such circumstances.
- The cryptic nature of small-leaved *Hibbertia* when not in flower also make their detection extremely difficult and population count or area calculation unreliable.
- The use of a surrogate site(s), with the possible exception of *Hibbertia puberula* subsp. *glabrescens*, as a base for the estimation, in this case, is also deemed not credible. *Hibbertia puberula* is a data-poor species group. Insufficient or no reliable data exists with regard to population density across its range of habitat niches and fluctuation in population density over time at any given site.

5. Information used in the assessment

Information used in this assessment includes taxonomic papers, BioNet and ALA records of the target species, Critically Endangered Listing, online Threatened Species profile and associated documents, personal observations and site inspections, and the spatial viewer including the layers: survey access and coverage, (BAM plots, polygons and transects), PGA layer and geology and soils.

6. References

Eco Logical, 2015. *Inspection and review of the Hibbertia sp. Bankstown Population at Bankstown Airport*, report for Bankstown Airport Limited, available at http://www.environment.nsw.gov.au/resources/threatenedspecies/s91ands95/Site_Assessment_ReportA06600-2016.pdf

Hills District Council website, https://webcache.googleusercontent.com/search?q=cache:-vpeh8rPRVEJ:https://www.thehills.nsw.gov.au/files/assets/public/library-documents/local-studies/aborigines-in-the-hills-district.pdf+&cd=3&hl=en&ct=clnk&gl=au

National Parks and Wildlife Service. 2002. *The Native Vegetation of the Cumberland Plain Final Edition*. NSW National Parks and Wildlife Service, Hurstville, available at http://www.environment.nsw.gov.au/resources/nature/cumbPlainMappingInterpguidelines.pdf

NSW Department of Environment, Climate Change and Water, 2010. *Cumberland Plain Recovery Plan*, available at http://www.environment.nsw.gov.au/research-and-publications/publications-search/cumberland-plain-recovery-plan

Price, O. F., Horsey, B. & Jiang, N. (2016). Local and regional smoke impacts from prescribed fires. *Natural Hazards and Earth System Sciences*, 16 (10), 2247-2257, available at http://ro.uow.edu.au/cgi/viewcontent.cgi?article=5192&context=smhpapers

Toelken, H. R. 2000. Notes on *Hibbertia* (Dilleniaceae) 3. *H. sericea* and associated species, *Journal of Adelaide Botanic Gardens* 19 (2000) 1-54.

Toelken, H. R. and Miller, R. T., 2012. Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in *Journal of Adelaide Botanic Gardens* 25 (2012) 71–96 and available at https://data.environment.sa.gov.au/Content/Publications/JABG25P071_Toelken.pdf

Toelken, H. R., 2013. Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia* Journal of the Adelaide Botanic Gardens 26 (2013) 31–69 and available at https://data.environment.sa.gov.au/Content/Publications/JABG26P031_Toelken.pdf

7. Appendices

Appendix 1. CURRICULUM VITAE

Robert Miller *Curriculum Vitae*

Contact Details:

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Current Position:

Principal of Cumberland Flora & Fauna Interpretive Services

Qualifications:

Associate Diploma Horticulture from the University of Western Sydney (formerly Hawkesbury Agricultural College), conferred on 17 April 1982

Journal Articles

H.R. Toelken & R.T. Miller **2012** Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in Journal of the Adelaide Botanic Gardens, Vol. 25.

Miller J and Miller R **2005** Aquatic macroinvertebrates of headwater streams in the south east forests – diversity and conservation management issues, Wetlands (Australia) 23 (1).

Employment Record

1993 - present

Cumberland Flora and Fauna Interpretive Services

Principal - flora surveys, plant identifications, vegetation assessment, project impact assessment, bush regeneration, rehabilitation, habitat enhancement, seed collection and propagation services.

1990 - 1997 **Sylvan Grove**
Native Gardens

Curator of gardens and adjoining bushland - maintenance of and improvement to the plant collection, training and supervision of staff, liaison with other botanic gardens, guided tours, technical advice.

1982 - 1990 **Sylvan Grove**
Native Gardens

Horticulturist Specialising in Australian Flora - collection, propagation, identification, and growing of native plants.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES INFORMATION AND RELEVANT EXPERIENCE

Cumberland Flora and Fauna Interpretive Services have provided technical expertise since 1993 to numerous clients including Local Government, NSW Roads and Maritime, NSW Office Environment Heritage NPWS and community groups. Following is a list of some of our projects and clients:

REPORT	**CLIENT**
Expert advice for Conservation Assessment of *Solanum celatum* Eren Delgado1 16/04/2018, Science Division, NSW Office of Environment and Heritage	OEH
Saving our Species (SoS) project for *Pomaderris adnata* a post fire population census Grid D 2018	OEH
Provision of expert advice to update the current ecological data for southern NSW threatened flora species, as part of the review of biodiversity assessments under the Biodiversity Conservation Act 2016.	OEH

REPORT	**CLIENT**
Expert witness in botany Residents Against Intermodal Development Moorebank Incorporated v NSW Minister for Planning and Anor – NSW Land & Environment Court Class 1 Proceedings No. 2017/81889. Review of project documentation, in particular the various biodiversity assessments including the BAM assessment for the project and Individual Expert Witness report of Dr David Robertson 15 October 2017; Site inspections to identify the location of and/or potential habitat for *Hibbertia fumana*, *Hibbertia puberula*, *Grevillea parviflora*, *Persoonia nutans*, *Acacia bynoeana*, provision of an expert report in accordance with Division 2 of Part 31 of the UCPR; confer with the other parties experts at a joint conference and produce a joint expert report; and f appear at the section 34 conciliation conference	EDO
Saving our Species (SoS) project for *Pomaderris adnata* a population census 2017	OEH
Central Coast Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Great Lakes Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2015 – Vegetation Consultant	OEH
Clarence Colliery Discharge Investigation April 2015	OEH
Vegetation Assessment as part of the Lachlan Wetlands Condition Assessment Project October 2013 – May 2014	Lachlan Catchment Management Authority
Field expertise and guidance in the Sydney basin to PhD candidate Karen Muscat studying the molecular phylogenetics and morphology of the genus Dianella with close scrutiny of the variation in the D. *caerulea* group of species in eastern Australia	Volunteer to University of Melbourne
Survey for *Pomaderris adnata* to determine population size, structure, occupancy and threats 2014	NPWS Illawarra Region
Survey of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats. Collection of voucher herbarium material for taxonomic review June 2014	OEH
Survey of the southern populations of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats May 2014	OEH
Investigation of works within the Sublime point precinct Illawarra Escarpment State Conservation Area February 2014.	NPWS Illawarra Region
Identification of Hibbertia species in proposed control burn sites Victoria Road precinct Dharawal National Park.	NPWS Illawarra Region
Assessment of impact of infrastructure upgrade Victoria Road, Dharawal National Park – location of threatened species.	NPWS Illawarra Region
APPEAL IN RESPECT OF PROPERTY AT Lot 1 and 2 DP 224431 Site 2 Sturdee Avenue, Bulli	Roy 'Dootch' Kennedy

REPORT	**CLIENT**
Expert Witness Report Relating to Some Environmental Issues Land & Environment Court of New South Wales PROCEEDINGS NO 10982 of 2012	Roy 'Dootch' Kennedy
Field surveys, collection, pressing, curation of botanical specimens and contributions of notes in association with the manuscript "Notes on Hibbertia subgen. Hemistemma (Dilleniaceae) 7. Eight new species, a new combination and four new subspecies from mainly central New South Wales H.R. Toelken & R.T. Miller 2006 - 10 July 2012	Volunteer to Adelaide Botanic Gardens
Vegetation Surveys and assessments & input into the preparation of REF for proposed car-park and amenities Victoria Road Precinct Dharawal National Park November 12.	NPWS Illawarra Region
Office of Environment and Heritage – Priority Action Statement Expert Consultant Interviews June 2012 – January 2013	OEH
Vegetation Surveys and assessments & input into the preparation of REF for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking tracks in Dharawal National Park input into conservation risk assessments 2011 – 12.	NPWS Illawarra Region
Nomination to list Prostanthera saxicola R. Br. S. Str. as an Endangered Species under the NSW TSC Act September 2011	
Field surveys, collection, pressing and curation of botanical specimens of undescribed Kunzea to assist in the taxonomic circumscription of previously presumed extinct, rare and/or poorly known taxa for Dr. H.R. Toelken Honorary Research Associate State Herbarium Science Resource Centre Department of Environment and Natural Resources SA 2011	Volunteer to Adelaide Botanic Gardens
Significant Plant Survey – Maddens Plains Forest Path to Mount Mitchell Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Significant Plant Survey – Wongawillii Precinct Illawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Kembla State Forest Precinct Illawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Site Inspections and Vegetation Survey of Proposed Minor Track Re-Alignments: Forest Path to Woodward Track & Sublime Point to Austinmer Track Maddens Plains To Sublime Point Precinct Illawarra Escarpment State Conservation Area August 2010	NPWS Illawarra Region

REPORT	**CLIENT**
Sandon Point Aboriginal Place and Kuradji Lands Vegetation Management Plan April 2010	Illawarra Aboriginal Land Council, Wollongong Council, Southern Rivers Catchment Management Authority.
Forest Path to Woodward Track Precinct Track-head Realignment Maddens Plains IESCA Vegetation Survey April 2010.	NPWS Illawarra Region
Bushland Conservation Project 95 Glendiver Road, The Oaks 2008	A & S Fitzsimmons / Hawkesbury Nepean Catchment Management Authority
Significant Plant Survey – Maddens Plains Forest Path to Woodward Track Precinct Illawarra Escarpment State Conservation Area June 2007	NPWS Illawarra Region
Nomination of Hibbertia "Bankstown Airport" (R.T. Miller & C.P. Gibson s.n. 18/10/2006) as Critically Endangered under the Environment Protection and Biodiversity Conservation Act	Bankstown Bushland Society
Proposal to Demolish A Derelict Amenities Block at Deepwater Park Webster Street Milperra Environmental Assessment of Impacts	Bankstown City Council
Significant Plant Survey – Sublime Point to Panorama House Precinct Illawarra Escarpment Conservation Area August – September 2006	NPWS Illawarra Region
A Consultant for Priority Action Statement Workshop July 2005	NPWS
PHD research assistance – 'The Benefits of Riparian Vegetation in Maintaining Water Quality as Assessed Using Biological Indicators".	UNSW
Plan of Management for Part Lot 11 Dp 1049307 Kurrajong Road Prestons January 2005	Sule College
Preliminary Investigation & Vegetation Survey of Lands At Prestons Bounded By Maxwells Creek, Kurrajong Road, Ash Road & The Western Sydney Orbital December 2003	Sule College
Supply and collection of seed for a research project entitled: Factors Affecting Seed Germination and Mycorrhizal Development of the Epacrid: *Woolsia pungens* (2001-2003)	UNSW
Compensatory Habitat Assessment Western Sydney Orbital March 2004	RTA
Compensatory Habitat Assessment Western Sydney Orbital July 2002	RTA
Compensatory Habitat Assessment of Flora at Rouse Hill, Doonside, Cecil Hills & Kemps Creek for The Western Sydney Orbital March 2002	RTA
Compensatory Habitat Assessment Western Sydney Orbital November 2001	RTA
Preliminary Vegetation Survey Between Lawson Rd & Alfords Point Rd, Menai as Part of The Proposed Bangor Bypass 2001	RTA
8-Part Tests for The Proposed Bangor Bypass 2000	RTA
Preliminary Vegetation Survey for The Proposed Bangor Bypass 2000	RTA
Species Impact Statement for the Western Sydney Orbital 2000	Sinclair Knight Mertz

REPORT	CLIENT
Review of Environmental Assessments – Proposed Cricket Ground - Louisa Reserve, The Crest of Bankstown 2000	Bankstown Bushland Society
Review of Environmental Assessments – Proposed Olympic Criterium Circuit the Crest Statement of Environmental Effects	Bankstown Bushland Society
Vegetation Survey – 60 Yanderra Road, Yanderra 1999	Mr. Brian Timmis
Review and Comments on Environmental Assessment – Bankstown City Council - Proposed Cricket Ground – 8 – Part Test- The Crest 1999	Bankstown Bushland Society
Vegetation Survey and Review of Proposed Sand Mining Restoration Works – Howard Park, Lansvale 1999	Chipping Norton Lakes Authority
Rare Species Survey – Blue Mountains & Central Western Slopes 1999	National Parks & Wildlife Service
Vegetation Survey - Kookaburra Road and Camden Valley Way Intersection 1999	Roads & Traffic Authority
Chullora Detention Basin Wetlands Habitat Enhancement 1998	Business Land Group DUAP
Vegetation Study Maxwells Creek Trunk Drainage Stage 1 Vegetation Assessment 1998	Bewsher Consulting
Vegetation Study Prestons Urban Release Area Part 3 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 2 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 1 1998	Liverpool City Council
Survey of Remnant Flora for Proposed Nth Liverpool Rd to Edensor Rd Interim Transitway 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management Discussion Paper 1998	Roads & Traffic Authority
Eastern and Western Alignments WSO Cecil Hills Flora Study 1998	Roads & Traffic Authority
Valmay Road Development Vegetation Study 1998	LesryK Pty Ltd
Western Sydney Orbital Prestons To West Baulkham Hills Descriptive Inventory of Remnant Bushland 1998	Roads & Traffic Authority
Vegetation Survey River Road M5 East 1998	Roads & Traffic Authority
Tree Survey, Great Western Highway, Faulconbridge 1998	Roads & Traffic Authority
Eve & Marsh Street Wetlands M5 East 1997	Roads & Traffic Authority
Beverley Grove Bush M5 East 1997	Roads & Traffic Authority
Vegetation Survey - Salt Pan Creek Bridge Duplication M5 East 1997	Roads & Traffic Authority

REPORT	**CLIENT**
Survey of Flora: Trees and Shrubs, Princes Highway Interchange M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Adjacent to Proposed Exhaust Stack Henderson Avenue, M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Illoura Reserve, Adjacent to Air Intake Vent M5 East 1997	Roads & Traffic Authority
Lansdowne Reserve Survey of Remnant Flora 1997	Bankstown City Council
Villawood Drain Vertebrate Fauna Survey 1997	Bankstown City Council
Kelso Wetlands Survey of Remnant Flora 1997	Bankstown City Council
Deverall Park Survey of Remnant Flora 1997	Bankstown City Council
Louisa & McClean Reserves Bass Hill Survey of Remnant Flora 1997	Bankstown City Council
The Crest of Bankstown Survey of Remnant Flora 1997	Bankstown City Council
Lawson Bridge Roadworks Survey of Remnant Flora 1997	Roads & Traffic Authority
Davidson Street Scrub Survey of Remnant Flora 1997	Strathfield Council
Freshwater Creek Bushland Survey of Remnant Flora 1996	Bankstown Bushland Society for the EPA
Vegetation Survey Forest Lawn Cemetery Roadworks, Leppington 1996	Roads & Traffic Authority
Vegetation Survey Catherine Fields Road Intersection, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Springfields Road Intersection and Camden Valley Way, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Deepfields Road Intersection Camden Valley Way, Catherine Fields 1996	Roads & Traffic Authority
Picnic Point Reserve Vegetation Survey 1996	Bankstown City Council
East Hills Park Vegetation Survey 1996	Bankstown City Council
Monash Reserve Vegetation Survey 1995	Bankstown City Council
Vegetation Consultant on Plan of Management for Cox's Creek for the Endangered Green and Gold Bell Frog 1995	Urban Bushland Management
Smith Park Vegetation Survey 1995	Bankstown City Council
Flora and Fauna Survey, Villawood Stormwater Channel 1995	Bankstown City Council
Virginius Reserve Vegetation Survey 1994	Bankstown City Council
Carysfield Park Vegetation Survey 1993	Bankstown City Council

Ongoing research projects:

Private taxonomic research into the Australian plant genera Prostanthera, Westringia, Dianella, Thelionema, Viola and Hibbertia.

Private research into the invertebrate fauna of the Illawarra with particular emphasis on the Mayfly genus Atalophlebia

Flora of Bankstown" a botanical inventory

Botanical inventories of the Sublime Point and Maddens Plains precincts in the Illawarra Escarpment State Conservation Area

Other Publications & Reports

Miller, R.T. (1984 to 2006) numerous papers for the Prostanthera and Westringia Study Group Newsletters.

Miller, R.T. (1991) Vegetation Consultant on Eloura Nature Reserve Vegetation Survey: Report to Liverpool City Council, Greening Australia.

Miller, R.T. Vegetation Consultant on Salt Pan Creek Stage 1 Vegetation Survey: Report to Bankstown City Council, Ian Olsen.

Gibson, C.P. & Miller, R.T. Plant Species List for Bankstown's Natural Heritage: McLaughlin, L., BCC.

Gibson, C.P. & Miller, R.T. Flora of Bankstown Scientific Inventory of Botanical Heritage: Report to Australian National Parks and Wildlife Service, Gibson, C.P. and Miller, R.T. (in preparation).

Nomination of Prostanthera saxicola R. Br. s. str. As an Endangered Species under the NSW TSC Act November 2011

Special Projects

- "Flora of Bankstown" a botanical inventory
- Founder & Convener Cookson's Landcare Group Bulli (2003 – 2007)
- President, Society for Growing Australian Plants, East Hills Region, 1987-1995.
- Vice President, Society for Growing Australian Plants, East Hills Region, 1996.

- Plant Steward, Society for Growing Australian Plants, East Hills Region, 1987-1996.
- Leader of the Prostanthera Study Group Australian Plant Society, 1992 - 2010.
- Editor and publisher of Prostanthera & Westringia Study Group's Newsletter *The National Mint* and the Study Groups' Journal – *Lasianthos*.
- Vice President and Founding Member, Bankstown Bushland Society.
- Coordinator Grants Application, Bankstown Bushland Society.
- Bushland Regeneration Grants Project Manager, Bankstown Bushland Society:

- Deverall Park Restoration and Rehabilitation Swamp Woodland ($17,880).
- The Crest of Bankstown Restoration and Rehabilitation ($27,850).
- Airport and Ashford Reserves Restoration and Rehabilitation Swamp Woodland ($45,000).

- Co-recipient of Save the Bush grant for Flora of Bankstown by Hon. Ross Kelly, Minister for Arts, Sports and Environment, 1992-93 ($11,050).
- Founding Member of Illawarra Grevillea Park, Bulli.
- Curator, Lamiaceae collection, Illawarra Grevillea Park, Bulli.
- Former Bankstown City Council's Bushfire Taskforce Community Representative.
- Former presenter of an adult education course in gardening at Bankstown Evening College.
- Development and curation of a private regional herbarium.
- Expert Witness for NSW Police murder trial
- Former appointee as Trustee of the Georges River State Recreational Trust by the Minister for the Environment (the Hon. Tim Moore).

Appendix 2. *Hibbertia puberula* subs. *puberula* COLLECTION RECORDS

Field notes compiled by Miller and Miller & Gibson

Site: Lucas Heights Site 1 16/10/07

Abundance: extremely localised, rare < 12 plants noted.

Field notes: Lucas Heights Soil Landscape, Gentle plateau slope, skeletal soil above first sandstone outcropping +/- intermittent seepage zone. Vegetation sparse and stunted probably from the impact of drought and fire episode > 2 years. All *Hibbertia* appeared to be seedlings at this locale. Open Woodland / heath – Canopy: *Eucalyptus haemastoma*? and Stringybark species. Associated understorey: *Banksia ericifolia, B. oblongifolia, Leptospermum arachnoides, Grevillea sericea, Xanthorrhoea* sp., *Cyathochaeta diandra, Burchardia umbellata, Hypoxis hygrometrica*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 1 Ridgetop Laterite

Field notes: Very disturbed site (past trailbike/FWD and possible laterite extraction but now protected and regenerating. Open Woodland/Laterite Heath: *Eucalyptus punctata.* Associated understorey species: *Exocarpos cupressiformis, Goodenia hederacea, Pomax umbellata, Brachyloma daphnoides, Patersonia sericea, Gompholobium minus, Leptospermum parvifolium, Kunzea ambigua, Persoonia laurina, Micrantheum ericoides.*

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 2 Easterly Plateau slope above Georges River

Abundance: Very localised but locally common c. 20 plants noted.

Field notes: Soil: fine sand with clay component, undisturbed habitat, walking track only. Habit: compact wiry shrub 30-60cm wide with many lax stems arising from a rootstock. In Open Woodland. *Eucalyptus sclerophylla?, E. punctata, Angophora bakeri*. Associated understorey: *Melaleuca nodosa, Lambertia formosa, Leptospermum trinervium, Callistemon linearis, Kunzea ambigua, Kunzea capitata, Helichrysum collinum, Xanthorrhoea sp., Stipa pubescens, Themeda australis*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 3 Upperslope/headwaters of upper drainage line.

Field notes: Undisturbed. *Eucalyptus punctata, E. sclerophylla*? and *Angophora bakeri*. Associated understorey: *Kunzea ambigua, Melaleuca nodosa, Gompholobium minus, Isopogon anemonifolius, Leucopogon, Kunzea capitata, Xanthorrhoea* sp. Dominated by *Kunzea* and *Melaleuca nodosa*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 4 Laterite Ridgetop.

Field notes: *Angophora bakeri. Leptospermum parvifolium* (dominates), *Kunzea ambigua, Petrophile sessilis, Micrantheum ericoides, Kunzea capitata, Lambertia formosa, Pimelea linifolia, Stipa pubescens*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 1: Lateritic Heath

Field notes: *Eucalyptus* sp. (Stringybark), *E. squamosa, Allocasuarina littoralis, Angophora hispida*. Associated understorey*: Leptospermum trinervium* (narrow-leaved form), *Petrophile sessilis, Persoonia lanceolata, Isopogon anemonifolius, Hakea laevipes, H. sericea, Grevillea diffusa, Actinotus minor, Cyathochaeta diandra, Entolasia stricta, Caustis flexuous*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 2: Lateritic Heath

Field notes: Soil very fine sandy loam. Habit: low +/- prostrate shrub sprawling through sedges. *Angophora hispida, Corymbia gummifera, Allocasuarina littoralis*. Associated understorey: *Leptospermum trinervium* (narrow-leaved form), *Petrophile sessilis, Persoonia lanceolata, Pultenaea elliptica, Isopogon anemonifolius, Banksia spinulosa, Grevillea diffusa, Actinotus minor, Cyathochaeta diandra, Entolasia stricta*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 3

Field notes: Soil sandy loam with small sandstone outcroppings. Open Forest *Eucalyptus punctata*, E. sp. (Stringybark), and *Corymbia gummifera.* Associated understorey: *Hakea laevipes, Leptospermum parvifolium, Isopogon anemonifolius, Lissanthe strigosa, Grevillea diffusa, Hakea sericea, Acacia linifolia, Themeda australis, Lomandra obliqua, Lomandra cylindrica, Cyathochaeta diandra*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 4

Field notes: Soil: fine sandy loam scattered lateritic fragments. Open Forest with grassy and herbaceous understorey comprised of *Eucalyptus punctata*, E. sp. (Stringybark), and *Corymbia gummifera.* Associated understorey: *Leptospermum parvifolium, Isopogon anemonifolius, Lissanthe strigosa, Grevillea diffusa, Goodenia hederacea, Stipa pubescens, Themeda australis, Entolasia stricta, Hypoxis hygrometrica, Hovea linearis, Cryptandra* sp., *Lobelia dentata, Patersonia sericea, Cyathochaeta diandra* and *Xanthorrhoea* sp.

Site: Peter Meadows Reserve Old Kent Road Kentlyn

Field notes: Soil: sandy, lateritic. Lateritic Ridgetop Heath *Eucalyptus sclerophylla, E. squamosa, Angophora hispida* heath. Lateritic Ridgetop Heath /Woodland interface: *Eucalyptus sclerophylla, E. punctata, Angophora hispida*. Associated understorey species: *Petrophile sessilis, Lambertia formosa, Kunzea capitata, Leptospermum arachnoides, Brachyloma daphnoides, Hakea laevipes, Xanthorrhoea sp., Actinotus minor, Pultenaea elliptica, Hakea sericea, Gompholobium minus, Goodenia hederacea* and *Entolasia stricta*.

Site: Freres Crossing Reserve, Freres Road Kentlyn 2/11/07, Ridgetop slopes

Field notes: *Eucalyptus punctata, Syncarpia glomulifera* Associated understorey: *Hakea laevipes, Persoonia linearis, Leptospermum trinervium, Isopogon anemonifolius, Gompholobium minus,* *Acacia terminalis, Gonocarpus tetragynus, Brachyloma daphnoides, Eriostemon australis, Grevillea diffusa, Hibbertia diffusa, Hypoxis hygrometrica, Xanthorrhoea* sp.*, Themeda australis, Lomandra obliqua, Entolasia stricta.*

Site: Freres Crossing Reserve, Freres Road Kentlyn 2/11/07, Ridgetop

Field notes: *Eucalyptus punctata, Angophora costata*, Stringybark sp. Associated understorey*: Allocasuarina littoralis, Kunzea ambigua, Acacia terminalis, Brachyloma daphnoides, Hypoxis hygrometrica, Themeda australis* and *Stipa pubescens*.

Site: Ella Avenue Barden Ridge (formerly Lucas Heights) 20/11/07 Below Detention Basin

Field notes: Localised in drainage line. Site impacted by housing development – weed invasion occurring due to urban runoff and sedimentation. *Eucalyptus punctata*, E. sp. (Stringybark), *E. haemastoma, Corymbia gummifera, Angophora hispida*. Associated understorey: *Hakea sericea, Banksia oblongifolia, Leptospermum polygalifolia, L. arachnoides, Lambertia formosa, Kunzea ambigua, Grevillea sericea, Epacris pulchella, Banksia spinulosus, B. marginata, Isopogon anemonifolius, Hakea laevipes, Phyllota phylicoides, Actinotus minor, Patersonia sericea, Xanthorrhoea resinosa, Stipa pubescens, Xanthosia tridentata, Lomandra obliqua, Cyathochaeta diandra, Lepyrodia scariosa, Schoenus brevifolius, Lindsaea linearis*.

Site: Ella Avenue Barden Ridge (formerly Lucas Heights) 20/11/07 Downslope of Detention Basin

Field notes: Scattered through sedges - relatively rare at edge of wet heath/swamp. *Eucalyptus haemastoma*, E. sp. (stringybark), *E. punctata*. Associated understorey: Sedges dominate understorey: *Leptocarpus tenax, Schoenus brevifolius, Xanthorrhoea resinosa, Leptospermum polygalifolia, Banksia oblongifolia, Actinotus minor, Dampiera stricta, Epacris pulchella, Entolasia stricta, Deyeuxia decipiens.*

Site: Little Forest Lucas Heights 20/11/07

Field notes: Soil: fine sandy loam with clay content, +/- impeded drainage, Lucas Heights Soil Landscape, Localised in narrow zone in upper drainage line. *Eucalyptus oblonga, E. haemastoma, Corymbia gummifera, Angophora hispida.* Associated understorey: *Callistemon citrinus, Banksia oblongifolia, Leptospermum polygalifolia, L. arachnoides, Lambertia formosa, Kunzea ambigua, Grevillea diffusa, G. sericea, Melaleuca thymifolia, Callistemon linearis, Hakea sericea, H. teretifolia, Acacia linifolia, Mirbelia rubiifolia, Actinotus minor, Patersonia sericea, Xanthorrhoea resinosa, Stipa pubescens, Xanthosia tridentata, Lomandra obliqua, Cyathochaeta diandra, Schoenus brevifolius*.

Site: Voyager Point Adjacent Old Single Mens Quarters

Field notes: Soil: Fine sand atop of lateritic gravels – Surface layer -Well drained, Aspect: easterly Slope: 0-2. Open Woodland: *Eucalyptus sclerophylla, E. parramattensis, Angophora bakeri*. Understorey diverse open to moderately dense with well-developed ground layer. Dominant Associated Shrub Species: *Melaleuca nodosa, Petrophile sessilis, Leptospermum parvifolium, L.*

trinervium, Banksia spinulosa, Hakea laevipes, Kunzea ambigua, Persoonia lanceolata, Callistemon linearis, Hakea sericea, Acacia brownii, Daviesia acicularis. Dominant Associated Ground Layer Species: *Platysace ericoides, Hovea linearis, Lomandra obliqua, Lepyrodia scariosa, Austrostipa pubescens, Austrodanthonia tenuior, Cyathochaeta diandra*.

Site: Voyager Point adjacent Sirius Drive

Field notes: Soil: Fine sand and laterite – Surface layer -Well drained. Aspect northerly slope 0-2. Open Woodland: *Eucalyptus sclerophylla, Angophora bakeri* and *Eucalyptus oblonga*. Understorey diverse, open to moderately dense with well-developed ground layer. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, Banksia spinulosa, Babingtonia densiflora, Brachyloma daphnoides, Kunzea ambigua, Persoonia levis, Grevillea sericea, Hakea sericea, Isopogon anemonifolius, Melaleuca nodosa, Lambertia formosa, Philotheca scaber, Styphelia laeta.* Dominant Associated Ground Layer Species: *Platysace ericoides, Dianella revoluta, Lomandra obliqua, Lepyrodia scariosa, Austrostipa pubescens, Cyathochaeta diandra*.

Site: Yeramba Lagoon 2/1/07 Ridge slopes 1

Field notes: Shelving sandstone terraces. Soil: Sandy loam. Surface layer: Well drained but drainage impeded by sandstone bedrock. Aspect: westerly slope: 5. Open Woodland: *Eucalyptus racemosa, Corymbia gummifera, Eucalyptus oblonga & Angophora bakeri.* Understorey diverse, open grassy site. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum polygalifolium, Banksia oblongifolia, B. spinulosa, B. marginata, Kunzea ambigua, Persoonia levis, Grevillea sericea, Hakea sericea, Grevillea sericea, Hakea laevipes, Leptospermum arachnoides, Epacris microphylla, Hibbertia stricta.* Dominant Associated Ground Layer Species: *Actinotus minor, Schoenus moorei, Austrostipa pubescens, Themeda australis, Entolasia stricta, Lomandra multiflora.*

Site: Yeramba Lagoon 2/1/07 Ridge slopes 2

Field notes: Ridge slopes – shelving sandstone terraces. Soil: Sandy loam. Surface layer: Well drained. Aspect: northwest. Slope: 5. Interface between Woodland*: Eucalyptus oblonga, Corymbia gummifera, Eucalyptus punctata* Open Woodland: *Eucalyptus racemosa, Corymbia gummifera, Eucalyptus oblonga & Angophora bakeri.* Understorey diverse and well developed moderately dense. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, B. marginata, Hibbertia stricta*, *Leucopogon microphyllus, Lambertia formosa, Callistemon linearis, Melaleuca thymifolia, Gompholobium grandiflora, Epacris microphylla, Lasiopetalum ferrugineum.*

Dominant Associated Ground Layer Species: *Themeda australis, Entolasia stricta, Burchardia umbellata*, *Actinotus minor, Lomandra obliqua, Schoenus moorei, Austrostipa pubescens.*

Site: Blackwall 2/1/07 Ridgetop / Plateau

Field notes: Soil: relatively deep sand. Aspect: Northerly Slope: < 2. Open Woodland: *Corymbia gummifera, Eucalyptus racemosa, E. punctata, and E. oblonga.* Understorey diverse. Dominant Associated Shrub Species: *Brachyloma daphnoides, Banksia spinulosa, Petrophile sessilis, Leptospermum trinervium, L. parvifolium, Isopogon anemonifolius, Babingtonia densifolia, Dillwynia* *retorta, Philotheca scabra, Grevillea sericea, Gompholobium glabratum, Xanthorrhoea media, Kunzea ambigua, Bossiaea heterophylla, Acacia myrtifolia.* Dominant Associated Ground Layer Species: *Phyllanthus hirtellus, Pomax umbellata, Austrostipa pubescens, Themeda australis* and*Cyathochaeta diandra.*

Site: Mickeys Point 2/1/07 Ridgetop / Plateau

Field notes: Soil: lateritic. Aspect: North east Slope: < 2. Open Woodland / Heath: *Eucalyptus racemosa, Angophora hispida,* and *Allocasuarina littoralis.* Understorey diverse. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, Hakea sericea, Persoonia levis, Kunzea ambigua, Styphelia triflora, Isopogon anemonifolius, Brachyloma daphnoides, Babingtonia densifolia, Hemigenia purpurea, Hibbertia stricta*. Dominant Associated Ground Layer Species: *Actinotus minor, Baeckea ramosissima, Poranthera ericoides, Lomandra obliqua, Austrostipa pubescens, Entolasia stricta.*

Appendix 3. *Hibbertia puberula* IDENTIFICATION CHARACTERS

All microscopic photos by Miller 2018.

Photo 14: *Hibbertia puberula* subsp. *puberula* Canoelands.

Photo shows that the hairs are “worn off” on the older growth.

Photo 15: *Hibbertia puberula* subsp. *puberula* Canoelands

Photo shows tomentum characteristics of new shoots, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface.

Photo 16: *Hibbertia puberula* subsp. *puberula* from Lucas Heights.

Photo 17: *Hibbertia puberula* subsp. *puberula* (Lucas Heights)

Photo shows leaf and stem tomentum, revolute margins and bulging broader central vein obscuring the leaf undersurface of new shoot.

Photo 18: *Hibbertia puberula* subsp. *puberula,* Smith's Creek Reserve 4th June 2018.

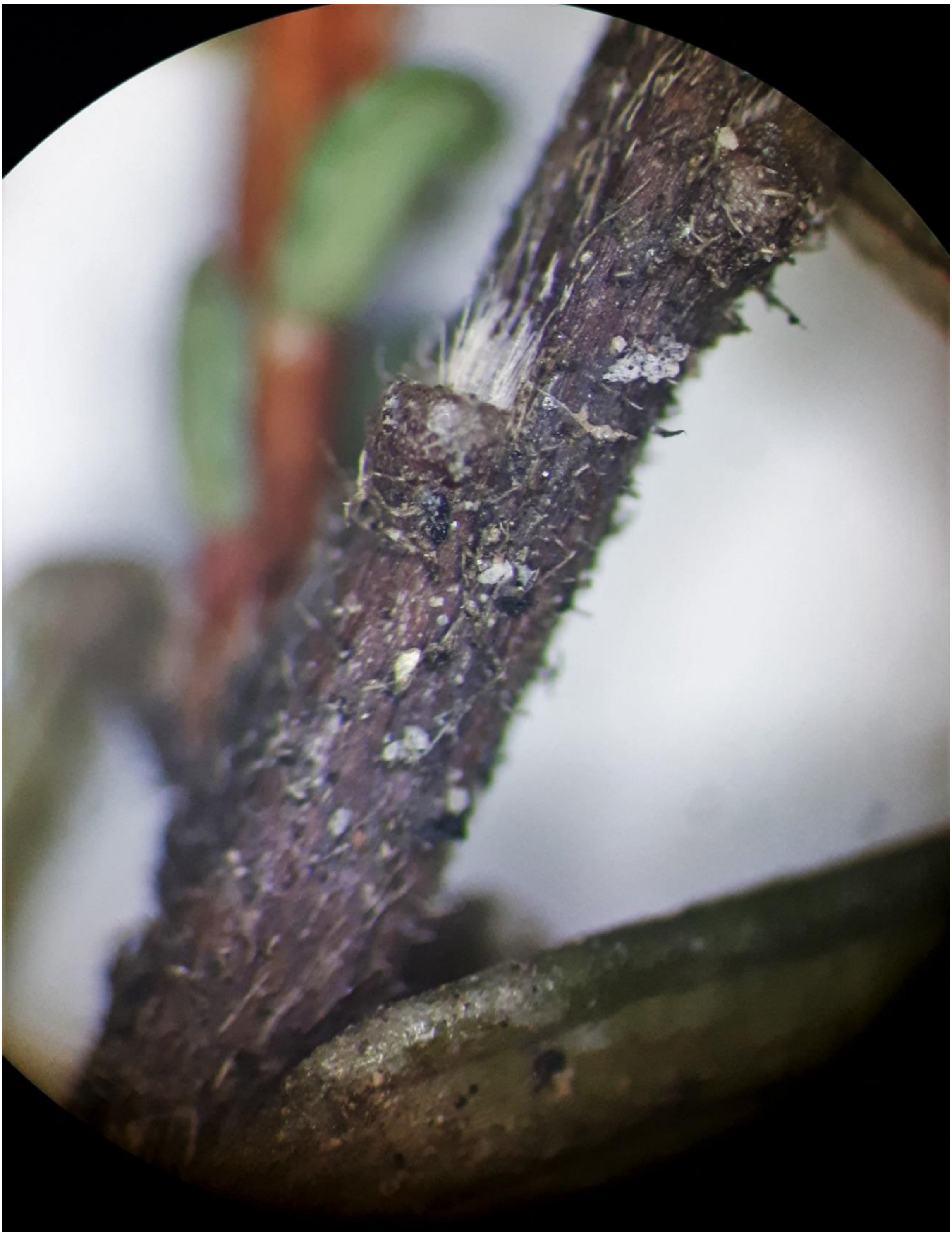


Photo 19: *Hibbertia puberula* subsp. *puberula,* Smith's Creek Reserve 4th June 2018.

Photo 20: *Hibbertia puberula* subsp. *extensa* juvenile shoot.

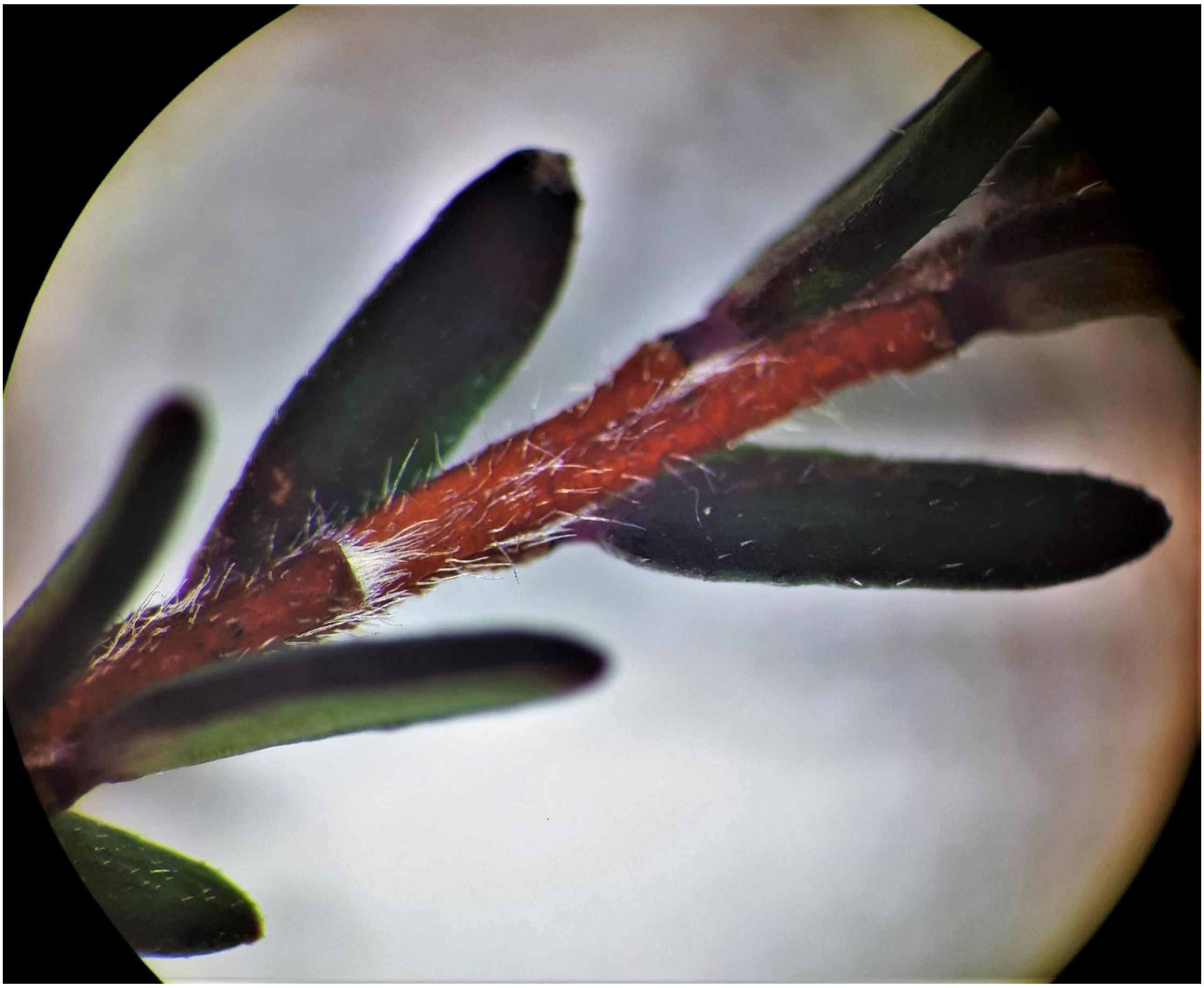


Photo 21: *Hibbertia puberula* subsp. *extensa* juvenile shoot showing tomentum characteristics.

Photo 22: *Hibbertia puberula* subsp. *extensa*

Photo shows typical lateral branching habit and tomentum characteristics of calyxes, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface.

Photo 23: *Hibbertia puberula* subsp. *extensa*

Photo shows tomentum characteristics of stem, revolute leaf margins and bulging broader central vein that obscures the leaf undersurface noting that tomentum has “worn off”.

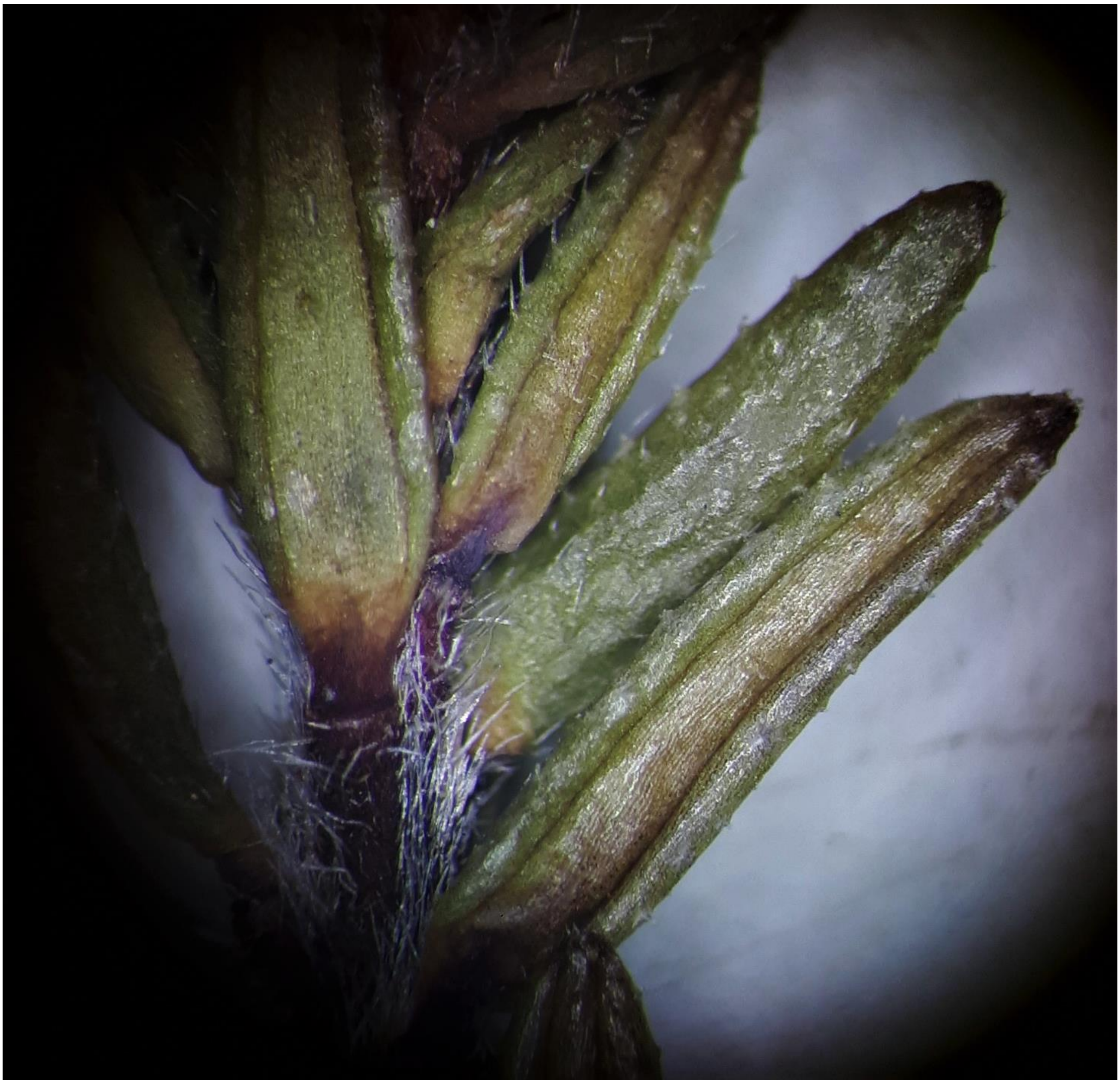


Photo 24: *Hibbertia puberula* subsp. *extensa.*

Photo shows tomentum characteristics of an upper portion of the branchlet, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Note that much of the tomentum has not “worn off”.

Photo 25: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing tomentum characteristics, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 26: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing interpetiolar tuffs, glabrescent tomentum characteristics, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 27: *Hibbertia puberula* subsp. *glabrescens.*

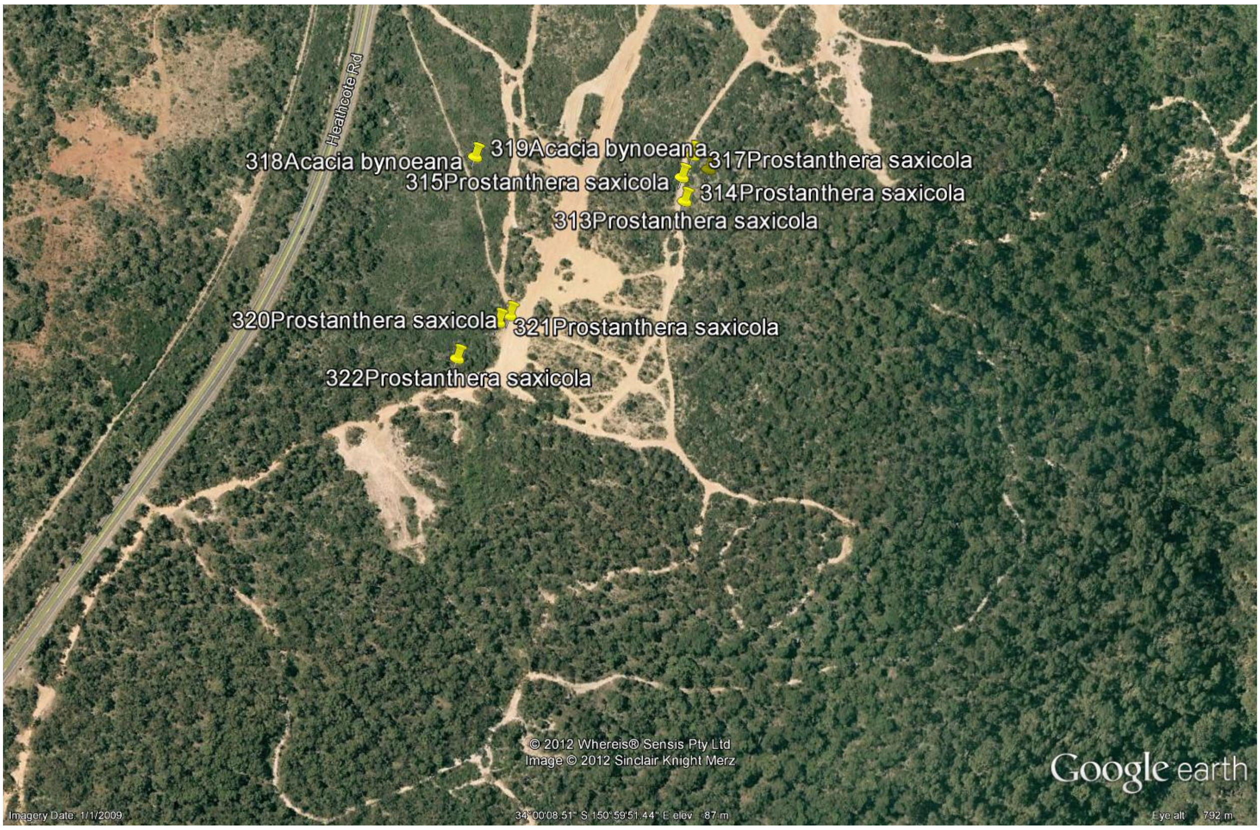
Photo showing interpetiolar tuffs of hair and scattered simple hairs on upper shoot. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 28: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing glabrescent calyces. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Appendix 4. INDICATIVE DISTRIBUTION OF *Hibbertia puberula* at MENAI.

The following Google Earth images show the indicative distribution of threatened taxa east of Heathcote Road within a Menai proposed development footprint, recorded on two brief CFFIS site inspections.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318Acacia bynoeana
319Acacia bynoeana
317Prostanthera saxicola
315Prostanthera saxicola
314Prostanthera saxicola
313Prostanthera saxicola
320Prostanthera saxicola
321Prostanthera saxicola
322Prostanthera saxicola
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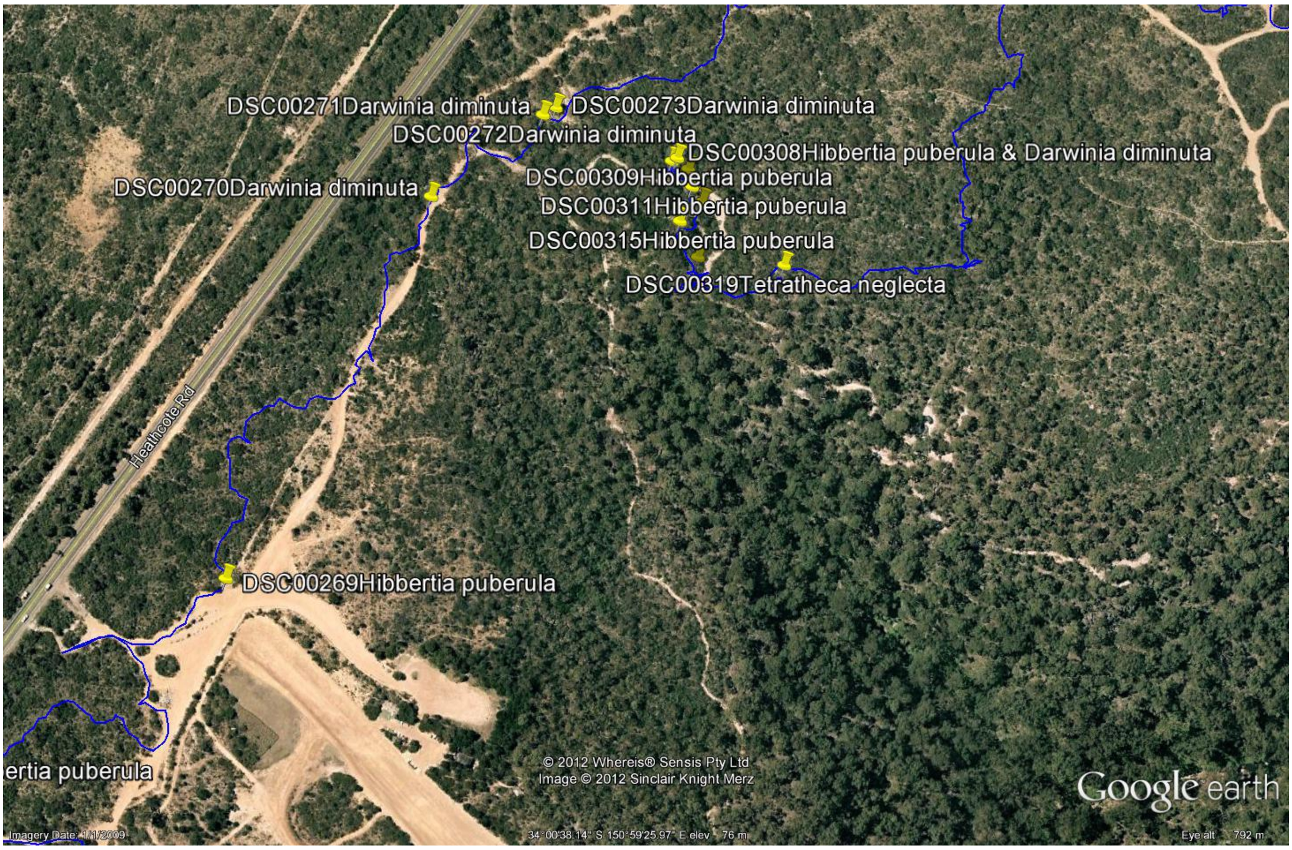
Image © 2012 Sinclair Knight Merz
Google earth


311Acacia bynoeana
312Acacia bynoeana
308Hibbertia puberula
310Hibbertia puberula
DSC00321Hibbertia puberula
Survey
DSC00277habitat
DSC00278habitat
DSC00275habitat
DSC00320Acacia bynoeana
DSC00274habitat
DSC00273Darwinia diminuta
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth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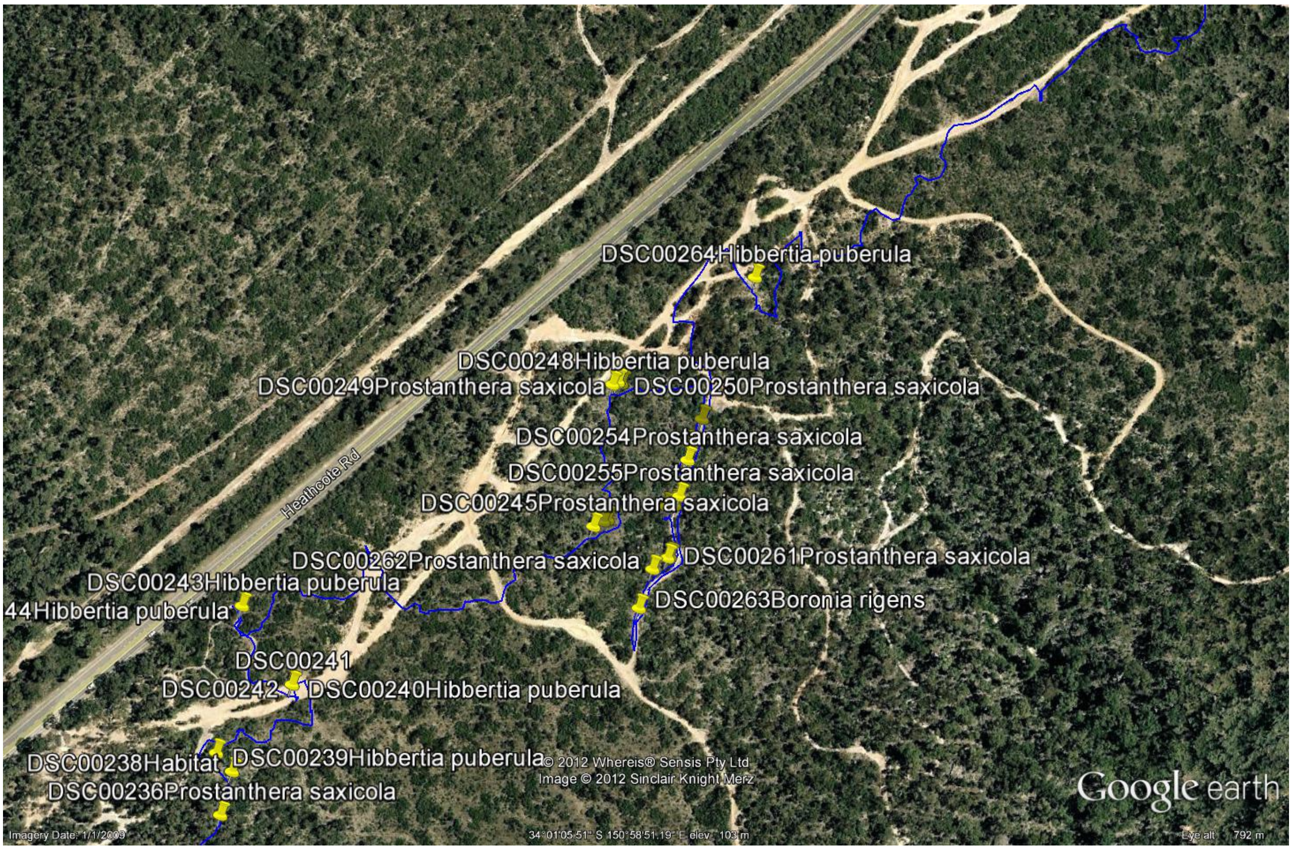
DSC00273Darwinia diminuta
DSC00272Darwinia diminuta
DSC00308Hibbertia puberula & Darwinia diminuta
DSC00270Darwinia diminuta
DSC00309Hibbertia puberula
DSC00311Hibbertia puberula
DSC00315Hibbertia puberula
DSC00319Tetratheca neglecta
Heathcote Rd
DSC00269Hibbertia puberula
ertia puberula
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth


DSC00268Hibbertia puberula
DSC00267Hibbertia puberula
DSC00265Hibbertia puberula
DSC00266Hibbertia puberula
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth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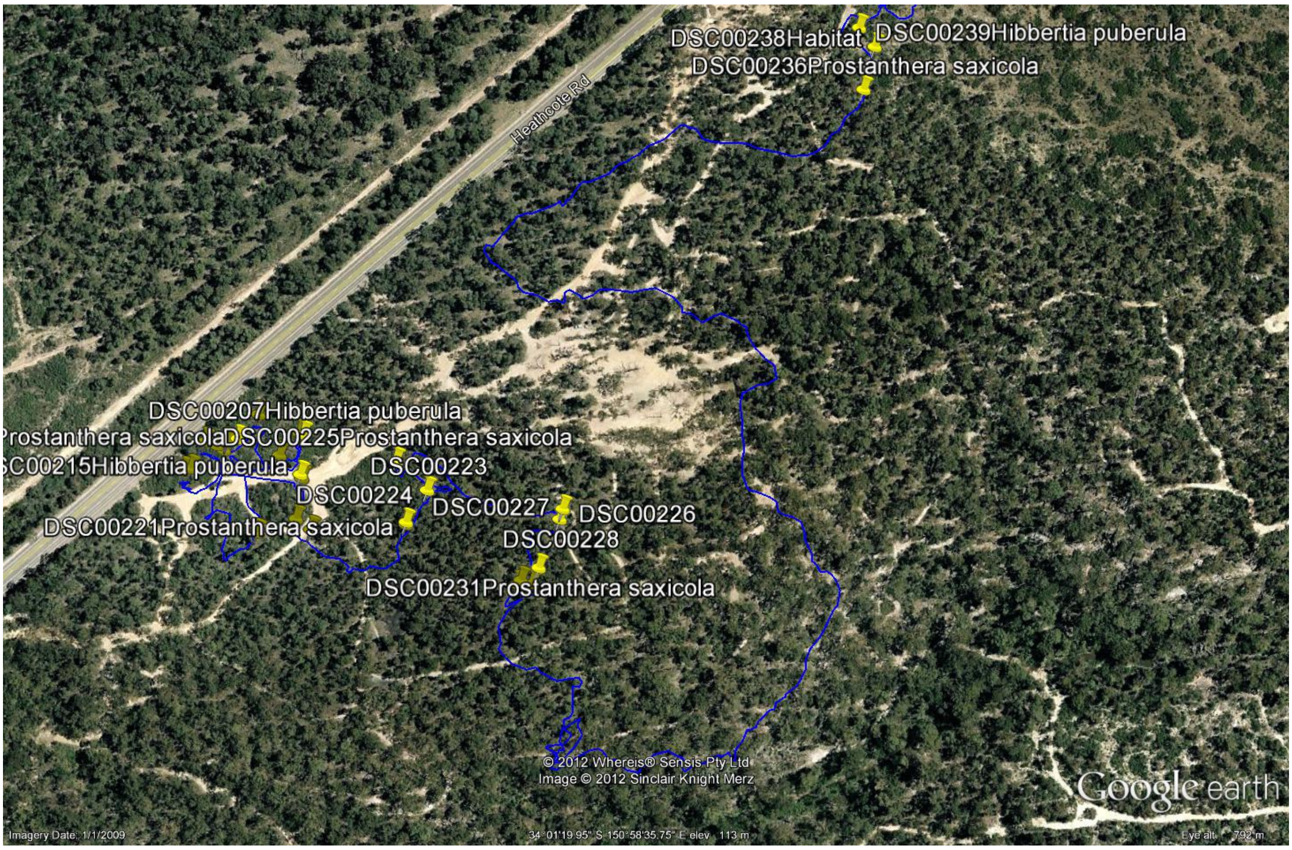
DSC00248Hibbertia puberula
DSC00249Prostanthera saxicola
DSC00250Prostanthera saxicola
DSC00254Prostanthera saxicola
DSC00255Prostanthera saxicola
DSC00245Prostanthera saxicola
Heathcote Rd
DSC00262Prostanthera saxicola
DSC00261Prostanthera saxicola
DSC00243Hibbertia puberula
44Hibbertia puberula
DSC00263Boronia rigens
DSC00241
DSC00242
DSC00240Hibbertia puberula
DSC00238Habitat
DSC00239Hibbertia puberula
DSC00236Prostanthera saxicola
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth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DSC00239Hibbertia puberula
DSC00236Prostanthera saxicola
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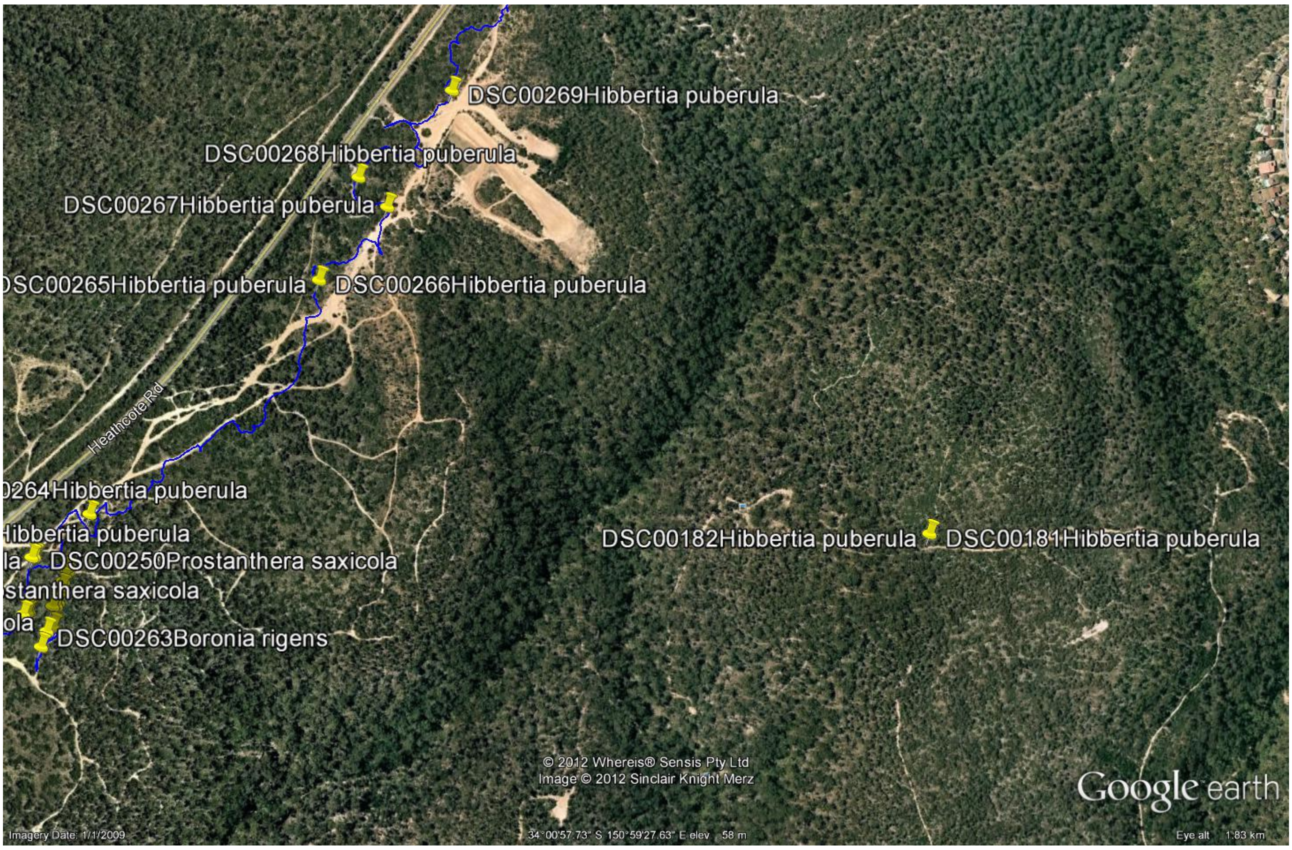
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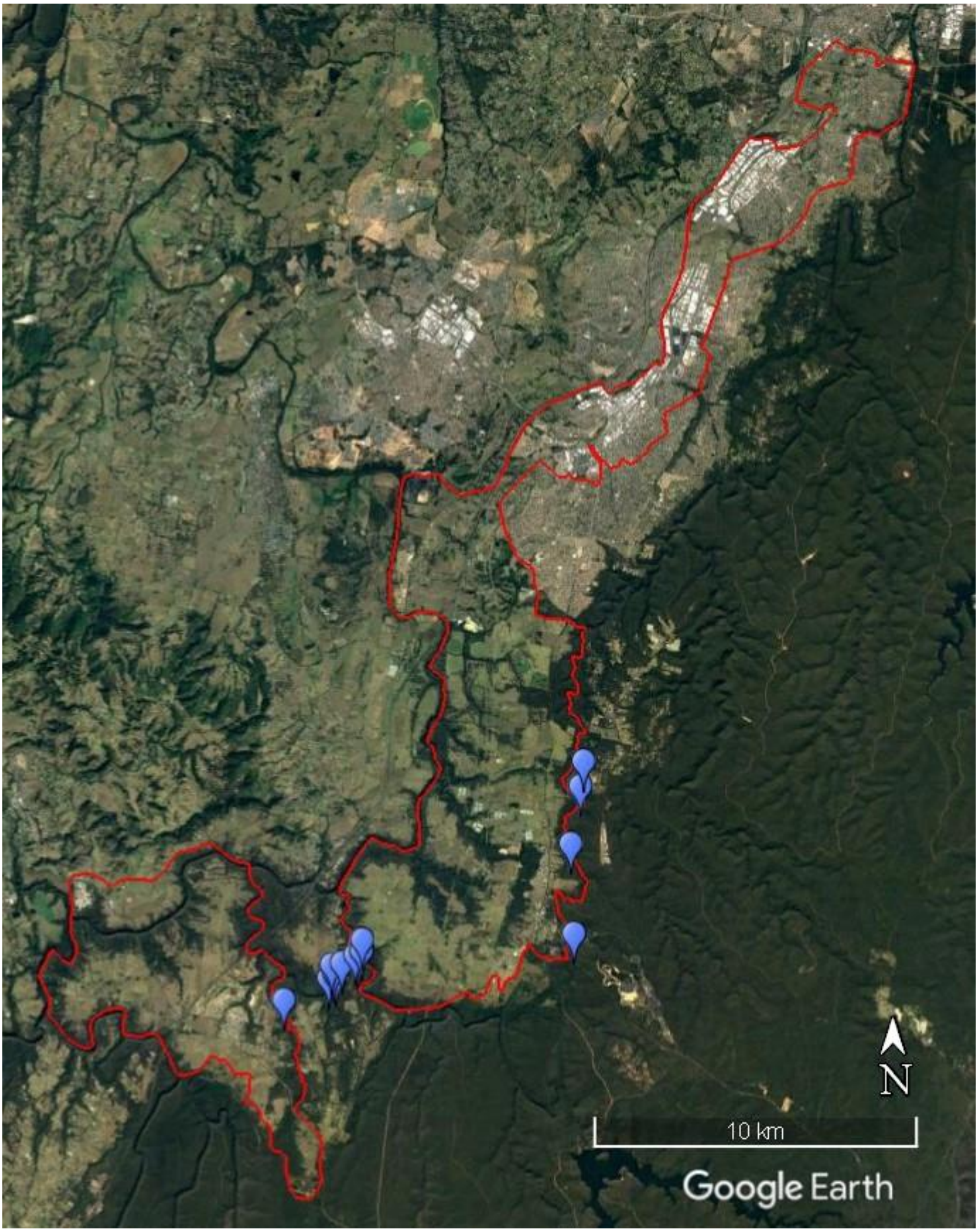
Heathcote Rd
264Hibbertia puberula
Hibbertia puberula
DSC00250Prostanthera saxicola
stanthera saxicola
DSC00263Boronia rigens
DSC00182Hibbertia puberula
DSC00181Hibbertia puberula
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth

Appendix 5. DISTRIBUTION OF *Hibbertia riparia* IN / CLOSE TO THE GROWTH AREAS.



Map 10: Records of *Hibbertia riparia* in or close to the Growth Areas.

Note that *H. riparia* is unlikely to occur in NSW and these records could be *H. puberula.*

Strategic assessment for Cumberland Plain Conservation Plan Aerotropolis and Greater Penrith,

Hibbertia puberula species group

Hibbertia puberula subsp. *glabrescens* at Bankstown Airport

Report prepared for Department of Planning and Environment

By

Cumberland Flora & Fauna Interpretive Services

Robert Miller - December 2018

Executive Summary

Hibbertia puberula subsp. *extensa* and subsp. *puberula* are listed as Endangered Species under the *Biodiversity Conservation Act 2016*. *Hibbertia puberula* subsp. *glabrescens* is listed as a Critically Endangered Species, being known from only one population at Bankstown. There is limited data on the life history and ecology of the species.

Survey for this report was limited by time constraints, lack of access to private property, and years of preceding drought conditions. Survey targeted areas of suitable habitat identified from the habitat of extant populations and DPE vegetation mapping.

Areas adjacent to the development footprint were included in the survey because *H. puberula* is a small shrub that could be severely affected by anthropogenic impacts, particularly in areas downhill of development. The proposed road corridors will fragment habitat exposing the species to greater edge effects.

Outcomes of the assessment:

<u>*Hibbertia puberula* subsp. *extensa*</u>: It is extremely unlikely that this subspecies exists within the WPEC and WSA growth areas. No suitable habitat is known to occur or is likely to occur within the proposed urban footprint or the growth areas. The likelihood of occurrence is assessed as negligible.

<u>*Hibbertia puberula* subsp. *glabrescens*</u>: The likelihood of occurrence within or adjacent to the GPEC is considered to be low to moderate, and the likelihood of occurrence within or adjacent to the WSA is assessed as low. From known occurrence data the subspecies does not have the capacity to exist in habitats that occur within the proposed WSA development footprint.

<u>*Hibbertia puberula* subsp. *puberula*</u>: Within the development footprint the subspecies is likely to occur within the Wianamatta Regional Park, as well as in areas adjacent to the footprints at Ropes Crossing and Kemps Creek. This study provided 7 new records for *H. puberula* subsp. *puberula*, two within the growth areas and 5 to the north. The species was unknown to occur within or adjacent to the growth areas prior to this survey.

Outcomes of this assessment are that 34 ha of habitat with a high to moderate probability of the species occurring are within the development footprint, and that more than 100 ha of habitat with high to moderate probability of species occurrence are outside the footprint but are likely to suffer from anthropogenic impacts caused by the development.

<u>Recommendations:</u> It is a recommendation of this study to list *Hibbertia pedunculata* as a Threatened species or an Endangered Population, and to take it into consideration as part of this biodiversity certification process as the known populations are likely to be severely impacted by development. It is also a recommendation that all bushland remnants adjacent to development be fenced and maintained to minimise anthropogenic impacts.

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Abbreviations

ALA	Atlas of Living Australia
AVH	Australian Virtual Herbarium
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
CFFIS	Cumberland Flora & Fauna Interpretive Services
DPE	NSW Department of Planning and Environment
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GPEC	Greater Penrith to Eastern Creek Urban Release Investigation Area
IBRA	Interim Biogeographic Regionalisation for Australia
OEH	NSW Office of Environment and Heritage
PCT	Plant Community Type
sp./spp.	species (species singular / plural)
s. str.	*sensu stricto* – in the narrow sense
subsp.	subspecies
UBBS	Urban Bushland Biodiversity Survey of Western Sydney NPWS 1997
WSA	Western Sydney Aerotropolis Growth Area

1. Introduction

1.1 PURPOSE

The purpose of this expert report is to determine the potential for future urban development in identified growth areas of Western Sydney to impact on *Hibbertia puberula*, the subspecies of which are listed as an Endangered or Critically Endangered Species under the *Biodiversity Conservation Act 2016*. This report forms part of the Cumberland Plain Conservation Plan, which will be assessed for:

- Biodiversity certification under the *Biodiversity Conservation Act 2016* (BC Act)
- Strategic assessment and approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Biodiversity Assessment Method (BAM) sets out the framework and methods to be used for assessment of impacts to biodiversity to provide preferred conservation outcomes while also supporting the development approval process. Under the BAM an expert report can be used when adequate survey is not possible. An expert report can only be used for species to which species credits apply.

The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report. The report must set out whether the subject species is likely to be present at the development site, and if present then the report must estimate, in the case of a species such as *Hibbertia puberula*, the area of habitat where the species is likely to be impacted, as well as areas from which it is known to occur in which it will be impacted.

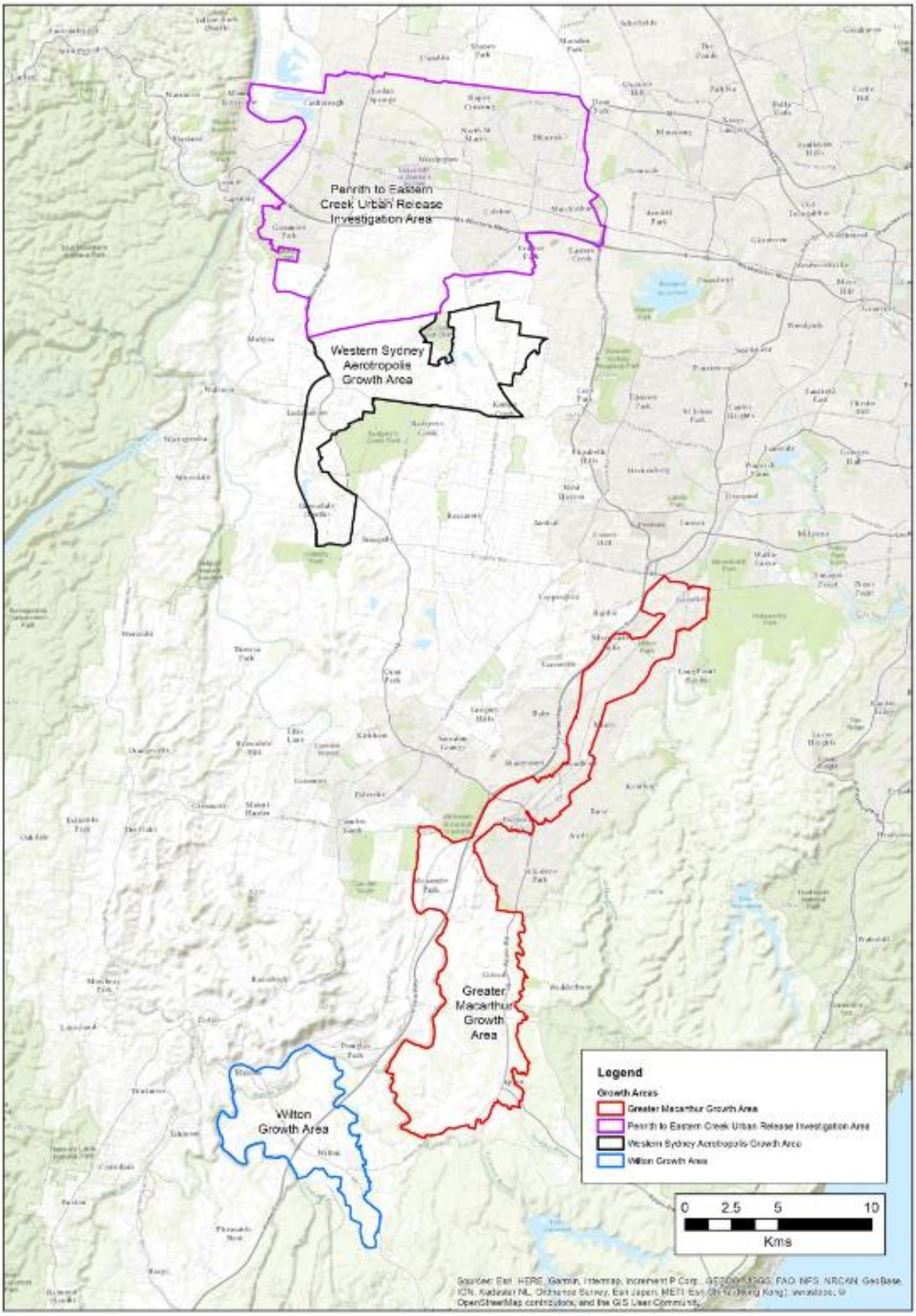
1.2 PROJECT CONTEXT

The NSW Government is planning for future urban development in Western Sydney. Four growth areas have been identified, these are Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Aerotropolis (WSA), and Greater Penrith to Eastern Creek (GPEC). These growth areas are all located within the Cumberland Subregion in version 7 of the Interim Biogeographic Regionalisation for Australia (IBRA) (2016).

As part of the planning for this future development, the Department of Planning and Environment (DPE) is preparing the Cumberland Plain Conservation Plan. This is a strategic regional assessment that will lead to the identification of preferred conservation outcomes for the Cumberland subregion.

1.3 STUDY AREA

Map 1 shows the growth areas of Greater Penrith to Eastern Creek (GPEC) and Western Sydney Aerotropolis (WSA) which are the subject of this report, and the Greater Macarthur and Wilton growth areas which are the subject of a separate report.



Map 1: The four Western Sydney Growth Areas

Map source: NSW Department of Planning and Environment.

1.4 JUSTIFICATION FOR USE OF EXPERT REPORT

The BAM allows for situations where an expert report will be required to replace or complement survey effort at a development site. While there has been some field survey for the Strategic Biodiversity Certification assessment, the area covered by the proposed GPEC and WSA are extensive and there have been issues with gaining access to some of the private properties.

An expert report is required to assess potential impact to *Hibbertia puberula* for the following reasons:

Insufficient survey: A large extent of the identified growth areas could not be surveyed because it was on private property and could not be accessed within the project timeframe. Expertise was required to identify and survey potential species habitat and propose additional habitat based on extant populations and prior knowledge of the species.

Survey following prolonged rainfall deficiency / drought: The Western Sydney region has been experiencing extremely dry conditions for several years, resulting in the *Hibbertia puberula* plants being subject to severe drought stress causing partial and/or full defoliation. In many instances the majority of the population at a particular site may have retracted to the soil seed bank.

Compounding the effect of reduced soil moisture, following drought many areas have a significant increase in leaf, twig and branch drop making this small and cryptic species more difficult to locate or possibly covering them completely.

Herbivory of a wide range of native species can severely impact small plants during dry conditions.

The discernible population was therefore likely to be significantly reduced from these causes.

Rainfall events in months prior to this assessment allowed many *Hibbertia* species to produce new growth and therefore flowers. However, the rainfall was insufficient to replenish subsoil moisture. A dry period and unusually hot conditions prior to, and during, this assessment resulted in moisture stress for many plants. In the case of some *Hibbertia* species this is noticeable by unusually early petal dehiscence making their detection difficult.

It requires an expert in the species to locate and identify rare *Hibbertia* under these conditions.

Reliable species identification: Identification of the genus *Hibbertia* to species level requires examination of flower parts in combination with stem and leaf characters, especially tomentum type and density. It is not practical nor reliable to identify small leaved species in the field as many of these morphological features require microscopic examination and comparison to known voucher specimens. This needs to be carried out by an expert in *Hibbertia*.

The use of an expert report to complement survey of the growth areas avoids the problems associated with *Hibbertia* misidentifications.

1.5 CREDENTIALS OF EXPERT

Robert Miller has over 30 years' experience in field botany. Over this time Robert has identified many rare and endangered plant species and has contributed to the scientific knowledge of native flora distribution and habitat in NSW.

Robert has been certified as an expert for *Hibbertia fumana* and *H. puberula* under the Biodiversity Assessment Methodology.

Robert has worked with Hellmut Toelken of the State Herbarium of South Australian, locating, collecting and identifying undescribed or rare species of *Hibbertia*. Some of these taxa were known only from historic records with non-precise locality details and depauperate or non-existent habitat information. Many of the specimens have been used for the taxonomic revision of the genus and are cited in various taxonomic publications including "Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*" published in the Journal of the Adelaide Botanic Gardens 26 (2013). Examples of the cited specimens include: *Hibbertia ericifolia* subsp. *acutifolia* Toelken, subsp. nov. Type: New South Wales, Sarahs Knob, R. & J. Miller s.n., 21.x.2006 (holo.: AD; iso.: BRI, CANB, NSW, PERTH) and *Hibbertia dispar* R.T. Miller s.n., 0.5 km S of Penrose Rest area, along western boundary track, Penrose State Forest, 12.x.2010 (AD, NSW).

Robert and Hellmut's paper "Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales", was published in the Journal of the Adelaide Botanic Gardens in 2012. The paper describes 13 new taxa including *Hibbertia fumana* Toelken and *Hibbertia puberula* subsp. *puberula,* – subsp. *extensa R.T.Mill.* and – subsp. *glabrescens Toelken.*

In 2017 Robert was called as an expert to identify the species of *Hibbertia* on the Moorebank bushland site that is the subject of the Intermodal development proposal.

Robert has recognised expertise for other threatened taxa including *Pomaderris adnata*, *Solanum celatum*, *Epacris purpurascens* var. *purpurascens*, and the genus *Prostanthera* including the threatened taxa *Prostanthera discolor*, *P. stricta*, *P*. *densa*, *P*. *junonis* and has provided expertise to the OEH Saving our Species programs.

2. Species information

2.1 SPECIES DESCRIPTION

There are 3 sub-species of *Hibbertia puberula*. The following descriptions are taken directly from the Toelken and Miller 2012 paper "Notes on Hibbertia (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. Hemistemma, mainly from the central coast of New South Wales".

***Hibbertia puberula* Toelken**

Typus: New South Wales, Yowie Bay, A.A.Hamilton s.n., 14.xi.1908

Description: Shrublets up to 0.25 m tall, decumbent or rarely suberect, much to sparsely branched or spreading; branches wiry to stiff from a woody stem or base, with decurrent leaf bases more or less flanged, pubescent to hirsute mainly between flanges, rarely glabrescent or glabrous. Vestiture often not persistent, with spreading longer over shorter simple hairs on all parts of the plant; on branches with few to many (rarely glabrous) mainly longer hairs (but varying very much in actual length) over much shorter ones, often predominantly in the grooves between flanges of the leaf bases, becoming appressed and wearing off soon; on leaves above with scattered spreading antrorse simple hairs becoming longer towards the margins, often wearing off; on leaves below with few scattered hairs as above on the revolute margins but not on the central vein, wearing off; on bracts with finer but similar hairs to leaves; on outer calyx lobes outside moderate to dense, with erect short hooked hairs overtopped by longer tubercled straight hairs up to 1.3 mm long, often becoming bristle-like particularly on the margins and the base and receptacle, persisting, inside dense, with fine, often silky appressed antrorse hairs; on inner calyx lobes outside and inside usually similar to the outer lobes, but hairs finer and decreasing in number and size towards the glabrous, membranous margins. Leaves usually with dense intrapetiolar tuft spilling over into grooves between flanges; petiole 0–0.6 mm long, ± flattened; lamina linear-lanceolate to oblong-lanceolate or oblong-elliptic, (1.2–) 2.8–5 (–7.6) × (0.5–) 0.7–1 (–1.2) mm, ± abruptly constricted into petiole, acute and usually with a terminal tuft of hairs wearing off soon, often becoming obtuse, above ± flat and sparsely pilose to glabrescent, below revolute margins and recessed to bulging broader central vein obscuring the undersurface, sparsely pilose to glabrous on the margins. Flowers single and terminal, rarely in clusters of up to three from subtending axils; pedicel 0–3 mm long; bracts linear-elliptic to elliptic-lanceolate, (2.9–) 3.2–3.8 (–4.2) × (0.4–) 0.6–0.8 (–0.9) mm, leaf-like but flatted with central vein ± visible, short pilose, rarely glabrous. Calyx distinctly accrescent; outer calyx lobes lanceolate to ovate, (5.3–) 6–8 (–11.7) × (1.6–) 2–3 (–4.2) mm, frequently longer than inner lobes, acute to beaked, usually with raised ridge and recurved distal margins, hirsute, strigose, rarely pubescent to glabrescent; inner calyx lobes oblong-ovate to oblong-elliptic, (4.6–) 5–8 (–11.6) × (2.1–) 2.5–3.5 (–3.7) mm, acute to cuspidate and with lateral membranous margins rarely up to the apex when obtuse and mucronate, hirsute to finely pilose, decreasing towards the margins. Petals broadly obovate to oblanceolate, or rarely oblong-oblanceolate, 5.5–10.6 mm long, ± bilobed. Stamens (4–) 10–14 (–18); filaments (0.6–) 1.4–1.7 (–1.9) mm long, up to one-third connate basally;

anthers obloid, (0.8–) 1.4–1.8 (–2.1) mm long, subequal, rarely unequal, abruptly constricted above and below. Pistils 2; ovaries erect-obloid and usually horizontally truncate, (4–) 6 (–8) ovules, puberulous, rarely shortly pubescent, with style attached apically, rarely laterally, then curved back- and upwards on either side of the anthers with style well above or rarely at the apex of anthers. Fruit puberulous to glabrescent with simple hairs. Seeds oblong-obovoid to almost obloid, 1.6–1.8 × (1.2–) 1.3–1.4 mm, brown; aril with fleshy base surmounted by one-sided membranous cup covering one-third to half of seed.

Notes: The extra specimens now available introduced a much wider range of variation in the *H. puberula* complex. Specimens from the Central Coast can frequently be recognized by almost sessile leaves, broadly ovoid to ellipsoidal buds with apices of the calyx erect to incurved, and often more than one flower is borne terminally on branches, while plants from more inland localities have usually petiolate leaves, slender ovoid to ellipsoidal buds with more or less recurved apices of the calyx and a single terminal flower on branches. None of these characters can be decisively used to distinguish these forms. The terminal flower clusters are formed by axillary growth from one or two leaves below the bract of the terminal flower and, in keeping with other species of the *H. sericea* group with fascicled hairs, immediately develop a terminal flower after usually two nodes with distinct internodes between, so that it becomes a more or less corymbiform cluster. (This is also a distinction from *H. stricta* s.l., which has usually spikiform (pyramidal) terminal clusters). Similar, but loosely branched cymbiform terminal inflorescences have been observed on only one collection (Turpentine Road, Flat Rock Creek, R.T. & J.Miller 22/30.x.2010). The most southern population of *H. puberula*, as represented by this and other mass collections, as well as R.D.Hoogland 11702 and E.Gauba NBG4784, is a particularly interesting extension of the species, as most of the flowers, though large, show a distinct reduction of hairs on the calyx and, more significantly, the styles tend to be laterally attached to the ovaries, similar to those of *H. cistiflora* in the *H. stricta* group. However, this phenomenon, indicative of a convergent development, can be observed in different stages on different plants, varying from an apically attached style curving down- and backwards to being attached laterally. The calyx lobes of most of the specimens identified as belonging to the *H. puberula* complex are hirsute to strigose on the outer surface, but in a few specimens both the shorter hooked hairs as well as the straight overtopping longer ones are very short or absent on plants from a few different localities (*cf*. variation under subsp. *glabrescens*). Among these, the plants from Bankstown Airport are smaller with thread-like branches and have consistently smaller calyx lobes, which are up to 2.7 mm broad, so that they are here described as subsp. *glabrescens*. The calyx of some flowers of subsp. *puberula* from Voyager Point (R.T.Miller & C.P.Gibson 52/20.x.2006) are of similar size, but hirsute and with a distinct terminal ridge on the outer calyx lobes. Furthermore, the flowering calyx of one plant must always be compared with other specimens at a similar stage, as the calyx (accrescent) elongates after flowering. Specimens from Lucas Heights are an extreme example, as the outer calyx lobes of a flower are 7.2 mm long and those of a fruit on the same specimen (R.T.Miller 3/16.x.2007) are 11.6 mm long. Of all the variation observed, *H. puberula* subsp. *extensa* is very unusual, as its androecium of commonly six stamens was previously unknown in *H. puberula*, which has ten or more stamens. There is a distinct gap between the two types of stamen numbers, as, unlike specimens of the typical subspecies from Simmos Beach Recreation Reserve (R.T.Miller 24–32/2.xi.2007), which has a range of stamens from 15–18, no specimen has as yet been recorded to complete the range from (4–) 6 or 7 stamens of the subsp. *extensa*. However, the wide variation recorded for the typical subspecies suggests this new form should be recognized at subspecific level. The anthers of subsp. *extensa* also tend to be smaller like those of the subsp. *glabrescens*, and their cuneate base into the filaments is rarely observed in the other subspecies.

Key to subspecies of the *H. puberula* complex

1. Stamens (4–) 6 or 7; lateral branches usually spreading up to about right angles to the main axis …… *H. puberula* subsp. *extensa*

1: Stamens (9) 10–14 (–18); irregularly and commonly untidily branched

2. Anthers (1.3–) 1.4–2.1 mm long; outer calyx lobes distinctly ridged toward the apex, strigose to hirsute or if pubescent to glabrescent then (2.5–) 2.6–3.0 (–3.8) mm broad when flowering .... …………………………………………………………… *H. puberula* subsp. *puberula*

2: Anthers 0.9–1.3 mm long; outer calyx lobes 1.6–2.1 mm broad when flowering, scarcely ridged towards the apex, puberulous to glabrescent

………………………………………………………………………………………………… *H. puberula* subsp. *glabrescens*

Hibbertia *puberula* subsp. *puberula*

Description: Branches wiry to stiff-woody from woody stems. Leaf lamina mainly lanceolate. Outer calyx lobes lanceolate to ovate, (7.3–) 7.8–9.3 (–11.6) × (2.5–) 2.6– 3.0 (–3.8) mm, acute to beaked with strongly recurved margins and distinctly raised central ridge towards the apex, strigose or hirsute to rarely puberulous; inner calyx lobes broadly elliptic to oblong-ovate, (6.9–) 7.3– 7.8 (–10.1) × (2.8–) 3.15–3.3 (–3.7) mm, with innermost two acute to ± cuspidate above broad membranous margins, hirsute to strigose, rarely pubescent along the central ridge becoming smaller to glabrous towards the margins. Stamens (9–) 10–14 (–18); anthers (1.3–) 1.4– 2.1 mm long. Flowering: October–December (January).

Variation: The few previous collections available have been disconcertingly variable, but mass collections from a few localities revealed that individual populations are often very variable in the size and number of hairs on various organs. Buds vary from almost spherical to narrow-ellipsoidal to -ovoid with lanceolate to ovate outer calyx lobes, each with an incurved, erect or recurved apex and more or less densely covered with spreading, straight and smaller hooked hairs of varying length. Flowers have usually 12–14 stamens in this subspecies, but the number varies locally from 9 or 10 at Wollemi National Park to 18 in one specimen from Yeramba Lagoon (C.P.Gibson & R.T.Miller 50/14.x.1993). Specimens from Simmos Beach Recreation Reserve show a few flowers with 15 to 17 stamens, while other flowers of similar plants of the same population have 12 to 14 (R.T.Miller 24–32/2. xi.2007). The filaments are up to one-third basally connate. Usually the anthers are described as subequal and forming a range from the slightly smaller to larger ones, but occasionally one or two distinctly larger ones were observed. The typical obloid ovaries are surmounted by a horizontal style base and, while the style is usually attached at the apex, it is sometimes more or less dipping to a lateral position in a number of populations, mainly from Morton National Park. This must not be confused with fruiting specimens, where the bulging developing seeds often displace the position of the style attachment. While the ovaries are usually puberulous, they may vary from pubescent (R.T.Miller 111–113/20.xi.2007) to almost glabrous (R.T.Miller 33–43/12.x.2007).

Hibbertia *puberula* subsp. *extensa* R.T.Mill., subsp. nov.

Typus: New South Wales, south of Appin Road, upper George River catchment, R.T.Miller 102 & A.Henderson, 8.x.2007 (holo.: AD; iso.: NSW).

Description: Branches stiff-woody and lateral ones spreading up to about right angles. Leaf lamina mainly lanceolate. Outer calyx lobes ovate, (6.1–) 66–72 (–7.9) × 3.1–3.5 (–3.8) mm, acute to beaked with ± strongly recurved margins and distinctly raised ridge towards the apex, strigose to hirsute; inner calyx lobes elliptic rarely oblong-ovate, (4.2–) 4.5–4.8 (–5) × 2.9–3.2 (–3.4) mm, with innermost two abruptly constricted into minute terminal point continuous with broad membranous margins, hirsute to strigose with hairs becoming smaller towards the margins. Stamens (4–) 6 (7); anthers 0.8–1.2 mm long. Flowering: October, November (March, April). Fig. 2Y–BB.

Variation: In spite of their often isolated occurrence very little variation was observed in the material examined. The specimens from south of Appin had usually 6 stamens, whereas several flowers from the Wanganderry Tableland had 7. The subspecies has generally very long straight hairs on the calyx and some of them are up to 1.3 mm long. Not only are the stamens shorter in this subspecies, but also the styles are short and robust and often just reach the apex of the anthers. These robust specimens are easily distinguished from superficially very similar plants with spreading branches of the typical subspecies from Lucas Heights (R.T.Miller 111– 113/20.xi.2007) by the number and size of the anthers. While most of the specimens of this subspecies occur in a restricted area from Appin to Wedderburn, a collection from Sackville Road (R.T.Miller 81/23.x.2008) seems to indicate that the taxon has a much wider geographic range. This preceding specimen exhibits in addition to six stamens also the robust spreading branching of the plants from the southern localities in spite of records of more slender forms of the typical subspecies nearby. Etymology. The epithet ‘extensa’, Latin, ‘stretched out, extended’ refers to the impression created by the lateral branches spreading at about right angles to the main branches.

Hibbertia puberula* subsp. *glabrescens Toelken, subsp. nov.

Typus: New South Wales, Bankstown Airport, G.M. Cunningham s.n., 13.xii.2006 (holo.: AD200524; iso.: CANB, K, MEL, NSW). Hibbertia sp. Bankstown (R.T. Miller & C.P. Gibson s.n. 18.x.2006) N.S.W. Herbarium in Australian Plant Census database (2011). Hibbertia sp. nov. (Bankstown Airport) C.P. Gibson, Bushland Bulletin 59: 4, 6 (2009).

Description: Branches thread-like wiry from short stiff-woody stems. Leaf lamina mainly elliptic-oblong. Outer calyx lobes linear-lanceolate, (5.3–) 5.5–6.1 (–6.3) × 1.6–2.1 mm, not beaked and with scarcely recurved margins and faint central ridge towards the apex, glabrescent or sparsely pubescent; inner calyx lobes narrowly oblongovate, (4.6–) 4.8–5.2 (–5.6) × 2.1–2.3 (–2.7) mm, innermost two abruptly constricted into minute terminal mucro continuous with broad membranous margins, glabrous or glabrescent along central ridge. Stamens 12–14; anthers 0.9–1.3 mm long. Flowering: October, November (December).

Variation: The plants at Bankstown Airport are comparatively uniform, as one would expect for such a small and extremely localized population. However, the plants and especially also the calyx lobes are rarely entirely glabrous. Although specimens of some plants of the typical subspecies, especially from nearby Simmos Beach Reserve (R.T. Miller 24–32/2.xi.2007), as well as those from the much further south population along Turpentine Road near Sassafras (e.g. R.T. & J. Miller AD15A–M), show a variation from a hirsute or strigose through to glabrescent tomentum of the calyx lobes, they are always more robust plants and in particular, the calyx lobes are larger and especially broader. Some specimens of the mass collection R.T. Miller 1622/12.x.2007 are very similar to subsp. *glabrescens*, but can be distinguished by the shape of the calyx or by their strigose to hirsute calyx (C.P. Gibson & R.T. Miller 27/23.x.1990). Furthermore, specimens from Bankstown Airport collected in subsequent years (since 2006) have not shown any significant change in morphology. Thus we must assume that a taxon has established itself here that is suited to the unusual ecological conditions artificially maintained by the Bankstown Airport management since about 1940. Etymology. Since all organs of this subspecies have very few small and delicate hairs which usually wear off soon, the epithet 'glabrescens', Latin, 'glabrescent' seemed appropriate.

2.2 LIFE CYCLE

Flowering time and duration

Peak flowering time is October to December and sometimes into January, and seed is set during this period. Anecdotal evidence (Miller pers. obs.) suggests time of flowering and time to petal dehiscence is variable across subspecies and appears also to be influenced by prevailing climatic conditions.

Very limited observations of the flowering times of *Hibbertia puberula* subsp. *extensa* suggest this subspecies has a very short period of flowering each day. Total petal dehiscence has been noted to occur before 1 pm on two occasions and before 11am on 30 November 2018 in the largest population south of Appin Road. It is not known at what time petal expansion commenced. The subspecies is virtually invisible when not in flower.

Hibbertia puberula and *H. diffusa* at Moorebank were noted to have a window of daily peak flowering (albeit in September, outside its normal recognised peak flower period) being not apparent in early mid-morning (8.40 am) and petal senescing by early afternoon (12:05 PM) on Friday, 29 September 2017.

This phenomenon has been observed with several *Hibbertia* species, whilst others appear to have protracted flowering across the day e.g. *Hibbertia dentata*.

Photo 1: *H. puberula* subsp. *puberula* at Berkshire Park dehiscing petals before our eyes.

Note: Photo 1 shows one of the few plants retaining petals on Friday, 2 November 2018 at 9:14 AM.

Additional information into flowering time and duration has been gained from this biodiversity assessment. On 29 October 2018 petal dehiscence had already commenced by 10 am and was finished before 11am at Ropes Crossing. On the 31 October 2018 total petal dehiscence was recorded to have occurred before 1.15pm but noting many plants of the co-occurring *Hibbertia pedunculata* still retained the majority of their petals though petal drop on those plants had begun.

Conversely, a site inspection of Bankstown Airport by Peter Ridgeway, Paul Bircher, Stephanie Clark, Colin Gibson, Damien Vella and Foster Walker – Environmental Manager Bankstown Airport Limited (BAL) revealed that *Hibbertia puberula* subsp. *glabrescens* was in full flower at 2.50pm and petals were still evident at approximately 4.30pm. It is unknown if the subspecies has a longer flowering duration than the other subspecies or whether the cool overcast conditions with a light shower earlier in the day prolonged flowering.

Photo 2: *H. puberula* subsp. *glabrescens* at Bankstown Airport.

Photo 2 taken on Friday, 16 November 2018 2:54 PM by Stephanie Clark.

Further research is needed to ascertain daily flowering ranges of *Hibbertia,* particularly for threatened taxa, as this has significant implications for reliable detection of threatened species during biodiversity assessments.

<u>Fire response</u>

No systematic fire response studies have been undertaken on *Hibbertia puberula*. Anecdotal observations and inferred information from similar species suggest *H. puberula* subsp. *puberula* is killed by fire in many instances. In certain circumstances the species is capable of re-sprouting from near or just below the soil surface as noted at the Keith Longhurst Reserve (formerly the Basin Reserve) in 2007 (R. Miller pers. obs.). At the same site Miller noted in June 2018 the species appeared to have mostly been killed by a recent control burn, with limited recruitment from the soil seed bank observed. It is unknown to what degree the protracted dry period has impacted apparent recruitment, but it is thought that the combined impact of fire and drought has been significant.

This current survey has noted that the "form" observed at Berkshire Park during this study is capable of resprouting from a thickened rootstock. This form is consistent with J.M. Lindale NSW 101952 shown in Figure 1 Toelken (2000) and reproduced as Figure 2 of this report.

Since its discovery there has not been a fire in the habitat of *Hibbertia puberula* subsp. *glabrescens*.

The impact of fire upon *Hibbertia puberula* subsp. *extensa* is also poorly known, with only observation by Miller providing a limited insight. The two occurrences south of Appin Road have recently been control burnt. Price *et al.* (2016) state that "The first fire was 52 ha, lit at 09:45 on 22 August 2015, and targeted patches of forest within the scout camp. The second was 700 ha, lit at 10:15 on 9 October 2015 and burnt the area surrounding the camp in an arc from north through west to south". All pre-existing plants appear to have been killed. Only three tiny plants presumably seedlings were apparent at one site and no plants were detectable at the other in a survey by Miller on 1 July 2018. A subsequent survey on 30 November 2018 confirmed the three plants had survived and flowered with 9, 8 and 8 plus 3 aborted and/or mature buds observed. Two plants were located at the second site both with 3 buds only.

Photo 3: *H. puberula* subsp. *extensa* with flower buds 30/11/2018 after the October 2015 fire.

2.3 DISTRIBUTION AND ABUNDANCE

Limited systematic population surveys have been undertaken for *Hibbertia puberula* s. lat.. The most comprehensive population survey undertaken is for *Hibbertia puberula* subsp. *glabrescens* at Bankstown Airport environs (refer to that subsp.). The population of *Hibbertia puberula* subsp. *puberula* occurring at the Moorebank Intermodal Terminal was, in part, surveyed in the environmental assessment for the project.

Hibbertia puberula* subsp. *puberula

This subspecies is known in New South Wales mainly from near Sydney (CC), but also from Wollemi National Park and near Morton National Park (SC, ST). The most significant sites are located at Moorebank and to lesser degree at Voyager Point.

Of most relevance to this study are those locations with similar attributes to those within the two growth areas. Few locations exhibit such habitat characteristics.

With the exception of the Moorebank and Liverpool records, known occurrences within the Sydney Metropolitan area occur in transitional soils adjoining sandstone areas, communities not found within the growth area boundaries. A selection of such sites includes the Georges River environs including The Georges River National Park, Lucas Heights to West Menai area, Simmos Beach Recreation Reserve, Peter Meadows Reserve, the Keith Longhurst Reserve (formerly the Basin Reserve), Kentlyn, Freres Crossing Reserve, Kentlyn, and Old Kent Road, Kentlyn.

Appendix 5 shows the indicative distribution of *H. puberula* at West Menai, where the species was found to occur as small subpopulations in suitable micro-habitats.

The species is also known from the lower Blue Mountains in the Warrimoo vicinity, and scattered occurrences within the Hawkesbury River Catchment including Sackville North, Canoelands, and the McCarrs Creek vicinity.

Historic collections localities include Yowie Bay 1908, Frenchs Forest 1946 and Coogee 1954.

Map 2 shows the areas proximate to the growth areas from which the subspecies had been collected prior to this study as well as new records provided by this biodiversity assessment.

Environmental assessment surveys for the Moorebank Intermodal Terminal have provided some population data on *Hibbertia puberula* subsp. *puberula*. At this site the species is relatively common and is significant in number. The population data derived cannot be inferred to reflect population density at other recorded sites of its distribution and specifically not within the GPEC or the WSA. The predominant vegetation communities found at the Moorebank Intermodal Terminal where surveys were undertaken are Castlereagh Scribbly Gum Woodland and Cooks River/Castlereagh Ironbark Forest with Shale-Gravel Transition Forest and Castlereagh Swamp Woodland being recorded proximally.

Extant examples of these communities are known to occur in and to the north of GPEC. Data obtained from field surveys for this assessment, though extremely limited, have found only small localised occurrences. Within the WSA, only the Kemps Creek area retains small remnants of the Castlereagh communities.

A selection of habitat and occurrence notes compiled by Miller in 2007 for herbarium specimens are:

- At Lucas Heights the population at a site in Open Woodland / heath – Canopy: *Eucalyptus haemastoma*? and Stringybark species is described as: “Abundance: extremely localised, rare < 12 plants noted”.
- At Lucas Heights Little Forest the population is described as Localised in narrow zone in upper drainage line.
- At Simmos Beach Reserve in Open Woodland of *Eucalyptus sclerophylla*?, *E. punctata, Angophora bakeri* one sub-population is described as “Very localised but locally common c. 20 plants noted”
- At Barden Ridge one population is described as scattered through sedges - relatively rare at edge of wet heath/swamp.

Further details of herbarium specimen collections from Western Sydney in 2007 are provided in Appendix 3.

<u>Details of prior collections proximate to growth areas</u>

The closest known prior collections to the growth areas are an McBarron, E.J. 1964-11-08 record stating “Glenbrook township”, “In open heathland” and Constable, E.F. 1949-10-28 Blaxland with no other collecting information presented on the data base. It is unknown if the species survives in these localities.

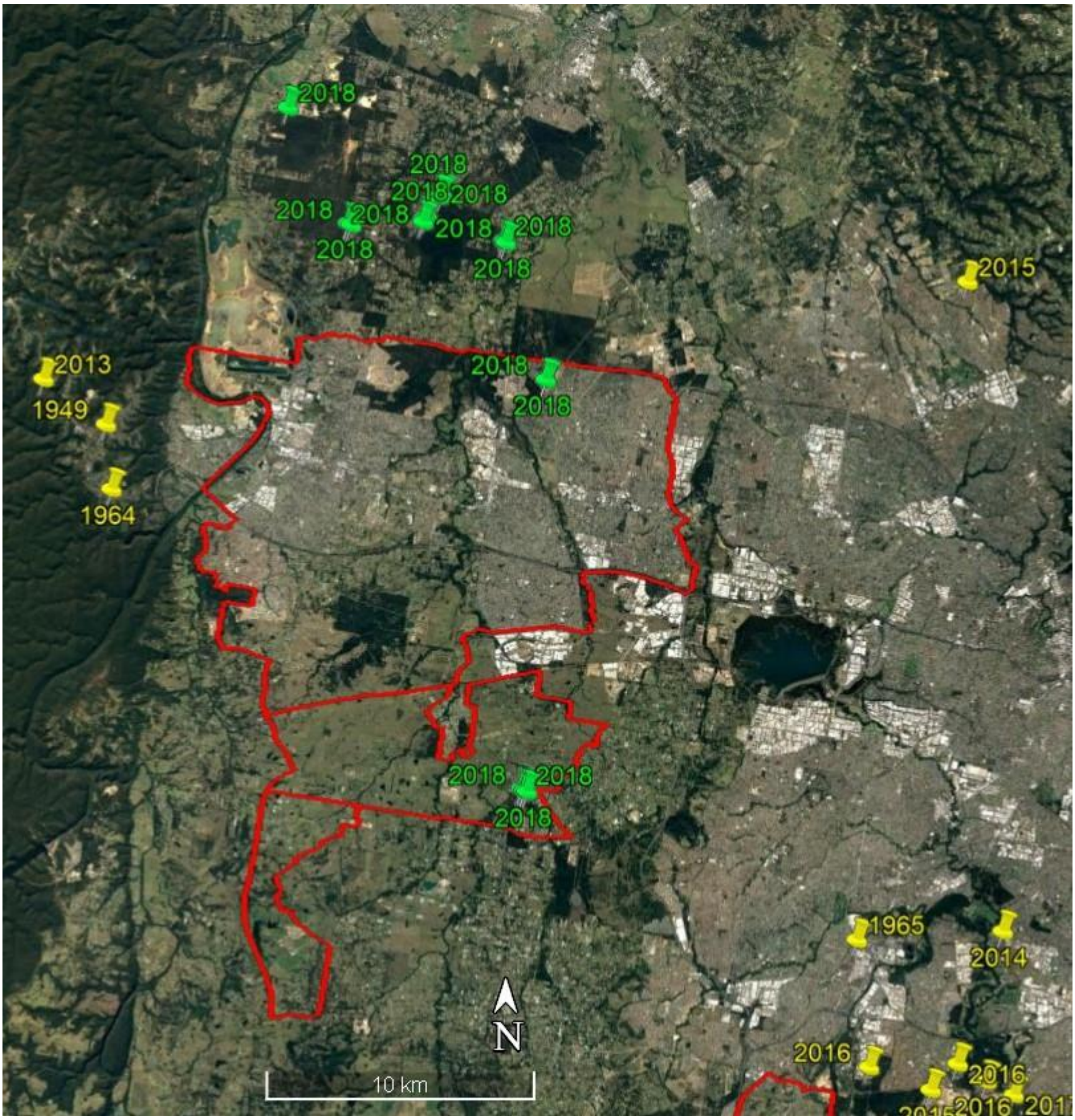
The closest extant population to the growth areas is 5.5 km from the NW corner of the GPEC at Warrimoo (observed and photographed by Greg Steenbeeke in 2018). The original Andrew Orme 2009-11-07 collection records this population as “5 plants noted over a 50m graded fire trail verge”. With habitat details “Low open forest of *Eucalyptus notabilis*, *E. consideniana*, *E. sparsifolia*, *Corymbia gummifera*, and *Angophora costata*, with dense understorey of *Leptospermum trinervium*, *Acacia linifolia* co-dominant, also with *Hakea laevipes*, *H. sericea*, *Petrophile pulchella*, *Leptospermum arachnoides*, *Grevillea phylicoides*, *Banksia spinulosa*, *Bossiaea rhombifolia*, *Pultenaea scabra*, *Schoenus imberbis*, *Lepyrodia scariosa*, etc. Gentle easterly slope on sandstone ridge. Shallow yellow sandy soil with some surface laterite over sandstone rock platforms. Disturbed graded fire trail edge”.

The closest record to the NE of the growth areas is a Mark Stables 2015-12-01 collection at Kellyville stating the habitat as: “Partially cleared area. Surrounding vegetation sandstone ridgetop woodland with laterite: *Eucalyptus sclerophylla*, *E. squamosa*, *E. sparsifolia*, *Angophora hispida*, *Banksia ericifolia*, *Leptospermum trinervium*, *Grevillea speciosa*, *G. buxifolia* subsp. *buxifolia*, *Calytrix tetragona*, *Boronia ledifolia*, *Phyllota phylicoides*, *Pultenaea tuberculata*, *Cyathochaeta diandra*, *Lepyrodia scariosa*, *Caustis flexuosa*, *Entolasia stricta* & *Austrostipa pubescens*”.

The closest record to the south east of the growth areas is a historic record McBarron, E.J. 1965-11-23, Liverpool Cemetery. The species is presumed extinct at this locality.

The closest extent record to the south east occurs at Moorebank 14 km from the WSA.

With the exception of the Moorebank and Liverpool records all other recorded localities occur in close proximity to Sandstone.



Map 2: Location of *Hibbertia puberula* subsp. *puberula* records and year of record.

Key – Historic *H. puberula* subsp. *puberula* records (yellow markers), CFFIS records (green markers) growth areas outlines (red line).

Hibbertia puberula* subsp. *extensa

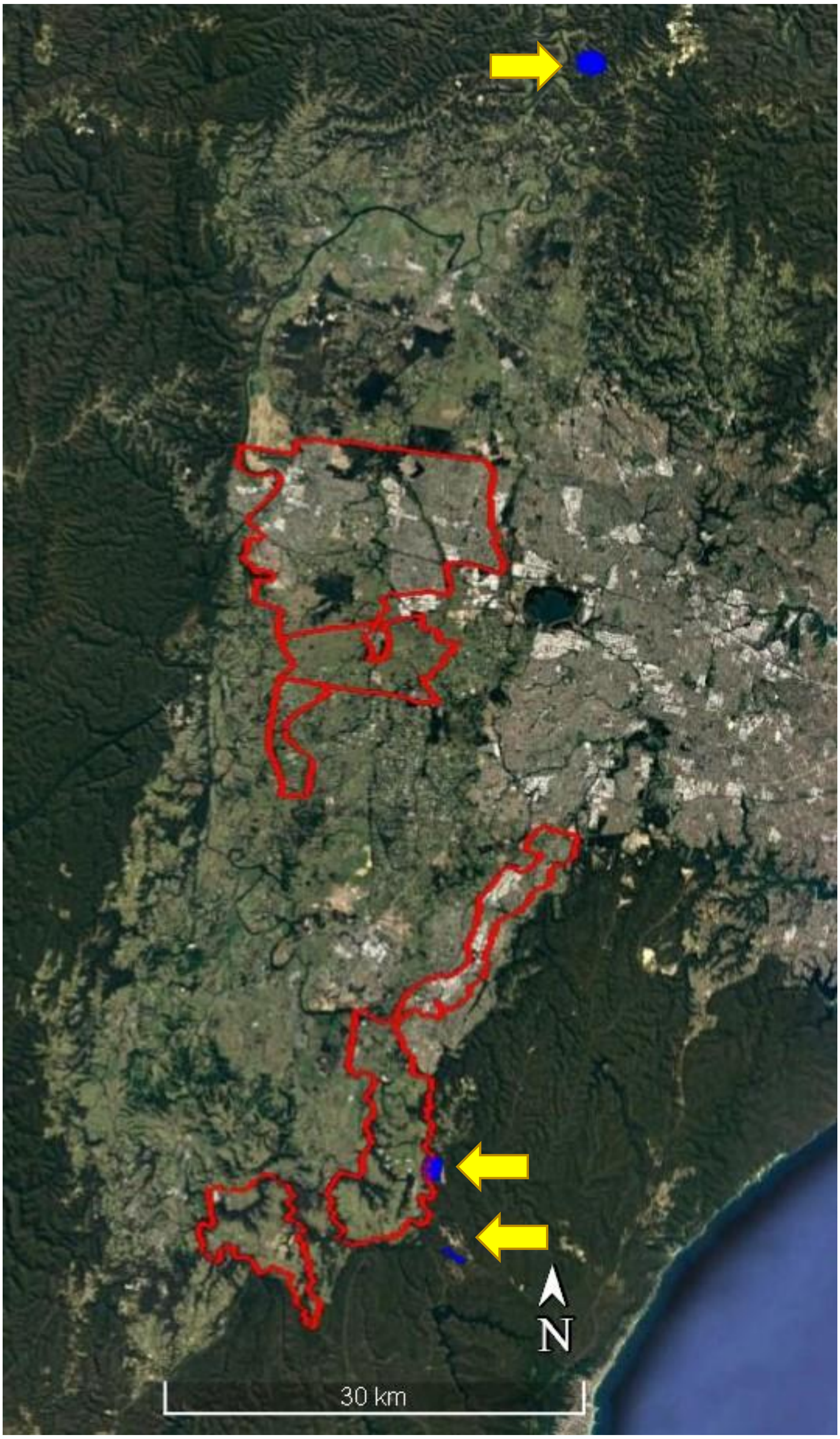
This subspecies grows with heath on upper headwaters of the Georges River and in rock plate heath on the Wanganderry Tableland, New South Wales (CC). Few collections are known of this subspecies.

The closest known extant sites are in the Wedderburn vicinity 27.5 km from the southern border of the WSA. A record cited in Toelken & Miller (2012) in the North Sackville vicinity is 29.5 km from the northern boundary. Map 3 shows the locations of collection sites.

No systematic population surveys have been undertaken for this subspecies. All known populations are thought to be small with most observations noting only a few individuals. One location south of Appin Road was the only population noted as having more than 10 plants. The sightings at Woronora Dam vicinity, Sackville North, the two recorded Wedderburn locations and the Bonnum Pic vicinity all recorded a few individuals only. The known Sackville North occurrence has subsequently been severely impacted by hazard reduction measures and is possibly now extinct at the known site. Similarly, the known occurrence west of Wedderburn Aerodrome has been impacted by grading and fill emplacement and only one specimen could be relocated (Miller pers. obs. July 2018).

A small population of a *Hibbertia* species with vegetative features consistent with *H*. *puberula* subsp. *extensa* was observed to occur on the verge of a fire trail within the Dharawal National Park at Wedderburn. Only six plants were noted. Positive determination can only be ascertained in combination with floral characters. The subject plants were not in flower at the time of observation and their identity remains unconfirmed.

Photo 4: *Hibbertia puberula* subsp. *extensa* habitat south of Appin Road.



Map 3: Generalised location of *Hibbertia puberula* subsp. *extensa* collections.

Key – Areas of past *H. puberula* subsp. *extensa* collections (blue) in relation to the growth areas (red).

Hibbertia puberula* subsp. *glabrescens

Subspecies *glabrescens* is known only from Bankstown Airport which is located approximately 16.5 km from the south eastern corner of WSA. Map 4 shows the general area where this species has been collected. The population contains between 50 and 100 individuals. Survey by Eco Logical in 2015 could not differentiate individual plants and recorded area of plants only.

The species has a limited area of occupancy. Most of the extant plants are known from one small area to the north of a modified drainage line colloquially referred to as Airport Creek. It was previously recorded by Gibson and Gibson & Miller to occur to the south of Airport Creek. Development and maintenance measures have negatively impacted upon those known occurrences and it had not been observed there again until October 2017 when one plant was observed (Gibson pers. obs.).

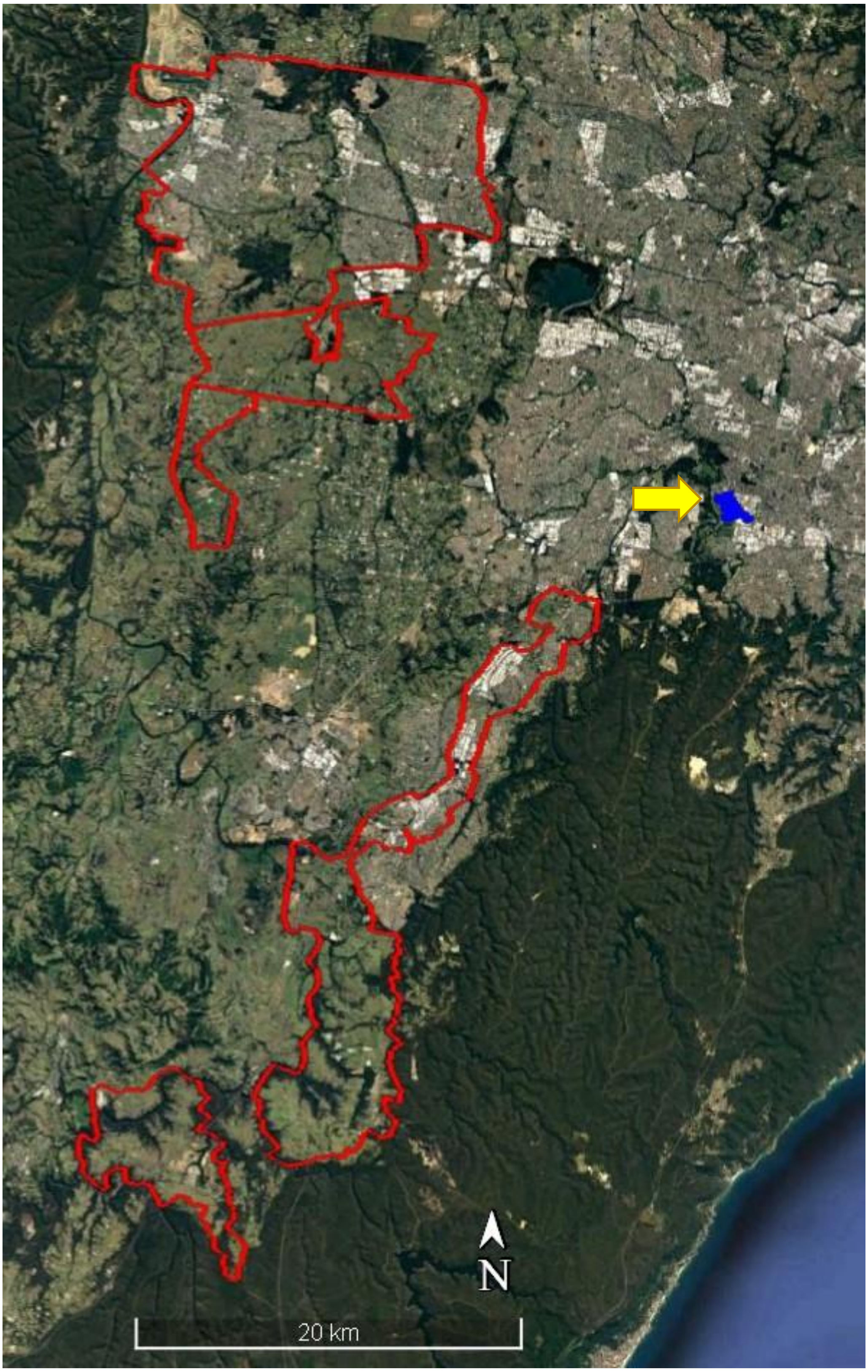
Photo 5: Measure of slashing height, *H. puberula* subsp. *glabrescens* at Bankstown Airport.

Note: See also photo of slashed area on front cover, photos taken by R. Miller 8 October 2014.

A site visit on 16 November 2018 found that creek stabilisation works had negatively impacted upon the site south of the creek, restricting mowing and resulting in dense swathes of *Eragrostis curvula* infesting the location (C.P. Gibson pers. obs.). No plants were detectible at this site despite the main colony being in heavy flower at the time of inspection (C.P. Gibson pers obs.) Site visit was 2.50pm – approximately 4.30 pm (Stephanie Clark pers. com.).

Photo 6: *Hibbertia puberula* subsp. *glabrescens* Bankstown Airport 16/11/2018.

Note: Photo by Stephanie Clark.



Map 4: Generalised location of past *Hibbertia puberula* subsp. *glabrescens* collections.

Key – Area of *H. puberula* subsp. *glabrescens* collections (blue) and the growth areas (red).

2.4 HABITAT REQUIREMENTS

Hibbertia puberula* subsp. *puberula

Occurs in a wide range of habitats, but usually low heath, on sandy soil or rarely in clay, with or without rocks underneath (Toelken 2000). Proximate populations have been recorded from habitats associated with the Mittagong formation, shale sandstone transitional vegetation and tertiary alluvial deposits. Associated canopy species may include, but not limited to, in combination or isolation: Scribbly Gum spp., Grey Gum (*Eucalyptus punctata*), Scaly Bark (*Eucalyptus squamosa*), Ironbark spp., Narrow-leaved Apple (*Angophora bakeri*), Dwarf Apple (*A. hispida*), and Stringybark spp.

Hibbertia puberula* subsp. *extensa

The habitat requirements of *Hibbertia puberula* subsp. *extensa* are poorly known. The subspecies has only been recorded from five localities: south of Appin Road, Wedderburn vicinity, Woronora Dam vicinity, Sackville North vicinity and Bonnum Pic vicinity Wanganderry Tablelands.

This subspecies appears to have highly specific micro-habitat requirements. The largest known population occurs south of Appin Road, where less than 30 plants of *Hibbertia puberula* subsp. *extensa* have been recorded. Its area of occupancy is small, being noted to occur in a narrow band within a small upland swamp amongst wet heath vegetation. In a larger nearby wet heath site a few specimens of the subspecies were recorded to occur on skeletal soil, in the downslope seepage zone, where the underlying sandstone substrate outcrops. The subspecies has not yet been observed in superficially similar nearby wet heath habitats but as it is very cryptic it may be present. The Woronora, Sackville North and one of the two Wedderburn populations grow in seepage zones of sandstone outcropping in skeletal soil downslope of heathland. In the Bonnum Pic vicinity a few plants were noted growing on rock plate heath.

Hibbertia puberula* subsp. *glabrescens

Subspecies *glabrescens* is known only from Tertiary alluvial soil along Airport Creek on Bankstown Airport and not from areas where subsequent fill has been deposited in between (pers. comm. Gibson). The plant assemblage is attributable to “Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion”.

The airport site is very heavily modified from the natural state, lacks canopy species and is currently a low grass/shrub association with many pasture grasses and other introduced herbaceous weeds.

Soil at the site is a sandy (Tertiary) alluvium with a high silt content.

The remnant at the site and soil type are consistent with an inferred pre-settlement cover of Castlereagh Ironbark Forest although some remnant vegetation at and near the site (along the channel in particular) suggests Castlereagh Scribbly Gum Woodland is equally valid.

Hibbertia sp. Bankstown has been observed to flower from October to December, with seed setting from October to January. Most *Hibbertia* species are primarily pollinated by bees, but many have specialised mechanisms requiring particular bee species, beetles or syrphid flies (OEH Threatened Species Profile).

2.5 ANTHROPOGENIC THREATS TO THE HABITAT

Threats to the habitat of *Hibbertia puberula* that are relevant to sites within or adjacent to urban development include:

- Direct loss of habitat through clearing.
- Reduction in size of habitats predisposing plants to edge effects.
- Fragmentation of habitat reducing the potential seed or gene dispersal across population or subpopulations.
- Damage to habitat by trailbikes, 4WDs and mountain bikes and other recreation activities.
- High densities of weeds and invasive grasses occur at the top of ridgelines; there is significant potential for encroachment into areas where the species occurs.
- Altered fire regime, either too frequent or too seldom.
- Potential for widening of major roads to affect populations of the species.
- Road maintenance and slashing works.
- Clearing for fire protection zones.
- Dumping of garden waste including invasive exotic species.

Field inspection of bushland remnants in the GPEC and WSA growth areas provided irrefutable proof of severe degradation arising from anthropogenic impacts and urbanisation (refer photos 6 through 9). Many of the remnants were heavily weed infested arising from a range of factors not limited to nutrification, stormwater discharge, garden refuse and fill dumping and exotic seed dispersal by various vectors. Environmental degradation was especially evident adjacent to creeks and drainage channels.

Hibbertia puberula is a small shrub that would not survive in bushland that is severely weed infested, or that is severely burnt on a regular basis.

The invasive grass species *Eragrostis curvula* is of significant threat to the species as it was observed to dominate extensive areas of the landscape.

Increased urbanisation is likely to see an upsurge in indiscriminate access into bushland that has not been cleared for development with increased illegal dumping, vehicular access including dumping and arson of stolen cars, and 4WD and trailbike causing serious long-term impacts.

Excluding EECs and Threatened Species habitats from the direct impacts of clearing will not ensure their long-term security without funding for fencing and active management. This funding and management could be a major outcome from the biodiversity certification process.

Photo 7: Dumping of rubbish in the eastern portion of Castlereagh Nature Reserve.

Photo 8: Clearing for asset protection zone, garden refuse dumping and invasive weeds.

Photo 9: Naturalised exotic species in the corridor behind housing.

Photo 10: Frequent fire, Wianamatta Nature Reserve.

3. Description of the study area

3.1 LAND USE HISTORY

The Cumberland subregion was first occupied by the Aboriginal peoples, who enjoyed a plentiful supply of fresh water and foods including fruit, tubers, fish, animals, birds and honey (Hills District Council website).

With the arrival of Europeans land use changed to timber gathering and agriculture, permanently altering the landscape. Particularly since the end of the second world war urban settlement and industry have expanded west from Sydney into the Cumberland subregion. Over the last 40 years many rural properties have been subdivided as lifestyle and hobby farm properties.

Currently there is great pressure for further residential development to the west of Sydney in the Cumberland subregion.

3.2 LANDSCAPE CONTEXT

The changes in land use have caused the clearing of a large proportion of the natural bushland of the Cumberland subregion. In 2011 the Cumberland Plain Recovery Plan stated “Only 13% of the pre-1750 extent of the region’s vegetation remains as intact bushland, with an additional 12% occurring as scattered trees in disturbed areas (NPWS 2002 in DECCW 2011). Consequently, much of the region’s biodiversity is listed as threatened under State and/or Commonwealth legislation.”

Widespread clearing of the remaining habitat has continued with much of the extant vegetation now being assessed as Critically Endangered. This widespread clearing has resulted in loss of habitat for endangered species such as *Hibbertia puberula*.

3.3 NATIVE VEGETATION

Since 2011 there has been further clearing, there are now 15 Plant Community Types that are listed as Critically Endangered, Endangered or Vulnerable in the Cumberland subregion.

The Cumberland Plain Recovery Plan states that “there are seven threatened species, four endangered populations and nine threatened ecological communities listed on the NSW *Threatened Species Conservation Act* 1995 that are found only on the Cumberland Plain. Seven of these are also listed as threatened under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999.” The remaining bushland is highly fragmented and much of it occurs on private lands.

Within the GPEC and the WSA nineteen Plant Community Types (PCTs) are mapped (mapping provided by the NSW Department of Planning and Environment). These PCTs are:

- 724 - Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion

- 725 - Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion
- 774 – Coast Banksia scrub on sand in the Elderslie area, Sydney Basin Bioregion
- 781 - Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion
- 806 - Derived grasslands on shale hills of the Cumberland Plain (50-300m asl)
- 807 – Derived grasslands on shale plains of the Cumberland Plain (<100m asl)
- 808 – Derived shrubland on Tertiary Gravels of the Cumberland Plain
- 830 - Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849 - Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- 850 - Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 877 - Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883 - Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1067 - Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion
- 1081 - Red Bloodwood – Grey Gum woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1105 – River oak open forest of major streams, Sydney Basin Bioregion and SE Corner Bioregion
- 1181 - Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion
- 1253 – Sydney Peppermint – White Stringybark – Smooth Barked Apple Forest on shale outcrops, Sydney Basin Bioregion
- 1292 – Water Gum – Coachwood Riparian Scrub along sandstone streams, Sydney Basin Bioregion
- 1395 - Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1800 - Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley

3.4 POTENTIAL HABITAT

Hibbertia puberula has the potential to occur within seven Plant Community Types (PCTs) mapped as occurring within the GPEC and the WSA. These community types are:

- 724 - Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion
- 725 - Cooks River Castlereagh Ironbark Forest

- 808 – Derived shrubland on Tertiary Gravels of the Cumberland Plain
- 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 883 - Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1067 - Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion
- 1395 - Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion

With the exception of PCT 883 at Moorebank, *Hibbertia puberula* has not been recorded to occur uniformly or in substantive numbers across any of the above listed communities. In general, it is usually confined to a variety of specific habitat niches within these regional mapping units. The area of occupancy within and/or the area of the specific habitat niches at any locale may be as small as a few square metres.

Specific habitat niches of potential occurrence may include upper drainage lines, seepages especially those associated with exposed sandstone bedrock or slabs, margins of hanging swamps / wet heath, exposed sandstone rock plates, and large and small occurrences of colluvial or alluvial deposits. At most locales presence or absence can only be positively determined by intensive targeted surveys that investigate such habitat niches thoroughly within the peak flowering period.

Photo 11: PCT 808 in power easement east of Ropes Crossing.

Note: Large numbers of threatened species survive in the derived habitat.

4. Assessment of species presence and suitable habitat

4.1 EXISTING RECORDS AND SURVEYS

Hibbertia puberula including its subspecies are poorly known and there is limited data on the life history and ecology of the species. Apart from Miller (November 2018), there have been no other specific targeted surveys for *Hibbertia puberula* within the study area. General vegetation assessments undertaken for various purposes appear also not to have found *Hibbertia puberula* as there are no prior database records of the species within the proposed growth areas.

In many instances the species group has not been considered within assessments or dismissed with statements of "unlikely no suitable habit present" and therefore no targeted searches were undertaken.

<u>Potentially misidentified *H. puberula* in the records</u>

Searches of databases revealed records of *Hibbertia riparia* at a number of locales within and adjacent to the growth areas. The name *Hibbertia riparia* is considered by Toelken to be misapplied to NSW taxa. Prior to the updated taxonomy a number of undescribed species were included within the name *Hibbertia riparia* then considered to be "a variable species complex".

Miller has observed that *Hibbertia puberula* is frequently still misidentified as *Hibbertia riparia*.

Reviewing the data set it became apparent that there were a number of records for *Hibbertia serpyllifolia* in the general Western Sydney area. Recent taxonomic work (Toelken 2013) investigating "The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia*", has identified that the name *Hibbertia serpyllifolia* is misapplied to NSW. The species concept is now considered to be confined to coastal forests of mid-northern Queensland. All records from other states are now recognised as new taxa e.g. *Hibbertia ericifolia* group or misidentifications of existing taxa.

As *Hibbertia* are notoriously difficult to identify, and more so if not in flower, it is not surprising to find records of *Hibbertia* sp. within the data set.

The Western Sydney Urban Bushland Biodiversity Survey 1997 undertook the first comprehensive survey of the biota across the region including bushland remnants within the GPEC and WSA area. Although the taxonomy of *Hibbertia* has changed significantly since that time, the records of *Hibbertia* contained within provide additional insight into the potential occurrences of threatened *Hibbertia* species.

The Straede T.M. 1990 "Vegetation of the proposed Londonderry Waste Disposal Site" report for Waste Management Authority, Sydney found *Hibbertia cistiflora* in the Castlereagh – Londonderry Crown Lands. It is unknown if this species occurs in the area or is a misidentification.

The current survey was limited in extent and did not visit the precise area of the Straede survey which is outside the growth area. The surveys conducted by CFFIS did not locate any specimens of *Hibbertia cistiflora*. There are no other records in the district and most vouchered records in the Sydney Metropolitan area occur north of the Harbour and are associated with sandstone ridges often in proximity to shale caps and Sandstone Shale Transition Forest associations.

It is noted in Toelken & Miller 2012 that subsp. *quadristaminea* is "often wrongly identified in herbaria as *H. serpyllifolia*, but subsp. *quadristaminea* has few stamens only in one dorsal cluster" c.f. *Hibbertia ericifolia* (*H. serpyllifolia* misapplied) possessing usually 8-16 but up to 30 stamens, dependant on the subspecies surrounding and obscuring the ovaries. This highlights that even herbaria have mis-assigned *Hibbertia* specimens. The fact that *H. cistiflora* has its anthers on one side of the ovaries opens the possibility that the Straede record could be what is now *Hibbertia puberula*. It is possible that Straede had another taxon from within the then *H. riparia* variable species complex previously identified. The current survey identified *Hibbertia puberula* to be present within the adjacent Castlereagh Nature Reserve.

It is unknown if the *Hibbertia serpyllifolia* UBBS Site (P1) Londonderry – Castlereagh Crown Lands survey by R.S. Lembit & T.A. James - woodland south of Devlin Road & NW end of Nutt Road record was based on field identification of fertile or infertile material. If it was based on fertile material it is most likely to be an unverified record of *Hibbertia ericifolia* group. If it was based on infertile material it is most likely to be *Hibbertia puberula.* CFFIS has recorded *Hibbertia puberula* in this vicinity.

Hibbertia pedunculata recorded at Mulgoa (Blue Mnts NP Sydney Sandstone complex) Coveny, R. 1976 – 95 Species lists for Mulgoa (off Fairlight Road – Nepean River) Blue Mtns National Park is likely to be that species, however there is a possibility that it could also be potentially be *H. fumana* or *H. puberula* if the Coveny observation was based on field identification of infertile material.

A *Hibbertia riparia* record from the Castlereagh Nature Reserve is most likely to be *Hibbertia puberula.* The current CFFIS survey recorded *Hibbertia puberula* within the Nature Reserve.

4.2 SURVEYS COMPLETED FOR THE BIOCERTIFICATION

From the information provided, no prior dedicated targeted searches have been undertaken for this species as part of the biodiversity certification process.

Surveys undertaken by Ecoplanning and Biosis consultancies since 2017 have largely been confined to the deemed "development footprint" and appear to have been undertaken predominantly to comply with the BAM protocols for vegetation sampling for assessment purposes with little survey for threatened species. As such, no new occurrences of threatened *Hibbertia* species including *Hibbertia puberula* were recorded by Biosis or Ecoplanning through their survey efforts.

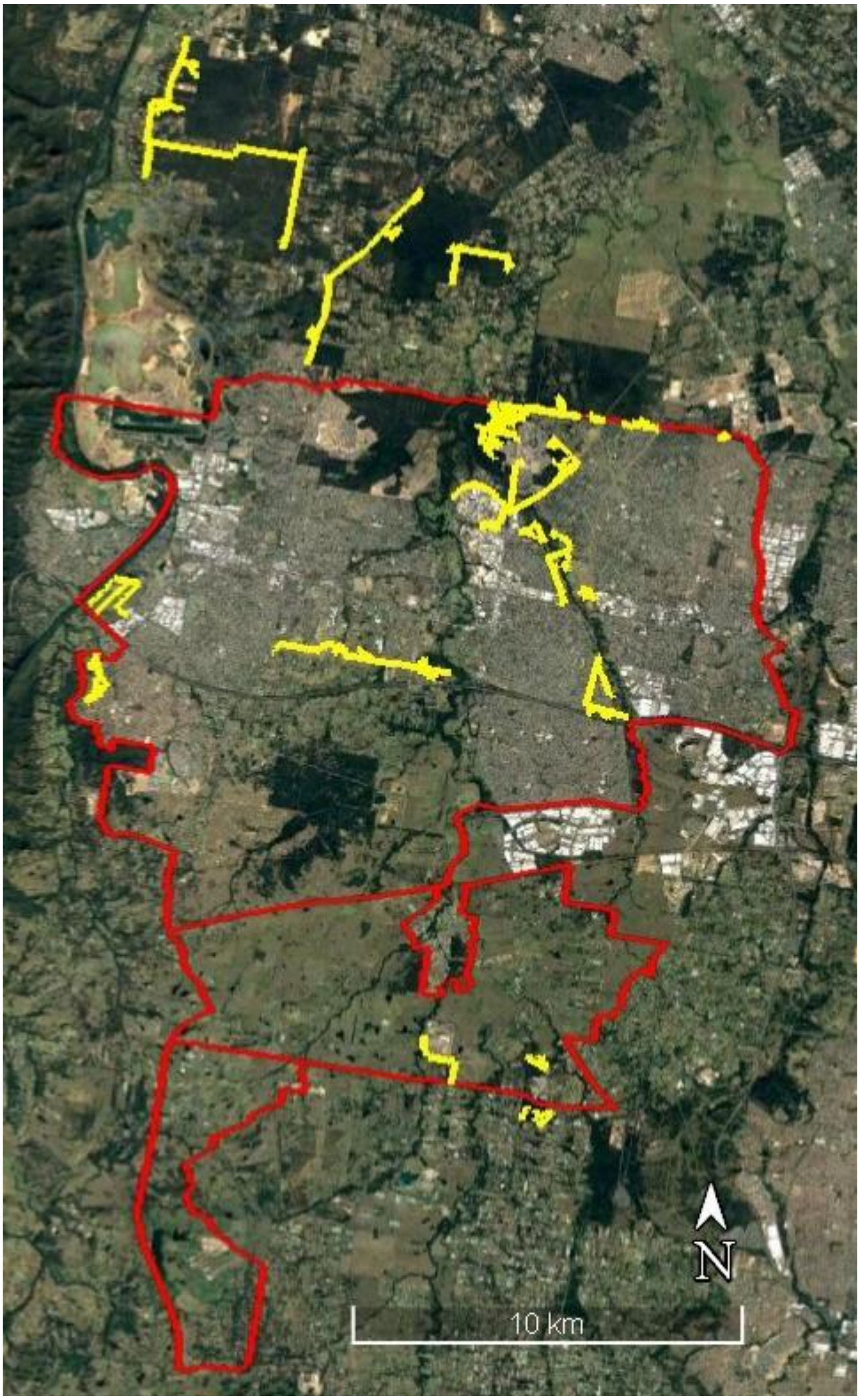
Access to a spatial viewer was provided by DPE to assist in the expert assessment. Whilst this tool has been useful in gaining a general overview, the information presented is limited and is acknowledged to "have been acquired and developed from numerous sources of differing dates, accuracy and completeness and may include errors in extent and content". CFFIS are not aware of any surveys performed specifically for *Hibbertia puberula* by DPE, Ecoplanning or Biosis Consultancies. The broadscale vegetation mapping of PCTs that was provided to assist with this assessment cannot identify the habitat niches that may be present on a localised scale.

The level of data available is insufficient to base an assessment of presence/absence for a Critically Endangered / Endangered species group purely as a desktop study.

4.3 SURVEYS COMPLETED FOR THIS ASSESSMENT

Surveys for the biodiversity assessment informing the development of the biodiversity certification were constrained by private lands access issues, time and the overall size of the biodiversity certification area. Map 4 shows the locations that were surveyed by CFFIS for this assessment.

Photo 12: *H. puberula* subsp. *puberula* located at Ropes Crossing by the CFFIS survey.



Map 5: Google Earth image of GPEC and WSA Growth Areas and tracks of CFFIS survey.

Key: Growth area approximate boundary shown in red, survey tracks shown in yellow.

4.3.1 SURVEY METHODS

Survey for this report followed the following steps:

- Visit a selection of known localities of the species, locate some *Hibbertia puberula* plants, and take particular note of the habitat characteristics, plant habit, co-occurring species and population density in the context of the protracted rainfall deficit.
- Search biological data sets for any records within the study area. The BioNet and ALA searches failed to find any records of the *Hibbertia puberula* group in the growth areas. *Hibbertia* species are notoriously mis-identified. Searches were then made of all *Hibbertia* recorded within and adjacent to the growth areas to ascertain if any misidentification may be included in the data set. Searches included UBBS NPWS 1997. Records stating *Hibbertia pedunculata*, *Hibbertia* sp., *Hibbertia* sp. A, *Hibbertia serpyllifolia*, *Hibbertia cistiflora* and *Hibbertia riparia* were included within the target survey effort where practical and survey access had been granted. The large amount of entries for *Hibbertia aspera* precluded visiting all known sites. An additional rationale for including these records apart from possible mis-identification is the presence of these species may indicate potential suitable habitat for the *Hibbertia puberula* group.
- Search for records of indicative co-occurring species other than *Hibbertia* such as *Grevillea parviflora* subsp. *parviflora* in order to further refine the survey effort.
- Examine the vegetation type maps provided by the Department of Planning and Environment.
- Locate potential habitat sites based on the mapping and expert knowledge of the plant habitat requirements.
- The prolonged rainfall deficient / drought period prior the survey effort posed significant challenges to the survey. Areas were targeted such as powerline easements where competition for moisture from large trees and shrubs may have been reduced and the targeted flora would have had a greater chance of persisting through the dry period. This strategy was significant in locating one new population *Hibbertia puberula* adjoining Wianamatta Regional Park.
- Survey in early to mid-morning. The greatest impediment to detecting *Hibbertia* species during the survey was early petal drop of some species thought to be increased due to the dry period and unusually high temperatures. Early petal dehiscence was most evident on 3 November 2018 where petal drop of *Hibbertia puberula* was noted to have commenced prior to reaching the site at 8.30am (temperature of 30) and was complete by 9 am (temperature 32).
- Visit as many of these potential habitat sites as possible, considering time and access constraints. Conduct drive-by and over-fence survey where habitat is clearly not suitable.
- Survey potential habitat sites for the species.

4.3.2 SPECIES IDENTIFICATION

As there were no prior records of the *Hibbertia puberula* group within or proximate to the growth areas it was deemed appropriate to prepare herbarium voucher specimens for later lodgement with the National Herbariums of NSW and Adelaide to substantiate the records. Selected specimens were taken according to protocols.

If we located a small-leaved *Hibbertia* specimen that was not in flower and it had macro morphological features resembling that of *Hibbertia puberula,* a specimen was retained for later microscopic examination. Due to the antecedent drought conditions many plants were depauperate, such that, in some cases specimens removed consisted of very small fragments (eco-scraps) some only a few cm in length. This is far from ideal, the challenge was to then identify the non-flowering eco-scraps to species using only stem and leaf characteristics, as shown in the drawing below (Toelken 2000).

The small branchlets of each specimen were compared to voucher material of *Hibbertia puberula* under a dissecting microscope. Note that positive identification of the species requires flowering parts, however, some species of *Hibbertia* can be ruled out based on stem and leaf characteristics. Microscope photographs of *H. puberula* characteristic features used during this survey by CFFIS are provided in Appendix 4.

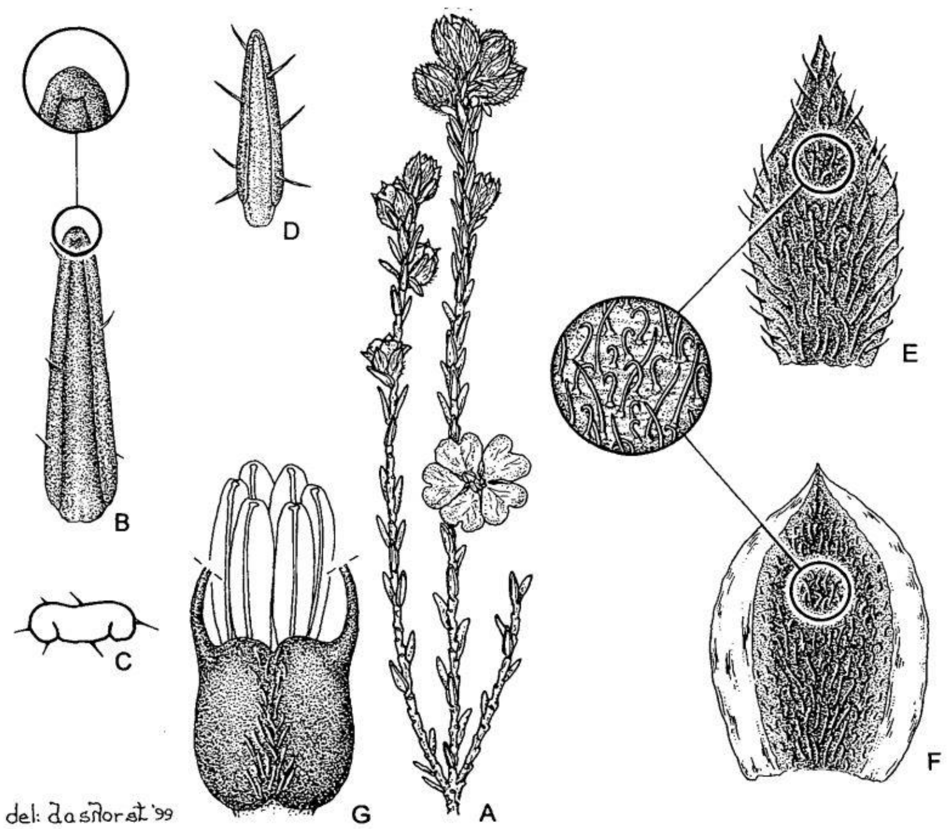


Fig. 7. ***H. puberula***. **A**, Flowering branch; **B**, cauline leaf; **C**, tranverse section; **D**. bract; **E**, outer calyx lobe; **F**, inner calyx lobe; **G**, two glabrescent ovaries. (**A–G**, *J.M.Lindale NSW 101952*; **A** ×1; **B**, **D** ×10; **C** ×15; **E**, **F** ×6; **G** ×20).

Figure 1: Line drawing of *Hibbertia puberula* distinguishing characteristics.

All non-flowering small narrow leaved *Hibbertia* specimens found during the survey were examined under the microscope to determine if the stem and leaf characteristics matched those of *Hibbertia puberula.* Essential characters considered include leaf dimensions and shape, the leaf undersurface having revolute margins and recessed to bulging broader central vein obscuring the leaf undersurface, and branchlets having interpetiolar tuffs of hairs. Some of these characters are shown on Figure 1Figure 2. Where the majority of characters were a match, the species could not be ruled out of consideration and so was assumed to be the subject species. It should be noted that these characters vary slightly between sub-species, as shown in Figure 2 below, and confident identification to sub-species requires flower characteristics.

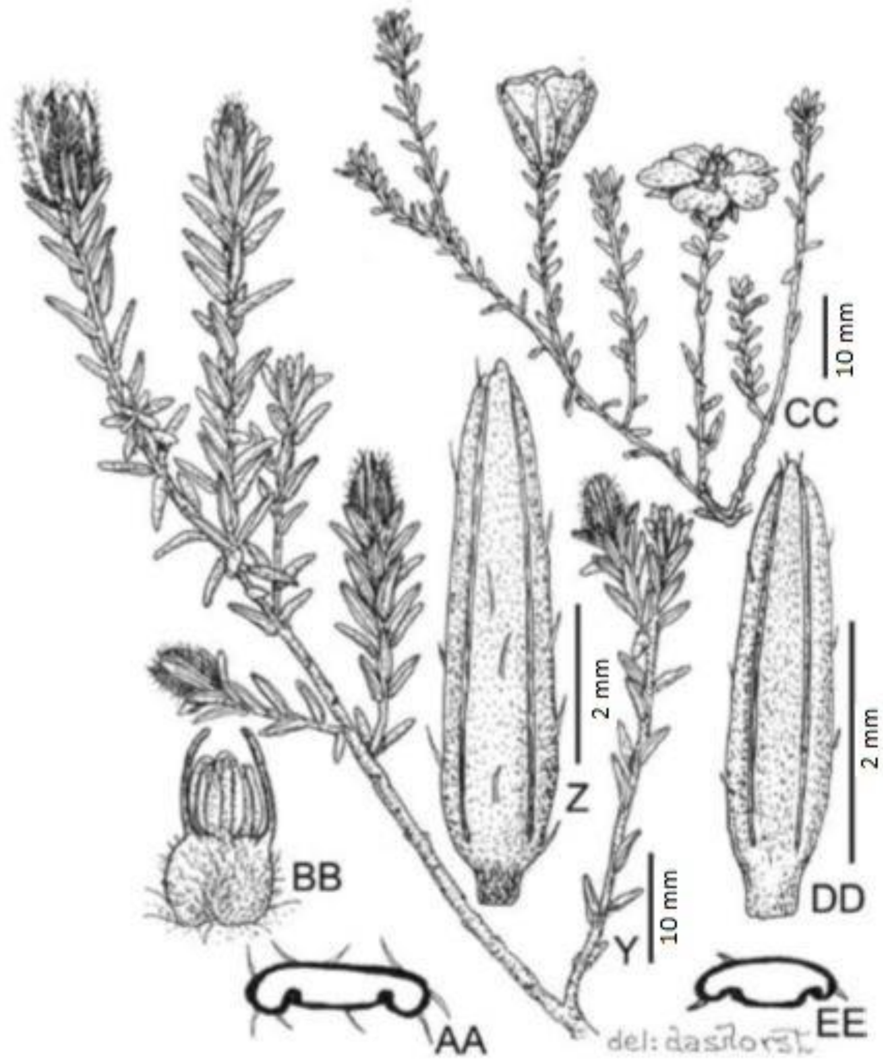


Figure 2: Line drawing of *H. puberula* subs. *extensa* and subsp. *glabrescens*.

Key: *H. puberula* subs. *extensa* Y flowering branch; Z leaf from below; AA transverse section through mid-leaf; BB flowers with petals and calyx removed. *H. puberula* subs. *glabrescens*: CC flowering branch; DD leaf from below; EE transverse section through mid-leaf.

A requisite taxonomic feature is hair types and the specific arrangement on leaf and branchlets. The persistence of the hairs on various parts of *Hibbertia* is variable according to the species. In many species such as *Hibbertia puberula,* hairs on the leaves and stem are notoriously non-persistent and "soon wear off" (Toelken). The full range hair expression is best observed on new and recent growth (Miller pers. obs.). The lack of new or recent growth is a significant limiting factor in the determination of the specimens as at all sites the vegetation was in severe drought stress.

Photo 13: A selection of *Hibbertia* voucher specimens, photo from c. 30cm away.

Key - A: *H. fumana* Moorebank; B: *H. pedunculata* Ropes Crossing; C: *H. empetrifolia* Appin; D: *H. puberula* subsp. *puberula* Ropes Crossing; E: *H. puberula* subsp. *puberula* Belrose; F: *H. puberula* subsp. *puberula* Nutt & Smeeton Roads; G: *H. aspera*

(Photo by R.T. Miller November 2018).

4.3.3 SURVEY ASSUMPTIONS

It was not feasible to survey all the many bushland remnants within the GPEC and WSA growth areas. As such, the first assumption was:

Assumption 1. *Hibbertia puberula* would not be found growing in bushland that is not its known habitat.

The author is familiar with the species' types of habitat across its entire known range. Using this knowledge of geology, soil and vegetation type that is the known habitat of the species, areas of bushland that would not be suitable habitat were ruled out of the assessment.

Using this knowledge of habitat requirement, the second assumption was:

Assumption 2. *Hibbertia puberula* is likely to be present in areas that are known to be suitable habitat.

Although there are occasions where the plant occurs in higher densities, the most common occurrences are rare and scattered throughout suitable habitat or low populations numbers localised to a small habitat niche. Areas of suitable habitat were surveyed using the random meander method. When only one or no individual specimens were located using this method, it was deemed likely that the species would occur scattered throughout these areas of suitable habitat.

The survey was carried out following several years of drought in western Sydney, and many shrubs forbs and grasses were dead. This led to the third assumption:

Assumption 3. In areas of suitable habitat, where *Hibbertia puberula* specimens have not been found, the species could be present in the soil seed bank.

There was a high amount of leaf fall in most locations and most locations have not recently been burnt. In these areas the species is likely to be present in the soil seed bank. An example is the Basin Reserve (outside the growth areas), where the species was previously scattered throughout suitable habitat within the reserve. Since the drought and control burning, the species appears to now be very rare at this site, however it is likely to be present in the soil seed bank.

4.3.4 *HIBBERTIA* RECORDED BY THIS SURVEY

Six species of Hibbertia were observed whilst undertaking surveys for this report. They are:

Hibbertia puberula: First records for the growth areas and to the north of the growth areas. See Appendix 2 for collection notes.

Hibbertia pedunculata: Very significant populations of this species were observed in the GPEC within and outside the biodiversity certification areas in the Wianamatta Regional Park, also to the north in the former Air Services Australia Site adjoining the north of the GPEC.

Hibbertia diffusa: Widespread, sometimes locally common inside and outside growth areas. Most commonly observed on shale derived or influenced substrates.

Hibbertia aspera: Widespread, sometimes locally common inside and outside growth areas. Most commonly observed on shale derived or influenced substrates.

Hibbertia acicularis: Noted in two areas outside the growth areas, at Agnes Banks Nature Reserve and Gulguer Nature Reserve.

Hibbertia fasciculata: Noted in one area outside the growth areas in Agnes Banks Nature Reserve, in Scribbly Gum Woodland only.

It is a recommendation of this study that *Hibbertia pedunculata* be listed as a Threatened species or an Endangered Population and taken into consideration as part of this biodiversity certification process.

Toelken (2013) in his revision of the *Hibbertia vestita* group, including *H. pedunculata* and *H. serpyllifolia*, considers *H. pedunculata* to be confined to NSW. Analysis of the cited specimens reveals that the species has two main areas of distribution the Greater Sydney Metro Area and the lower Hunter.

In the Greater Sydney Metropolitan area the species has suffered a significant reduction in numbers and extant distribution due to urbanisation. Two cited locales occur within the growth area at St Mary's. The Greater St Mary's – Shane Park vicinity is now the only general vicinity that has long term viable habitat remaining for the species, that is, Wianamatta Regional Park including areas within the former ADI site not gazetted and the Former Air Services Australia site.

Of the twenty specimens cited in the Greater Sydney area six only are known to have extant populations, however all are under severe threat due to small population size and anthropogenic impacts. Nine populations are known or highly likely to be extinct (refer to Appendix 6).

Prior to this survey *H. puberula* had not been recorded within or adjoining the growth areas, although potential habitat had been identified. Seven new locations of the *H. puberula* group were confirmed by this study, 2 within the Growth areas and 5 to the north west.

At the time of publishing (Toelken 2000) few collections were known of *H. puberula*. The J. M. Lindale collection was the only known specimen which displayed a predominance of hooked hairs on the calyxes and a reduced number and number of overtopping +/- straight simple hairs. It is a significant outcome of this survey that additional specimens of this "form" have been located. Although from limited sampling these new specimens may indicate a distinct localised form (Toelken pers. comm.) as all specimens of *Hibbertia puberula* identified for this survey appear to +/- consistent with the Lindale NSW 101952.

Further investigation is warranted to ascertain both the morphological trend observed and the abundance at each of the sites of occurrence.

4.3.5 INCIDENTAL SIGHTINGS OF SIGNIFICANT FLORA DURING THIS SURVEY

The bushland remnants surveyed were observed to support numerous threatened species including but not limited to *Hibbertia puberula*, *Persoonia nutans*, *Pultenaea parviflora*, *Dillwynia tenuifolia*, *Micromyrtus minutiflora* and *Grevillea juniperina*.

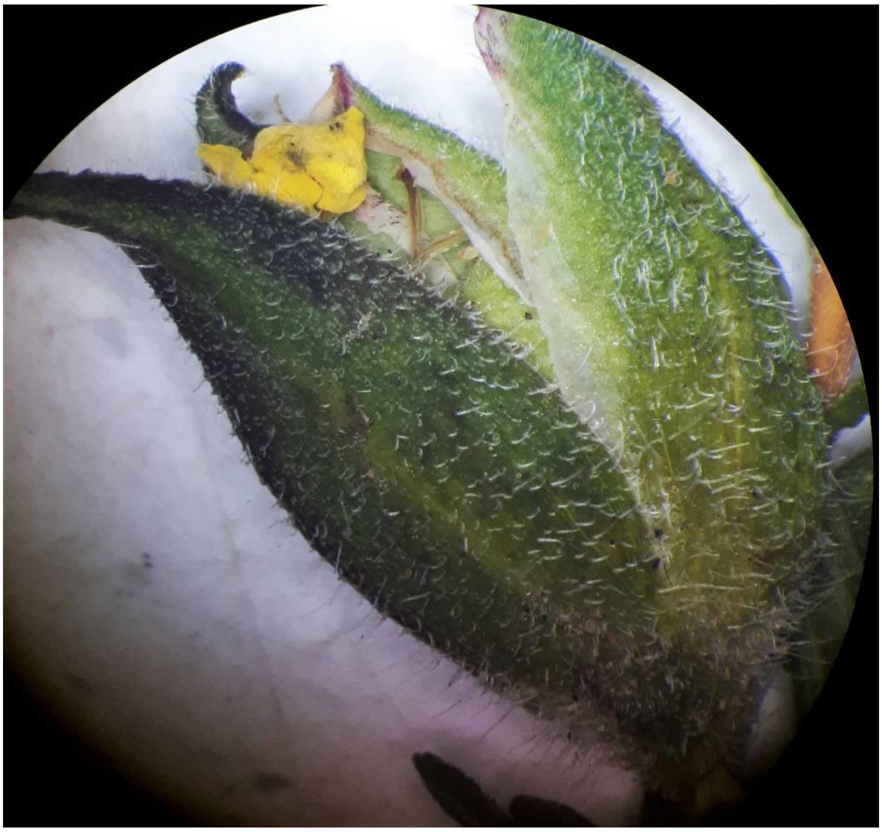


Photo 14: *H. puberula* Kemps Creek showing close similarities to the Lindale NSW 101952

Photo 15: *H. puberula* subsp. *extensa* showing long simple hairs.

4.4 ASSESSMENT OF SPECIES PRESENCE

Within the GPEC and WSA growth areas the species group could be present in the following PCTs:

724 - Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion,

725 - Cooks River Castlereagh Ironbark Forest,

808 – Derived shrubland on Tertiary Gravels of the Cumberland Plain,

835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, and

883 - Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion,

1067 - Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion,

1395 - Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion.

Occurrences within these broadscale mapping units are most likely to occur in microhabitats. Broad scale vegetation survey and mapping do not identify habitats at this scale. Potential habitat within these PCTs were targeted for survey where access was available.

Determination of potential habitat for *Hibbertia puberula* includes areas identified outside the deemed biodiversity certification area. Anthropogenic impacts are well documented to adversely affect vegetation well beyond the direct urban footprint.

Although there were no pre-existing records of the species within the growth areas, as previously discussed in section 4.1 there are records that could be misidentifications and that could be *H. puberula.* There have been no previous targeted surveys for the species in the growth areas.

4.4.1 LIKELIHOOD OF SPECIES PRESENCE

Hibbertia puberula **subsp.** ***extensa***

It is extremely unlikely that *Hibbertia puberula* subsp. *extensa* exists within the WPEC and WSA growth areas. No suitable habitat for the subspecies is known to occur or is likely to occur within the proposed urban footprint or the growth areas. The likelihood of occurrence is assessed as negligible.

Hibbertia puberula **subsp.** ***glabrescens***

The likelihood of occurrence within or adjacent to the GPEC is considered to be low to moderate, and the likelihood of occurrence within or adjacent to the WSA is assessed as low.

From known occurrence data the subspecies does not have the capacity to exist in habitats that occur within the proposed WSA development footprint. No further, specific targeted surveys are warranted for this subspecies in the WSA footprint. In the unlikely event that this subspecies was to occur it would be picked up in the targeted surveys for *H. puberula* subsp. *puberula*.

Hibbertia puberula* subsp. *puberula

Within the development footprint the subspecies is likely to occur within the Wianamatta Regional Park, as well as in areas adjacent to the footprint at Ropes Crossing and Kemps Creek (see maps 6 to 10).

<u>Within the GPEC</u>

From CFFIS limited field surveys, *Hibbertia puberula* subsp. *puberula* was found to occur at one site immediately adjacent to the Wianamatta Regional Park east of Ropes Crossing. The area of occurrence is a highly modified environment which prior to clearing would have been identified as PCT 725. Mostly now devoid of trees, the derived habitat consists of grassland/herbland/shrubland which is periodically slashed.

It is probable that this subspecies occurs at other locales within the Wianamatta Regional Park and nearby vicinity, especially in the former Air Services Australia Site at Shane Park, the southern border of which is within the biodiversity certification area boundaries. Any occurrences are likely to be confined to small populations restricted to very localised habitat niches. Potential habitat areas adjacent to the footprint would be highly susceptible to significant indirect impacts from a range of anthropogenic influences arising from the increase in urbanisation.

<u>Within the WSA</u>

Whilst undertaking field surveys for this report *Hibbertia puberula* subsp. *puberula* was found to occur at Kemps Creek. The Kemps Creek area is therefore now a known habitat for this species. The likelihood of occurrence within identified suitable habitat within the Kemps Creek vicinity ranges from high (known to be present) to moderate to low depending on location and condition of vegetation. Highly modified environments such as derived shrubland/grassland/herbland cannot be ruled out of consideration and remain assessed as moderate/high as evidenced by the presence of more than 20 *H. puberula* subsp. *puberula* plants observed on Lot 3 DP812284 at Kemps Creek.

A low rating is only justifiable where the soil profile has been significantly altered by fill emplacement or soil chemistry has been significantly altered by past agricultural practices or through urban runoff and where weed invasion is acute.

<u>North of the growth areas</u>

Whilst undertaking field surveys for this report new occurrence records of *Hibbertia puberula* subsp. *puberula* were located in the Agnes Banks, Castlereagh to Berkshire Park vicinities to the north of the GPEC growth area (see Map 2).

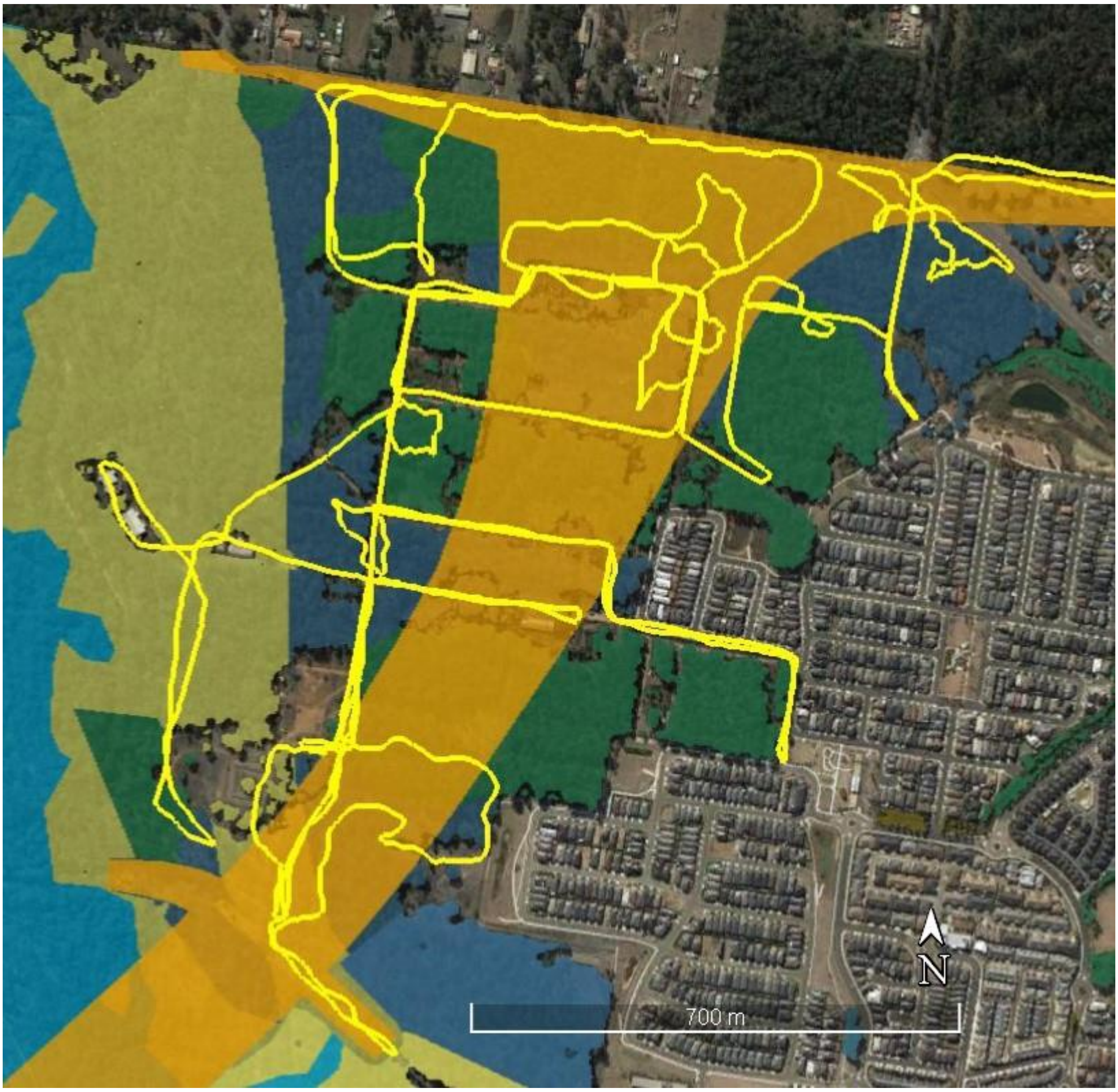
4.4.2 JUSTIFICATION FOR DETERMINATION

The following maps show an overview of areas containing potential habitat of *Hibbertia puberula* group, based on vegetation mapping and BioNet records, within the GPEC and WSA. These areas were surveyed by CFFIS for this assessment. Vegetation mapping provided by DPE.

Key to the maps is:

- development footprint – light orange
- CFFIS survey tracks - yellow
- vegetation type PCT 724 – dark blue
- vegetation type PCT 725 - dark green
- vegetation type PCT 835 – light blue
- vegetation type PCT 849 – olive green
- vegetation type PCT 883 – red
- vegetation type PCT 1800 – light green

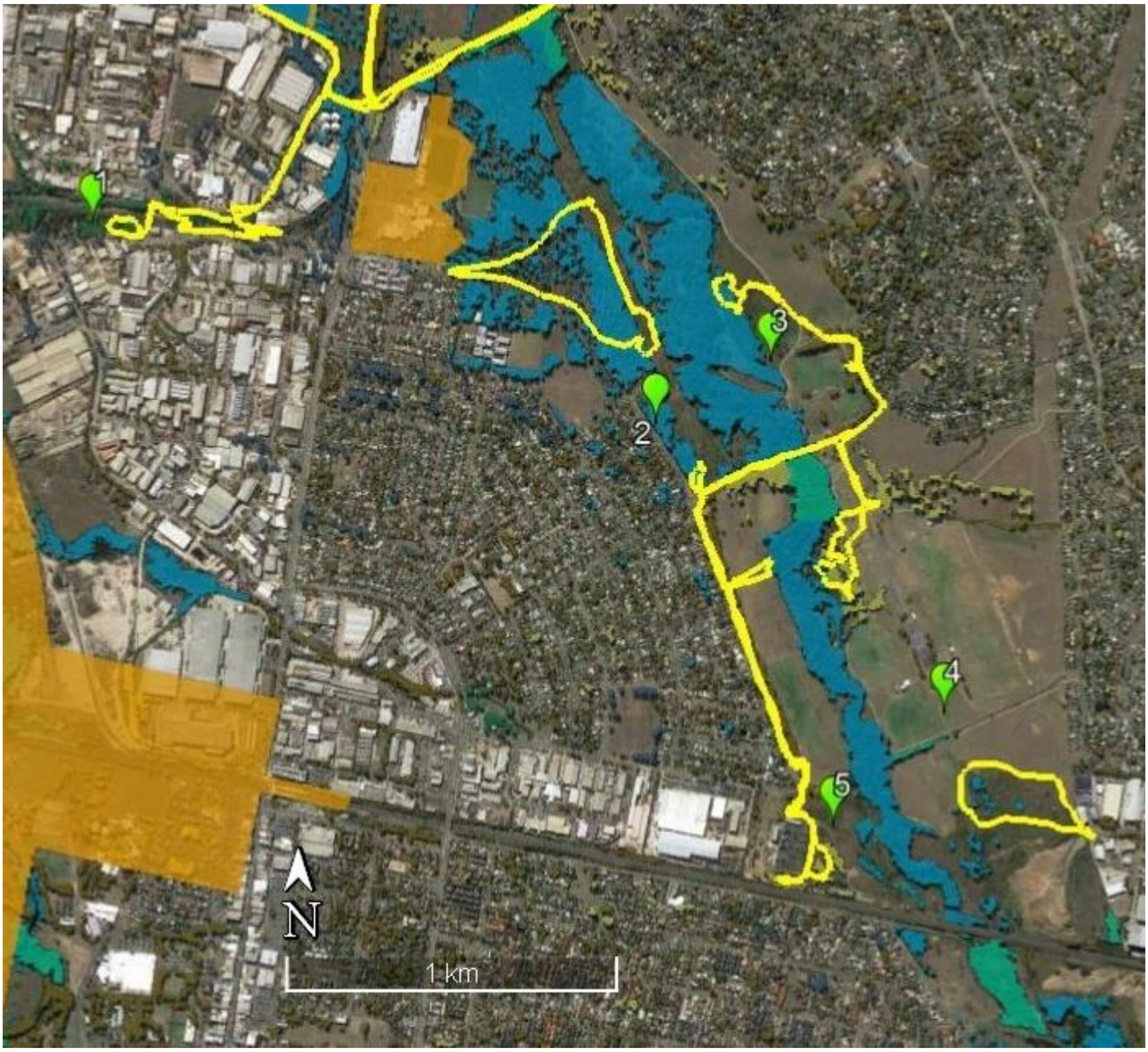
Map 6: Wianamatta Regional Park south section and powerline easement.



Map 7: Northern section of the Wianamatta Regional Park with road corridor footprint.

Map 8: Bells Line of Road Castlereagh Connection corridor footprint.

Note: former Air Services Australia site is to the north.



Map 9: Ropes Crossing and North St Marys areas of potential habitat and development footprint.

Survey locations:

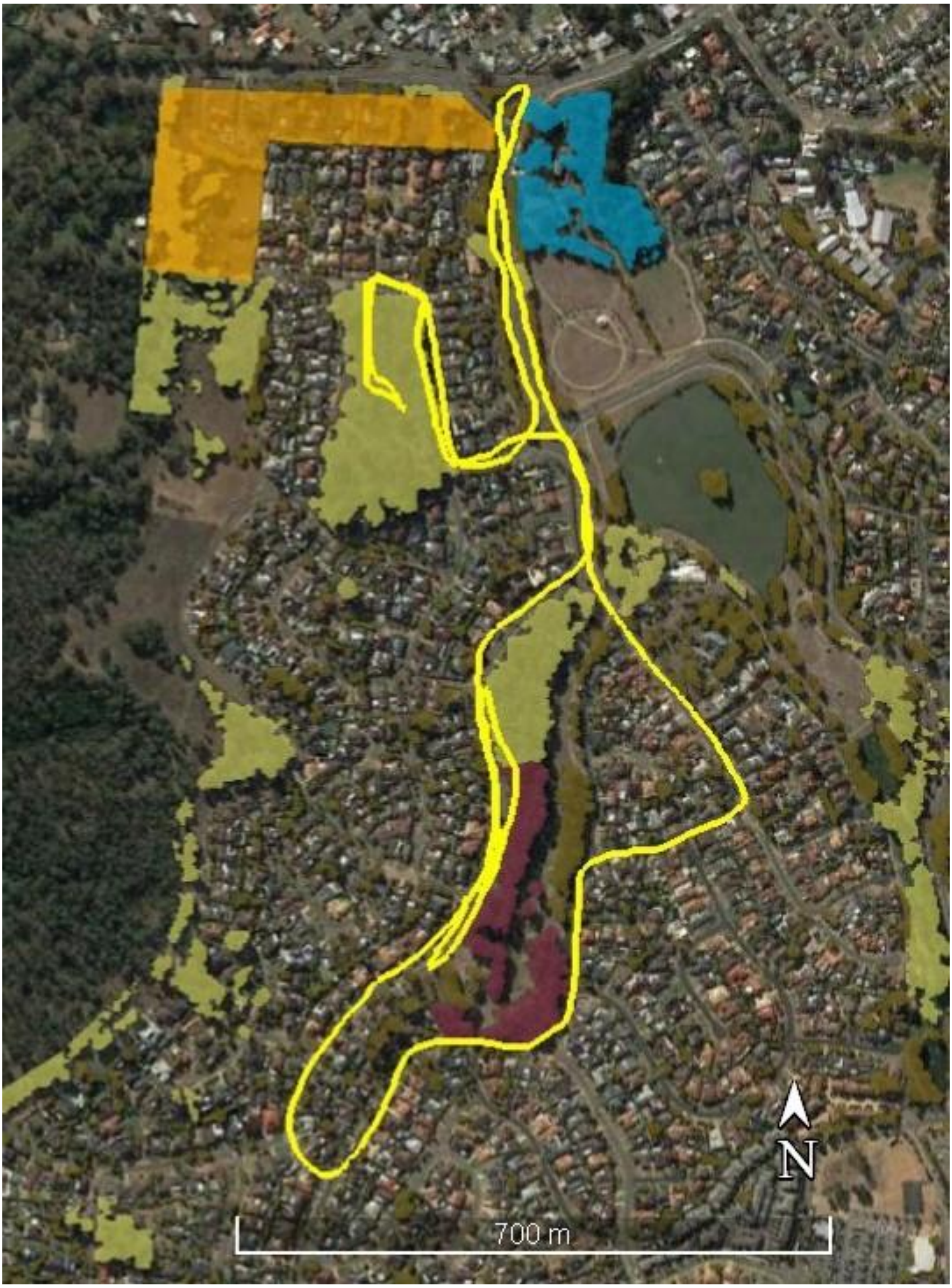
1. Dunheved Estate Reserve
2. Boronia Park
3. Tregear Reserve
4. Whalan Reserve
5. Substation, Kurrajong Road North St Marys

Map 10: Shepherd Street vicinity, St Marys areas of potential habitat.

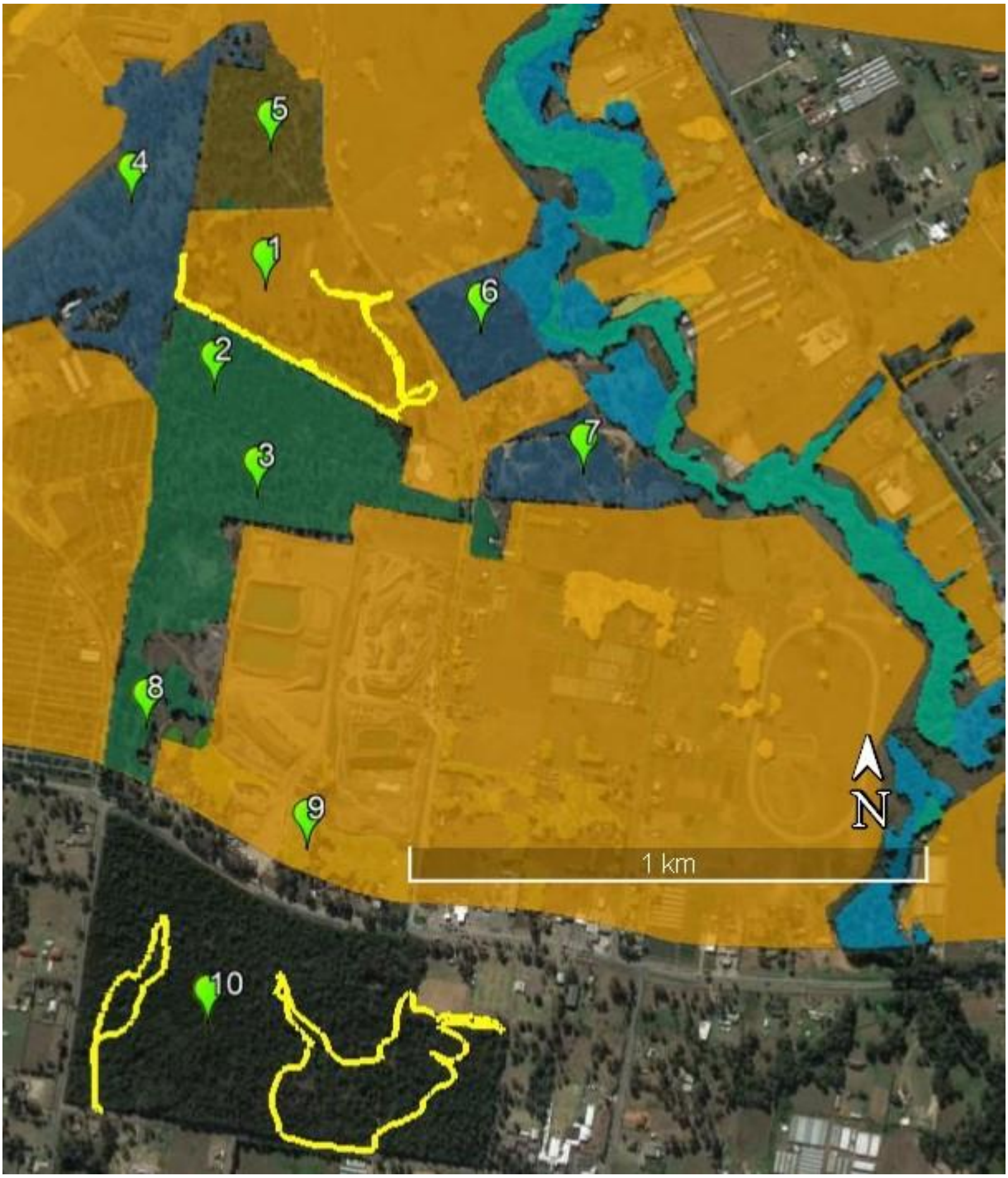
Survey locations:

1. Shepherd Street Park
2. Corner of Motorway bushland remnant

Map 11: Claremont Meadows area of potential habitat and development footprint.



Map 12: Apple Gum Reserve at Glenmore Park, area of potential habitat and development footprint



Map 13: Kemps Creek potential habitat and development footprint.

1. Lot 3 DP812284
2. Lot 2 DP812284
3. Lot 1 DP812284
4. Lot 22 DP60122, Lot 2 DP587135
5. Lot 47 DP734584
6. Lot 6 DP812284
7. Lot 4 DP812284
8. Lot 1 DP716403
9. Lots north of Elizabeth Drive
10. Cross Street bushland

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Map 14: Kemps Creek, south of SUEZ facility, block of land partially cleared.

Map 15: Jamisontown area showing development footprint and potential habitat.

4.5 ASSESSMENT OF SUITABLE HABITAT

4.5.1 SUITABLE HABITAT WITHIN THE GROWTH AREAS

This section provides detail of areas of suitable habitat within the growth areas that have been surveyed by CFFIS, and the outcomes of that survey.

Powerline Easement Adjacent Forrester Road, Ropes Crossing

Vegetation of the powerline easement has not been allocated a PCT despite the area containing high population numbers of threatened taxa.

The Powerline easement is periodically slashed, maintaining a grassland/herbland/shrubland derived habitat. Scattered remnant trees adjacent Forresters Road are mapped as PCT 725 and are mostly *Eucalyptus fibrosa* with a few Stringybarks noted. Along the western portion of the easement the vegetation grades into +/- intact remnants found within the Wianamatta Regional Park and mapped as PCT 725 and PCT 883 (refer Map 6).

The easement supports a high diversity of indigenous flora and has minor incursion of invasive exotic species which are mainly confined to areas adjacent to Forresters and Palmyra Roads. A small upper gullyline, however is weed impacted and a vector source into the regional park.

40 plants of *Hibbertia puberula* subsp. *puberula* were located within the easement and are presumably the same taxon as that assigned as *Hibbertia riparia* in UBBS. The species was only observed in 3 discrete but proximate patches in a limited area. On 29 October 2018 two large plants were noted with petals, approximately 8 other plants with no flowers were scattered amongst plants of *Hibbertia pedunculata.* On 31 October 2018 a further 15 plants were observed at two additional patches. The plants mostly aborted all their petals or were not in flower, so it is likely that more plants are present but were not observed.

Hibbertia pedunculata was observed to be abundant within the easement, the majority of the plants possessing many flowers and easily detectable. This is significant, as virtually no plants of *Hibbertia pedunculata* were noted within the more heavily vegetated western edge of the easement and within the immediate adjoining sector of the regional park.

Similarly, *Pultenaea parviflora* and *Dillwynia tenuifolia* were frequently encountered within the easement but were noticeably infrequently observed within the adjoining intact vegetation.

It is thought that this is attributable to the preceding drought conditions and fire regime. The absence of trees in the easement meant that there was less competition for water allowing smaller plants to thrive.

The power easement is within the GPEC growth area but is not within the development footprint.

Photo 16: Detail of flower structure, *H. puberula* subsp. p*uberula* from powerline easement.

Photo 17: From *H. puberula* site, lush shrub regrowth including large numbers of threatened species.

Photo 18: Photo of powerline easement edge adjacent to trees.

Note that within the sphere of influence of trees the ground layer is sparse and shrubs regrowth stunted.

Photo 19: A large plant of *H. puberula* subsp. *puberula* located in the powerline easement.

Photo 20: *H. pedunculata* within the powerline easement growing with *H. puberula*.

Note: The density of *H. pedunculata* flowers makes detection easy as compared to low-density occurrences under the long-unburnt Cooks River Castlereagh Ironbark Forest.

Photo 21: Lateritised gravel soil substrate within the area of occurrence of *Hibbertia puberula.*

Note: Lateritised gravel soil is common within the Wianamatta Regional Park and the former Air Services Australia site.

Photo 22: Western boundary of the powerline easement.

Note: Few threatened species were detectable, and none were in flower. The population of threatened species is presumed to be reduced to the soil seed bank.

Photo 23: Typical sparse understorey within Wianamatta Regional Park adjacent easement.

Note: no flowering threatened species.

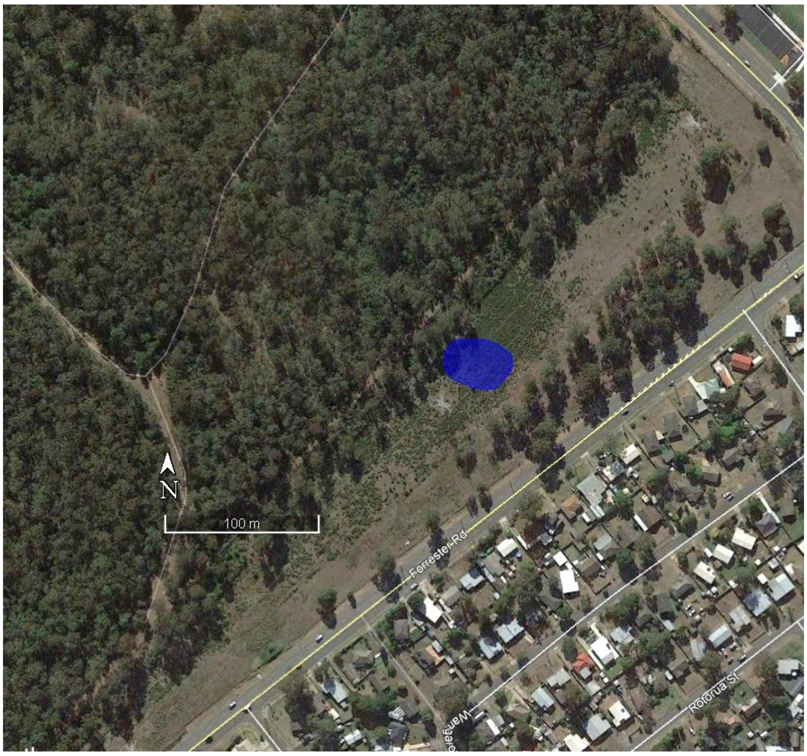


Photo 24: Google image of power easement, location of *H. puberula* subsp. *puberula* in blue.

Wianamatta Regional Park area and Outer Sydney Orbital corridor

Within the Regional Park and the Outer Sydney Orbital (OSO) corridor are areas mapped as having PCTs appropriate for *H. puberula* habitat. The potential for the species to occur in these areas is moderate. Survey of the area did not locate the species, however, the bushland was very dry, had not been burnt for years, and it is likely that the species could be surviving in localised patches in the soil seed bank.

This assessment is based on the proximate record of *Hibbertia puberula* within the electricity easement, the associate species observed there and the presence of lateritised clay soils at both locales.

Hibbertia pedunculata and to a lesser degree *Dillwynia tenuifolia* and *Pultenaea parviflora* were used as surrogate indicator species in determining the likely impact of drought and fire regime on the population densities, within and outside of canopy cover in the assessment of likely occurrence of *Hibbertia puberula*. *Hibbertia pedunculata*, *Dillwynia tenuifolia* and *Pultenaea parviflora* were observed to be locally frequent species within some modified habitat areas.

In areas where these species were noted away from the influence of large trees and shrubs they were easily discernible, flowering and vigorous. Under the canopy or within the sphere of influence of trees and shrubs, flowering was significantly reduced but mostly absent and the apparent population densities low. Visible plants were typically in a late stage of senescence. This was particularly apparent with *Hibbertia pedunculata*.

Photo 25: Typical sparse shrub and ground layer in the regional park.

Other shrub and ground layer species were also noted to be particularly sparse within the areas mapped as PCT 725 and PCT 724 within the Wianamatta Regional Park.

These observations support the conclusion that non-detection of *Hibbertia puberula* within or adjacent to the development footprint (OSO corridor) within the Wianamatta Region Park is likely to be attributable to a retraction to the soil seed bank rather than non-occurrence.

Photo 26: Typical thick detritus suppressing the ground layer in the regional park.

Photo 27: Photo of Wianamatta Regional Park showing depauperate understory.

Note that the extended dry conditions in the Regional Park means that understory species cannot compete with trees for available water. Most of the ground layer has retracted to the soil seedbank.

Photo 28: Sparse shrubs of *Grevillea juniperina*, *Dillwynia tenuifolia* and *Daviesia ulicifolia* subsp. *stenophylla*.

Photo 29: *H. pedunculata* within derived habitat away from trees and shrubs.

Photo 30: Typical condition of *H. pedunculata* within "intact" vegetation of the Regional Park.

Note: The plant is exhibiting extreme water stress and lack of flowers. Detectability of *Hibbertia* in this condition is very low.

The Bells Line of Road Castlereagh Connection Corridor (BLRCCC)

The vegetation within the road corridor can be generalised to consist of PCTs 725 and 724 interspersed with areas of Scribbly Gum Woodland on lateritised clays in the western portion and with PCT 849 more apparent in the eastern sector. Minor and major drainage lines interrupt the generalised vegetation pattern and were noted to be often degraded by urban runoff and weed invasion, at least within and immediately adjacent to the road corridor.

Areas of PCT 1800 - Swamp Oak were noted in the eastern sector. PCT 835 Forest Red Gum - Rough-barked Apple grassy woodland and PCT 1067 Parramatta Red Gum woodland are mapped on the Spatial viewer in the vegetation 100km consolidated layer as occurring adjoining and to the north of the corridor. However, presence or absence of these PCT was not confirmed, as inspection was confined to the road corridor in these locales due to time constraints.

Photo 31: Northern verge of the Bells Line of Road Castlereagh Connection corridor.

Note: A deep trench separates the predominantly intact high-quality remnants from the urban impacted vegetation existing south of the trench adjacent to the cleared sections of the road corridor. The photo foreground has moderate potential habitat and is within the footprint and background has high potential, adjacent to and outside of the growth area boundary. The adjacent highly significant vegetation will be very prone to indirect impacts.

The presence of PCTs 725 and 724 in conjunction with Scribbly Gum Woodland provide potential suitable habitat for *Hibbertia puberula*. Within the growth area boundary, the potential of occurrence is rated as moderate due to disturbance factors.

Adjacent to the northern boundary (the road corridor), being the former Air Services Australia Site, the likelihood of occurrence is rated as moderate to high.

Photo 32: The former Air Services Australia site adjacent to the north of the growth area contains significant populations of *H. pedunculata* and other threatened taxa.

Photo 33: Areas of Scribbly Gum Woodland in the former Air Services Australia site provide likely potential habitat.

Note: Illegal access to the Air Services Australia site by trail bikes and cars has caused impact to vegetation and facilitated rubbish dumping.

The northern edge of the road corridor consists of predominantly intact high-quality remnant vegetation including the edge of the Scribbly Gum Woodland.

A large part of the road corridor is cleared and weed impacted including most of the ground flora which is intermittently slashed. *Eragrostis curvula* dominates much of the disturbed corridor environs.

The following photos show examples of clearing, weed invasion and rubbish dumping along the length of the corridor behind the houses and within the former Air Services Australia site. The photos highlight the significant indirect impacts acting upon remnant vegetation in the region.

Hibbertia puberula is highly unlikely to survive within areas of nutrified mown exotic grasses, dense swathes of *Eragrostis curvula* and thick piles of garden refuse.

Photo 34: Stark contrast in vegetation condition.

Left is highly degraded. Right is intact high quality PCT 725 in part protected from urban runoff and unauthorised access and rubbish/garden refuse dumping by a trench acting as a physical barrier.

Photo 35: Significant species *H. pedunculata* still apparent within disturbance zones.

Photo 36: Anthropogenic impacts along the corridor.

Note: Top left rubbish dumping on verge of high-quality habitat, top right clearing for fire break, mid left acute weed invasion from garden refuse dumping: Mother of Millions, Wandering Jew and *Eragrostis curvula*, mid right commercial scale refuse dumping, bottom left garden refuse dumping facilitating the invasion of *Eragrostis curvula*, bottom right chronic weed invasion and clearing for fire break.

Photo 37: Unsuitable habitat for the *H. puberula* group.

Left, looking westward from the electricity easement to disturbed PCT 849. Right, looking eastward across a highly disturbed electricity easement chronically infested with exotic pasture.

Photo 38: Unsuitable habitat for the *H. puberula* group.

Left, highly disturbed PCT 849, the ground layer dominated by *Eragrostis curvula*. Right, farmland.

The electricity easement in the eastern sector of the road corridor is unlikely habitat, it is the wrong PCT for the species and is highly degraded due to past rural uses, urban runoff and subsequent weed invasion.

Ropes Creek Vicinity

A number of areas were targeted for survey along the Ropes Creek corridor, these were

- Whalan Reserve
- Tregear Reserve
- South of Whalan Reserve
- East of and to the south of St Marys Rugby League Club, Boronia Road North St Marys
- Electricity Substation vicinity Kurrajong Road and Boronia Road, North St Marys, and
- Shephard Street Vicinity, Colyton.

The potential habitat sites in the Ropes Creek vicinity were selected based on the PCT mapping, aerial imagery and the following BioNet records:

Grevillea parviflora: 28/01/2015, Ropes Creek, Mt Druitt includes Whalan Reserve and Tregear Reserves, -33.77797 150.80575.

Dillwynia tenuifolia: near corner Roper Rd & Carlisle Ave, Colyton, -33.78435, 150.80540, Ropes Creek, Mt Druitt includes Whalan Reserve and Tregear Reserves -33.78544, 150.80727

Eucalyptus parramattensis subsp. *parramattensis*: Roper Road, St. Marys, -33.78435, 150.80540

Hibbertia pedunculata: Between power station and railway line near Boronia Park, St Marys

Grevillea juniperina: M4 Motorway, Ropes Creek includes Whalan Reserve and Tregear Reserves and near corner Roper Rd & Carlisle Ave, Colyton.

Grevillea parviflora and *Eucalyptus parramattensis* subsp. *parramattensis* are known co-occurring species at Moorebank and at Voyager Point. *Dillwynia tenuifolia* is a known co-occurring species at Kemps Creek and at Ropes Crossing. These species indicate the possibility of potential suitable habitat present in the Ropes Creek vicinity.

The condition of the vegetation and population status of some of the BioNet records remain unknown.

Both *Grevillea parviflora* and *Eucalyptus parramattensis* subsp. *parramattensis* were not located by this survey effort and the GPS points do not align with the descriptors.

Much of the Ropes Creek vicinity was found to be severely impacted by weed invasion displacing most native species in many of the likely habitat areas.

Further details of the habitat at these sites follows.

Whalan Reserve

Whalan Reserve is primarily developed as a recreational facility including sporting fields, BMX bike jumps, Whalan Model Car Club track, walkway / cycleway and exercise equipment.

West of the path remnant river-flat forest and supplementary plantings were observed.

In the area surveyed the canopy / subcanopy was variously comprised of *Eucalyptus tereticornis*, *Angophora floribunda*, *Casuarina glauca, Acacia decurrens, A. parramattensis* and *Melaleuca decora*. A stand of Blue Box was noted west of the access road.

Photo 39: Whalan Reserve bushland west of the pathway.

The ground layer was impacted by weeds and dominated by *Eragrostis curvula* in many places. Despite this, numerous areas were observed to support a diverse array of indigenous species including: *Acacia falcata*, *A. elongata*, *Bursaria spinosa*, *Indigofera australis, Ozothamnus diosmifolius*, *Daviesia ulicifolia* var. *stenophylla*, *Tricoryne elatior*, *Phyllanthus virgatus*, *Opercularia diphylla*, *Cyanthillium cinereum*, *Cheilanthes sieberi*, *Glossogyne tannensis*, *Goodenia hederacea*, *G. bellidifolia*, *G. paniculata*, *Brunoniella australis*, *Chorizema parviflora*, *Chrysocephalum apiculatum*, *Centella asiatica*, *Glycine tabacina*, *Desmodium varians*, *Polymeria calycina*, *Zornia dyctiocarpa*, *Dianella longifolia*, *Lomandra longifolia*, *Microlaena stipoides*, *Themeda australis* and *Aristida* *vagans*. *Eucalyptus crebra*, *Melaleuca armillaris*, *Callistemon viminalis*, and *C. salignus* were noted in the plantings.

The riverflat community is atypical of *Hibbertia puberula* habitat as the higher nutrient status of the soils supporting typically a dense grassy /herbaceous layer is unsuitable habitat. However, the presence of minor alluvial terraces in combination with lateritised soil areas with relatively open ground layer provides habitat with low potential for the species to occur.

Photo 40: Weedy understorey and habitat plantings at Whalan Reserve.

Photo 41: Remnant vegetation at Whalan Reserve severely impacted by *Eragrostis curvula*.

Photo 42: Minor alluvial terrace, potential habitat for *H. puberula* in Whalan Reserve.

Tregear Reserve

Tregear Reserve is primarily a developed recreational reserve with sporting fields, walkways/ cycleway, exercise facilities and an off-leash dog compound.

Undeveloped portions remain west of the pathway and include riverine remnant vegetation and large areas of unmown exotic grassland / herbland that has predominantly displaced the indigenous vegetation. Habitat enhancement plantings were noted along the bushland verge.

Habitat for *Hibbertia puberula* may have once existed at the interface between the alluvial floodplain and the lateritised rise. The potential habitat is mostly too degraded to now support this species.

In the area surveyed the riparian vegetation was dominated by *Eucalyptus baueriana* with *Casuarina glauca*, *Acacia parramattensis*, *Melaleuca styphelioides*, *Bursaria spinosa* and the native grass *Microlaena stipoides* being relatively common.

Other indicative indigenous species noted included *Carex appressa*, *Scaevola albida*, *Dichondra repens*, *Centella asiatica* and *Alternanthera denticulata*.

The understorey in many locales is heavily weed impacted with species such as: *Eragrostis curvula*, *Chloris gayana*, *Setaria sphacelata*, *Verbena bonariensis*, *Rumex* sp. and *Tradescantia fluminensis*.

Enhancement plantings include: *Eucalyptus crebra*, *Casuarina glauca*, *Melaleuca styphelioides*, *M. decora*, *M. linariifolia* and *Bursaria spinosa*.

Photo 43: Looking across Tregear Reserve to the riparian zone of Ropes Creek

Photo 44: Treagar Reserve chronic weed infestation eliminating potential habitat for the species.

Although very limited in extent, a number of indigenous ground layer species were noted under the canopy of the enhancement plantings and to a lesser degree within the adjoining predominantly exotic weed meadow. Indigenous species noted include: *Wahlenbergia gracilis, W. communis, Centella asiatica, Tricoryne elatior, Microlaena stipoides, Cynodon dactylon, Phyllanthus virgatus*, *Rubus parviflorus*, *Glycine tabacina*, *Haloragis heterophylla* and *Glossogyne tannensis*.

Weed meadow adjoining plantings was dominated by *Eragrostis curvula, Hypochaeris radicata Plantago lanceolata*, *Melilotus albus* and *Paspalum dilatatum*.

The majority of the potential habitat was blanketed by dense weeds, primarily comprised of: *Eragrostis curvula*, *Cirsium vulgare*, *Verbena bonariensis*, *Melilotus albus*, *Foeniculum vulgare*, *Solanum sisymbriifolium*, *Bidens pilosa*, *Lactuca serriola*, *Plantago lanceolata*, *Chloris gayana*, *Nothoscordum gracile*, *Chenopodium album* and *Sorghum halepense*.

South of Whalan Reserve

The generalised geomorphology of the site is summarised by the intersection of the alluvial floodplain deposits of Ropes Creek with low lateritised rises. It is possible that such conditions once provided localised suitable habitat for *Hibbertia puberula*.

The potential habitat in this section of Ropes Creek is severely impacted by weed invasion and the potential for threatened species to now exist is negligible. A large area is being infilled with road ballast.

Photo 45: Eastern side of Ropes Creek south of Whalan Reserve.

Photo 46: *Eragrostis curvula* smothers potential habitat area of lateritised clay.

Photo 47: Only one small area of Themeda grassland was noted to remain.

Photo 48: Photos show dense growth of *Imperata cylindrica* (top left) and a variety of weeds eliminate potential habitat for the species.

Boronia Road, North St Marys

A diverse herbaceous layer was observed in recently burnt sections of the powerline easement at North St Mary's. Most locales including the adjacent wooded areas and including PCT 724 were heavily infested with dense *Eragrostis curvula* tussocks, and this was smothering the ground layer.

Flowering species noted in one burnt area included *Murdannia graminea*, *Tricoryne elatior*, *Hypoxis hygrometrica* var. *hygrometrica*, *Isotoma fluviatilis* and *Hibbertia diffusa*, as well as fertile *Ophioglossum lusitanicum.* All of these plants were non-discernible under the adjoining tree cover and within the dense *Eragrostis* tussocks.

No *Hibbertia puberula* or *H. pedunculata* plants were observed in this locale though the survey was very limited in its extent and duration.

Photo 49: North St Marys electricity easement environs.

Photo 50: East of and to the south of Boronia Road North St Marys.

Electricity Substation vicinity Kurrajong Road and Boronia Road, North St Marys

The potential habitat areas in the vicinity of Kurrajong and Boronia Road intersections occur on slightly higher ground outside the influence of nutrified stormwater discharges and overflows from Ropes Creek.

A small highly disturbed remnant exists between the substation and the western rail line supporting a population of *Hibbertia pedunculata* estimated +/- > 50 plants.

Planted/escaped *Eucalyptus maculata*, *E. sideroxylon*, *Melaleuca armillaris*, *Callistemon salignus*, *Leptospermum petersonii*, *Melaleuca hypericifolia* and *Casuarina glauca* were common in the tree and shrub layer adjoining the substation facility.

Indigenous species noted include *Eucalyptus moluccana*, *E. tereticornis*, *Daviesia ulicifolia* subsp. *stenophylla*, *Hibbertia pedunculata, Dillwynia tenuifolia*, *Acacia decurrens*, *A. elongata*, *Ozothamnus diosmifolius*, *Pimelea linifolia*, *Leptospermum trinervium*, *Goodenia hederacea*, *Cheilanthes sieberi*, *Lepidosperma laterale*, *Microlaena stipoides* and *Entolasia stricta*.

Eragrostis curvula formed extensive swathes throughout the surrounding area including the mown perimeter of the substation.

Photo 51: An indigenous regrowth area between the substation and western railway line is potential habitat for *H. puberula*.

Photo 52: Indigenous and non-indigenous “native” vegetation form the remnant between substation and railway line.

Photo 53: *H. pedunculata* in the remnant between the substation and the railway line.

Potential habitat also exists to the east of the substation adjacent to a small stand of *Eucalyptus fibrosa* and *Melaleuca decora* within an electricity easement and extending toward the rail line. Significant numbers of *Hibbertia pedunculata* were noted in open areas.

Photo 54: Foreground, *H. pedunculata* within open areas of native grassland/herbland.

Note: Background shows dense swathes of *Eragrostis curvula* adjacent electricity substation.

Photo 55: Slashed native vegetation in the powerline easement, potential habitat for *H. puberula*.

Photo 56: Open areas of lateritised clay soil east of the substation and north of railway line west of Ropes Creek support *H. pedunculata* and provide potential habitat for *H. puberula*.

Shephard Street Vicinity, Colyton

Bushland Remnant Roper Road / Shephard Street / Western Motorway interchange.

A linear bushland remnant between Shephard Street and the Western Motorway was targeted for survey due to BioNet records for *Hibbertia pedunculata* and *Grevillea juniperina* at the site and mapping on the spatial viewer indicating the presence of PCT 724.

In consideration of its size the remnant is in good condition with the exception of the eastern extremity which has recently been further degraded by roadworks.

The understorey was noted to be impacted by drought (refer photos 60 and 61). Specimens of both *Hibbertia pedunculata* and *Grevillea juniperina* were observed but were drought impacted. A number of specimens of the *Grevillea* had senesced adjacent to the roadworks.

No *Hibbertia puberula* plants were observed at the time of survey undertaken between 11-12 am, after likely petal dehiscence. Due to the site conditions, detectability was rated as extremely low and as such the species could have easily been overlooked as the plants, if present, would have existed as tiny sprigs with a few leaves only. It is also possible that the species has retreated to the soil seed bank in response to drought.

The indigenous species noted at the site include: *Eucalyptus fibrosa*, *Melaleuca decora*, *M. nodosa*, *Allocasuarina littoralis*, *Pimelea linifolia*, *Kunzea ambigua*, *Acacia elongata*, *A. falcata*, *Callistemon pinifolius*, *Grevillea juniperina*, *Dillwynia tenuifolia*, *Hibbertia pedunculata*, *Exocarpos cupressiformis*, *Bursaria spinosa*, *Daviesia ulicifolia* subsp. *stenophylla*, *Lissanthe strigosa*, *Xanthorrhoea* sp., *Boronia polygalifolia*, *Phyllanthus hirtellus*, *Billardiera scandens*, *Goodenia hederacea*, *Cheilanthes sieberi*, *Lobelia purpurascens*, *Wahlenbergia gracilis*, *Dianella laevis*, *D. revoluta*, *Opercularia diphylla*, *Centella asiatica*, *Lomandra multiflorus*, *L. filiformis*, *Lepidosperma laterale*, *Entolasia stricta*, *E. marginata* and *Microlaena stipoides*.

Photo 57: Bushland remnant south of Shephard Street, adjacent the Western Motorway

Photo 58: *Eucalyptus fibrosa*, *Allocasuarina littoralis*, *Melaleuca decora* and *M. nodosa*.

Photo 59: Drought impacted *H. pedunculata*, the largest and only plant noted in flower.

Photo 60: Severe drought impacted understorey in western sector of the site

Photo 61: Severe drought impacted understorey in middle section of the site

Shephard Street Park environs, Colyton

The spatial viewer identifies the Shephard Street Park vicinity as PCT 724 thinned remnant, urban.

Shephard Park itself is devoid of indigenous understorey and is dominated by an upper canopy of *Melaleuca decora* and widely scattered *Eucalyptus* trees. The ground layer consists mainly of mown exotic grasses with scattered small areas of mixed native/exotic grasses and herbs. It is extremely unlikely to support a viable population of *Hibbertia puberula* due to past and current management.

Photo 62: Left and right, Shephard Park.

At the rear of Shephard Park, a linear band of remnant vegetation extends along the Western Motorway. A fire break separates the bushland from residential properties. Edge effects have and will continue to have a deleterious impact upon the vegetation.

Photo 63: Linear band of remnant vegetation along the Western Motorway near Shephard Park.

Photo 64: A small core area of weed free vegetation exists above the Motorway cutting.

South of Dunheved Circuit and north of Christie Street, St Marys

The area was included as it is mapped as PCT 725 and PCT 724 on the spatial viewer and recent records exist for *Grevillea juniperina*, *Dillwynia tenuifolia* and *Pultenaea parviflora* suggesting that sufficient habitat remains that may support *Hibbertia puberula*.

Photo 65: Dunheved Estate Reserve bushland remnant adjacent Dunheved Circuit

Photo 66: Bushland remnant north of Christie Street

Site inspection of the Dunheved Estate Reserve and surrounds observed transitional vegetation grading from PCT 725 in the eastern end to PCT 724 westward. The soil was clay with laterite nodules. The remnant vegetation was confined to a narrow band on both sides of the disused railway cutting. Of the threatened species noted; *Grevillea juniperina* was observed to be widespread and common even colonising the former station platform. *Pultenaea parviflora* and *Dillwynia tenuifolia* were more localised but frequently observed.

Eucalyptus fibrosa was the dominant tree species eastward with *E. tereticornis, Angophora floribunda* and *E. moluccana* becoming more prevalent and dominating westward. A small stand of *E. baueriana* was noted within Dunheved Estate Reserve along with planted *Corymbia maculata* and *E. crebra* noted on the northern verge.

Indigenous species recorded include: *Allocasuarina littoralis, Melaleuca decora, M. nodosa, Acacia elongata, A. falcata, A. parramattensis, Daviesia ulicifolia* var. *stenophylla, Ozothamnus diosmifolius, Bursaria spinosa, Lissanthe strigosa, Astroloma humifusum, Phyllanthus hirtellus*, *Cyanthillium cinereum*, *Linum marginale*, *Caesia parviflora* var. *vittata*, *Goodenia hederacea*, *Phyllanthus virgatus*, *Dichondra repens*, *Glycine tabacina*, *Einadia nutans*, *E. polygonoides*, *Cheilanthes sieberi*, *Opercularia diphylla*, *Hibbertia diffusa*, *Brunoniella australis*, Vittadinia sp., *Dianella revoluta*, *D. longifolia*, *Themeda australis*, *Lepidosperma laterale*, *Lomandra multiflora*, *L. filiformis*, *Microlaena stipoides* and *Aristida vagans*.

Single specimens of both *Glochidion ferdinandi* and *Melia azedarach* were observed near the overpass. *Eragrostis curvula* is the dominant weed above the cutting. Sufficient site integrity remains to support diminutive species such as *Hibbertia puberula.*

Photo 67: Park at Dunheved Circuit, rail cutting on the right of picture.

Photo 68: Rail cutting with remnant bushland on steep banks.

Photo 69: Looking along rail cutting to footbridge, remnant bushland on banks.

Photo 70: *Grevillea juniperina*, *Pultenaea parviflora* and *Dillwynia tenuifolia* on the rail cutting embankment.

Photo 71: *Grevillea juniperina* colonising the abandoned railway platform.

Photo 72: Abandoned railway platform, remnant bushland both sides of cutting.

Claremont Meadows Bushland

The area was included for consideration as the Claremont Meadows bushland is identified on the spatial viewer as containing two vegetation communities, primarily as PCT 724 and with small areas of PCT 849 indicated.

Photo 73: Equestrian Circuit - Ridgetop Woodland *Eucalyptus moluccana*, *E. eugenioides*? and *E. fibrosa*

Photo 74: Equestrian Circuit - regrowth with understorey dominated by *Eragrostis curvula*.

Claremont Meadows bushland remnant contains small areas of ridgeline vegetation primarily in the Equestrian Circuit and Blackwood Street vicinities comprised of a varying combination of *Eucalyptus tereticornis*, *E. moluccana*, *E. eugenioides*? and *E. fibrosa*. The majority of the vegetation is found on the slopes and flats and is mainly comprised of *Eucalyptus tereticornis* and *E. moluccana* with a dense understorey of *Bursaria spinosa* present on the slopes.

All the ridgetop areas adjoin recent subdivisions and are impacted by past landuse practices with most of the understorey being cleared or significantly thinned. Some areas remain unvegetated, but most are now colonised by exotic grasses and herbaceous species.

Although PCT 724 may have potential as habitat for the *Hibbertia puberula* group in some circumstances, from current known habitat information it is thought that this is only the case where this community intergrades with PCT 725, and/or PCT 883 and/or PCT 1067.

Claremont Meadows bushland is assessed as unsuitable habitat for the *Hibbertia puberula* group.


Photo 75: Understorey is cleared or dense swathes of exotic grasses.


Photo 76: Much of the understorey in the Blackwood and Fowler Street vicinities is comprised of dense swathes of exotic grasses.

Apple Gum Reserve, Glenmore Park

Apple Gum Reserve in Glenmore Park is identified on the spatial viewer as containing two vegetation communities, PCT 1395 and PCT 849, with areas mapped as Urban native / exotic – noting planted native exotic.

Apple Gum Reserve is a highly modified urban park / linear bushland reserve. The majority of the indigenous flora is situated within and on the slopes of a +/- south – north gully line to the east of Lady Jamison Drive. PCT 1395 is mapped as occurring in the higher southern portion of the reserve and PCT 849 at the northern portion. Over 1/3 of the Reserve is mown exotic grassland with significant areas of mulched beds surrounding both remnant trees and plantings including all the vegetation mapped as PCT 1395.

Although PCT 1395 is known potential habitat for the *Hibbertia puberula* group no suitable habitat exists for *Hibbertia puberula* at this locale irrespective of the mapping accuracy.

Photo 77: Apple Gum Reserve at Glenmore Park from Lady Jamison Drive.

Note: photo taken from Lady Jamison Drive looking across to the intersection of Bursaria Drive and Honeysuckle Avenue from an area mapped as Urban exotic to PCT 1395 adjoining Bursaria Drive.

Photo 78: Google Earth image of area mapped as PCT 1395, mown and mulched at corner of Bursaria Crescent and Honeysuckle Avenue.

Photo 79: Google Earth image of area mapped as PCT 1395 mown and mulched at corner of Bursaria Crescent and Honeysuckle Avenue.

Photo 80: Google Earth image Corner of Bursaria and Acacia Avenues Mapped as PCT 1395 mown and mulched.

Photo 81: Google image looking across to linear bushland remnant bordering Lady Jamison Drive mapped as PCT 849.

Photo 82: Apple Gum Reserve at Glenmore Park remnant bushland.

Note: *Eucalyptus tereticornis*, *E. moluccana* and *Bursaria* dominated bushland remnant mapped as PCT 1395 is unsuitable habitat for the *Hibbertia puberula* group.

Photo 83: Photo of Apple Gum Reserve showing mown weeds of the bushland margin.

Photo 84: Photo of Apple Gum Reserve showing chronic weed infestation of the bushland margin.

Photo 85: Apple Gum Reerve at Glenmore Park bushland remnant.

Note: *Eucalyptus tereticornis*, *E. moluccana* and *Bursaria* dominated bushland remnant is unsuitable habitat for the *Hibbertia puberula* group. Mapped as PCT 1395.

Kemps Creek area, Lot 3 DP 812284, 90 Clifton Avenue Kemps Creek

Most of the block is cleared and is used for storage of materials and logged timber.

A narrow strip along the southern boundary supports native plants including 4 endangered species. More than 20 plants of *H. puberula* were found in this area during our survey on 9 November 2018. The majority of the *Hibbertia puberula* plants observed had shed their petals prior to start of the site inspection at 11am to 12.15pm. The species had not previously been recorded for the Kemps Creek vicinity.

The remaining species habitat has been excluded from the biodiversity certification footprint but remains threatened by vast mounds of mulch, fill and invasive weeds.

Photo 86: The remaining threatened species habitat at 90 Clifton Avenue Kemps Creek.

Note that the habitat exists only as a linear band adjacent to northern boundary of the adjoining block to the south.

The vegetation in the immediate vicinity has been variously described as PCT 883 by Eco Logical Australia (2013), Ecoplanning (2015) and the Vegetation 100km consolidated layer in the Spatial Viewer, and Shale Gravel Transition Forest by Envirotech (2013). It is identified on the spatial viewer as PCT 725 on Lots 1, 2 and 3 DP812248 and PCT 724 as occurring to the east and west.

The vegetation in the Kemps Creek area has been dramatically altered with clearing for agriculture and removal of trees for various uses such as fence posts and firewood. The precise abundance of the various *Eucalyptus* species through the area is difficult to ascertain. *Eucalyptus sclerophylla* is obviously a major component within limited areas with stands still occurring south of Elizabeth Drive adjacent to Bill Anderson Park and the Christadelphian Heritage College Sydney. Scribbly Gum also appears to have been a major component of the canopy within Lot 3 DP 812284 prior to clearance as documented within the Eco Logical 2013 report, refer photo 88.

Photo 87: Looking westward along the remaining threatened species habitat

Photo 88: Scribbly Gum was an obvious common component of the site (photo Eco Logical 2013).

It is likely that *Hibbertia puberula* was widespread in localised patches across the site prior to development. It was observed to be co-occurring with and often intertwined amongst the remaining

Dillwynia tenuifolia noted on site. Although there is discrepancy in numbers, both the Eco Logical 2013 and Ecoplanning 2015 reports indicate the *Dillwynia* to have been widespread across the site prior to clearing.

Photo 89: Habitat and location of *H. puberula* on Lot 3 DP 812284.

Photo 90: *H. puberula* co-occurring with *Dillwynia tenuifolia,* Lot 3 DP 812284

Photo 91: *H. puberula* petal dehiscence prior to 11.24 am.

Photo 92: *H. puberula* interwtinned amongst *Dillwynia tenuiifolia.*

Photo 93: Close up photo of *H. puberula,* one partial flower remains at 11.24am.

Photo 94: *H. puberula* showing petal dehiscence 11.24 am

Photo 95: *H. puberula* floral structure, petal dehiscence prior 11.22am 9/11/2018.

Lot 1 & 2 DP812284 Clifton Avenue, Kemps Creek in the Penrith local government area

Potential habitat is likely to occur within remnant vegetation located on Lots 1 and 2 DP812284 on Clifton Avenue.

No access was granted therefore site assessment was limited to "through the fence" observation made from the adjoining property (90 Clifton Road), spatial viewer information and literature review of the Envirotech 2013 assessment.

Several plants of *H. puberula* were observed by Jan Miller, Steve Douglas and confirmed by Robert Miller approximately 5-6 metres from the fence line. Although without petals, the plants were just discernible due to the coloration of the open calyxes. Therefore, the site is known habitat for the species. Other threatened species noted include *Dillwynia tenuifolia* and *Pultenaea parviflora.* The vegetation was assessed as potential suitable habitat for a range of other threatened taxa as it is contiguous to the known habitat on Lot 3 and a number of co-occurring species were noted. The vegetation of the general area has been variously described as PCT 883 by Eco Logical Australia (2013), Ecoplanning (2015) and the Vegetation 100km consolidated layer in the Spatial Viewer, and Shale Gravel Transition Forest by Envirotech (2013). It is identified on the spatial viewer as PCT 725 on Lots 1, 2 and 3 DP812284 and PCT 724 as occurring to the east and west.

Photo 96: Bushland on Lot 2 DP812284, photo taken through fence.

Note: Subtle variation in elevation and possible substrate consistency providing periodic damp conditions supporting range of species e.g. *Xanthorrhoea minor* and potential habitat for threatened plants such as *Grevillea parviflora* and *Hibbertia* species.

An environmental assessment on this block by Envirotech 2013 noted a relatively intact flora community and that there was a healthy seed bank evidenced by the regeneration of native vegetation in disturbed portions of the property. Envirotech considered the site to have high species diversity including "well-represented herbaceous, understory and canopy layers that were clearly identifiable". Weeds were confined to the perimeter of the property.

Photo 97: *Dillwynia tenuifolia* and habitat of the two observed *H. puberula* plants on Lot 2 DP812284.

Envirotech (2013) found no threatened fauna or individual flora species to be present on the site at the time of inspection. The habitat potential of the site for threatened species was considered to be relatively high. The Endangered Ecological Community Shale Gravel Transition Forest was detected on the site. The non-detection of threatened species is likely to be attributable to the survey being undertaken on 20 August 2013, outside the flowering period.

Lot 22 DP 60122, 1541A Elizabeth Drive Kemps Creek and Lot 2 DP 587135, 146B Clifton Avenue Kemps Creek

These two blocks in the Kemps Creek area are assessed as having a low to moderate probability of occurrence for *Hibbertia puberula*.

The majority of the understorey on Lot 2 DP 587135, 1468 Clifton Avenue could not be observed. It is included as potential habitat based on its continuity and close proximity to known habitat. The area is mapped as PCT 724 thinned on the spatial viewer.

Lot 22 DP60122 was assessed by ‘’through the fence’’ inspection. The area is mapped as PCT 724 thinned on the spatial viewer. Much of the observable portions of the site are disturbed with weeds and fill dumping. Small areas were noted to contain an intact ground layer.

Photo 98: Lot 22 DP 60122, photo taken from Lot3 DP812284.

Note: small areas of regenerating native vegetation and intact ground layer occur within Lot 22 DP 60122. These provide potential habitat for threatened taxa.

Photo 99: View from south western corner of Lot 3 DP812284 into Lot 22 DP 60122.

Note: degradation of habitat by fill dumping and invasion of weeds, notably dense swathes of *Eragrostis curvula.*

Photo 100: Evidence of clearing, fill dumping and weed invasion degrading the habitat potential for threatened species Lot 22 DP 60122.

Lot 47 DP 734584 146 – 196 Clifton Avenue Kemps Creek

The block of land to the north of Lot 3 DP812284 is cleared and under investigation. It is most likely that this block supported populations of *H. puberula* prior to clearing. From the most recent 31/10/2018 Google Earth imagery no habitat now remains in Lot 47 (referPhoto 103). A narrow strip of low potential habitat remains roadside.

Photo 101: Street view Google earth November 2016 of block to the north of Lot 3 DP812284.

Photo 102: Street view Google earth November 2016 of block to the north of Lot 3 DP812284.

Photo 103: Location of Lot 47 DP 734584, Lot 3 DP812284, Lot 2 DP587135 and Lot 22 DP601022.

Bushland Remnants Lot 4 DP812284, 373 - 381 Clifton Road and Lot 6 DP812284, 316 Clifton Road, Kemps Creek

There are two blocks on the east side of Clifton Road that both have suitable habitat type although they are disturbed. These blocks have low to moderate probability for the species to occur.

The assessment was made from data shown in the Spatial Viewer from two BAM plots located on Lot 6. Species recorded include:

BIO WSAN 13: *Eucalyptus fibrosa* 15% coverage, *Eucalyptus globoidea* 1%, *Melaleuca decora* 2% and *Melaleuca nodosa* with a 15% coverage. Other species recorded each with a 1% coverage include: *Ozothamnus diosmifolius*, *Dillwynia sieberi*, *Dodonaea viscosa*, *Bursaria spinosa*, *Exocarpos* *cupressiformis*, *Aristida vagans*, *Lomandra gracilis*, *Daviesia ulicifolia*, *Dillwynia parvifolia*, *Pultenaea microphylla*, *Einadia hastata*, *Phyllanthus hirtellus*, *Pratia purpurascens*, *Eragrostis leptostachya*, *Entolasia stricta*, *Lepidosperma gunnii*, *Lepidosperma laterale*, *Cyathochaeta diandra*, *Lomandra longifolia*, and *L. multiflora*.

The only weed recorded in the BAM data is *Eragrostis curvula* with a 2% coverage.

BIO WSAN 14: *Eucalyptus globoidea* 30%, *Melaleuca decora* 2%, *Bursaria spinosa* 1% and *Cassinia uncata* 1% coverage. Ground layer species recorded cover 45% of the ground layer. They include: *Einadia hastata*, *Lomandra multiflora*, *Entolasia stricta*, *Eragrostis brownii*, *Dichelachne micrantha, Cynodon dactylon* and with *Microlaena stipoides* a 40% coverage.

Weeds in total had an 8% coverage, species recorded are: *Axonopus affinis*, *Sporobolus creber*, *Hypochaeris radicata*, *Sida rhombifolia*, *Eragrostis curvula* 1%, *Senecio madagascariensis*, and *Setaria parviflora*.

Photo 104: Google Earth image of Lot 6 DP812284 viewed from Clifton Road.

Remnant Vegetation North of Elizabeth Drive, Kemps Creek

The following Lots contain potential habitat for *Hibbertia puberula*: Lot 1 DP747285 1521 – 1539 Elizabeth Drive, Lot 1 DP1212980 1503 Elizabeth Drive, Lot 10 DP 1087346 1495 Elizabeth Drive Lot 16 DP2566 1491 Elizabeth Drive and Lot 1 DP 1o90754 1481-1489 Elizabeth Drive.

The two vegetation remnants north of Elizabeth Drive and south of Lot 1 & 2 DP812284 Clifton Avenue were assessed by ‘’over the fence’’ and ‘’drive-by’’ observation as access was not granted at the time of survey. Both sites were noted to have potential habitat from information contained within the spatial viewer, field observation revealed the small observable areas to be in poor condition and with low habitat suitability. Most of the vegetation was not able to be seen from the roadside.

The majority of the largest remnant Lot 1 DP716403 1521 – 1539 Elizabeth Drive was not visible from the road. It is a large block extending northward and adjoining Lot 1 & 2 DP812284 Clifton Avenue. There is no BAM Plot data available for this site. The spatial viewer maps two vegetation types PCT 1067 thinned and PCT 725 thinned providing potential likely habitat for the species. The remnant is bordered by a wholesale nursery in the west and a quarry to the east. Numerous site disturbances such as large areas of fill emplacement are observable on Google Earth Imagery providing evidence of degradation of habitat across much of the site.

The smaller remnant is bordered by the quarry on two sides and rural residential properties on Elizabeth Drive, consequently the impact of edge effects is likely to be high. Two BAM plots are located in this remnant and the Spatial viewer maps the site as PCT 725. The information provides some insight into the habitat.

BIO WSAN 9: *Angophora floribunda*, *Eucalyptus tereticornis*, *Melaleuca decora, Acacia decurrens*, *Ozothamnus diosmifolius*, *Bursaria spinosa*, *Dillwynia sieberi*, *Themeda triandra*, *Glycine tabacina*, *Einadia trigonos*, *Opercularia diphylla*, *Brunoniella australis*, *Centella asiatica*, *Pratia puberula*, *Polymeria calycina*, *Microlaena stipoides*, *Aristida vagans*, *Entolasia marginata*, *E. stricta*, *Paspalidium distans*, *Dichelachne crinita*, *Echinopogon caespitosus*, *Lomandra multiflora*, *Carex inversa*, *Dichondra repens*, *Lepidosperma laterale*, *Cynodon dactylon*, *Lomandra filiformis* and *Cheilanthes sieberi*.

Weeds recorded in the BAM Plot include: *Senecio madagascariensis*, *Ehrharta erecta*, *Asparagus asparagoides*, *Cirsium vulgaris*, *Pennisetum clandestina*, *Cuscuta campestris*, *Sida rhombifolia*, *Opuntia stricta*, *Plantago lanceolata*, *Tradescantia fluminensis* and *Hypochaeris radicata*.

BIO WSAN 10: *Angophora subvelutina* 15%, *Eucalyptus tereticornis* 5%, *Allocasuarina littoralis*, *Acacia decurrens*, *Ozothamnus diosmifolius*, *Acacia elongata*, *Cryptandra spinescens*, *Eragrostis brownii*, *Themeda australis*, *Glycine clandestina*, *Solanum prinophyllum*, *Hibbertia aspera*, *Microlaena stipoides* 50%, *Panicum simile*, *Eragrostis brownii*, *Cynodon dactylon*, *Lomandra multiflora*, *Juncus usitatus*, *Dichondra repens*, and *Lepidosperma laterale*.

Weeds recorded in the BAM Plot include: *Ligustrum lucidum*, *Verbena bonariensis*, *Setaria parviflora*, *Bidens pilosa*, *Sonchus oleraceus*, *Eragrostis curvula*, *Senecio madagascariensis*, *Cyperus eragrostis*, *Ehrharta erecta*, *Anagallis arvensis*, *Araujia sericifera*, *Passiflora subpeltata*, *Chloris gayana*, *Axonopus compressus*, *Conyza* sp., *Sida rhombifolia*, and *Asparagus asparagoides*.

The representativeness of the habitat information contained within the BAM plot data is unknown. It is also unknown whether or not localised habitat niches prevail within the broader vegetation type as observed at other locales at Kemps Creek. Accordingly, the presence of *Hibbertia puberula* could not be ruled out but the likelihood of occurrence was assessed as low.

Photo 105: Location of BAM plots BIO WSAN 9 and BIOWSAN 10.

Note: Labels show the location of Lot 1 DP716403, Lots 4 and 5 DP255566, Lot 1 DP1212980 and Lot 230 DP1134016.

SUEZ Kemps Creek Resource Recovery Park and Landfill, Elizabeth Drive, Kemps Creek

Remnant vegetation exists on the western margin of the Suez facility which is managed under the facilities' conditions of consent.

The vegetation is mapped as PCT 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats intact and PCT 849 - Grey Box - Forest Red Gum grassy woodland on flats - Scattered Trees on the spatial viewer.

Survey of this site was incorporated into the survey strategy to:

- confirm that the habitat was not suitable for the subject species,
- check habitat because suitable habitat is mapped as occurring proximally, and to
- facilitate over the fence inspection of adjoining properties mapped as containing the suitable habitat and where access was not granted.

Photo 106: Intergrading vegetation between PCT 849 and PCT835 between the Suez facility and Badgery's Creek.

Understorey species noted at the site included *Melaleuca decora*, *Bursaria spinosa*, *Einadia hastata*, and *Hibbertia aspera*, with a relatively dense grassy and herbaceous layer.

This is not suitable habitat for *Hibbertia puberula.*

Photo 107: Mown mixed native / exotic grassland/herbland at edge of the Suez western access road.

A diverse derived grassland herbland exists at the interface of the remnant vegetation on the SUEZ site. Weeping Meadow Grass (*Microlaena stipoides*) is the dominant grass with common herbaceous species such as *Brunoniella australis*, *Goodenia hederacea, Caesia parviflora, Cheilanthes sieberi, Commelina cyanea, Dichondra repens, Lomandra filiformis, Oxalis perennans, Lobelia purpurascens, Tricoryne simplex, Veronica plebeia,* and *Wahlenbergia gracilis* noted.

Lot DP860456 South of Suez, Elizabeth Drive, Kemps Creek.

Inspection of Lot DP860456 was not granted. The area has been excluded from the certification area due to pending investigations.

The determination of potential habitat occurring on Lot DP860456 was therefore based on the information contained within the spatial viewer and google earth imagery. Drive-by inspection was constrained by the high volume of trucks entering and exiting the site and the adjoining Suez approved facility. There is a moderate probability that the species occurred there, as the spatial viewer identifies the area to have contained both PCT 725 and 724. Lot 4 is now mostly cleared and under investigation, with high volumes of fill emplacement being observe adjacent Elizabeth Drive and the Suez facility 1.

Photo 108: Lot DP860456 viewed from Elizabeth Drive, Google Earth image taken prior to clearing.

Photo 109: Fill batter at northern end of Lot DP860456, South of Suez facility.

Note: This area is identified as not to be certified, area under Investigation. Photo taken through fence from the adjoining SUEZ facility.

Photo 110: Lot 4 DP860456 showing moist swale in the central portion of image prior to clearance and fill emplacement.

Photo 111. Google Earth Imagery 31/10/2018 Lot 4 DP860456 showing high volume of fill emplacement across most of the site. A small area remains providing some habitat potential.

Cross and Western Streets, Kemps Creek

This area of bushland between Cross Street, Western Street and Elizabeth Drive, and adjacent to the Bill Anderson Park, was included within the survey for this assessment as a surrogate site, as the presence of threatened taxa here is well documented and the site has previously been assessed by CFFIS in 2002 and NPWS *Dillwynia tenuifolia* survey CFFIS 2001.

This current survey revealed significant decline of the apparent population of all recorded threatened species. It is likely in most cases to be attributable to the fire regime in combination with drought. Areas were noted to be impacted by anthropogenic factors, mostly in association with illegal dumping of waste including asbestos and other rubbish requiring remediation. This has resulted in the bulldozing of tracks which facilitates the spread of invasive weed species through the displacement of weed seed infected soils and the infilling of minor habitat swales which previously supported *Grevillea parviflora*.

Despite the signage the area is poorly managed and is an example demonstrating that non-clearance is not protection without fencing and appropriately allocated management funds. The site requires selective management burns, but this should be avoided until the site is fully secured by barriers to exclude indiscriminate access by rubbish dumpers.

Photo 112: Bushland remnant at Cross Street Kemps Creek, adjacent to Bill Anderson Park.

Photo 113: Suppressed understorey under canopy at Cross Street bushland.

Photo 114: Cross Street bushland showing track bulldozed to remove dumped asbestos.

Photo 115: Disturbed bushland verge adjacent Bill Anderson Park.

Note scattered occurrences of *Dillwynia tenuifolia* and assorted indigenous grasses and forbs. The invasive *Eragrostis curvula* is common along the bushland margin and is a serious threat to the biodiversity of the remnant.

Photo 116: Chronic rubbish dumping in bushland on the verge, Western Street, Kemps Creek

Photo 117: Chronic rubbish dumping in bushland on the verge, Western Street, Kemps Creek

Jamisontown Vicinity, Huntington Reserve and fields in the area

During the course of the field survey many areas were traversed by car to the designated target survey locations. Targeted 'drive-by' assessments were selected on route to sample both identified PCTs and unidentified derived habitats in light of the high diversity of species located under the powerline easement adjacent to the Wianamatta Regional Park. An example of such an area is in the Jamisontown vicinity.

Review of Google Earth Imagery identified areas proposed for future urban development in the Jamisontown vicinity that appeared to have the prospects of derived native grassland habitat east of Tench Avenue and east and west of Blaikie Road. 'Drive-by' assessment revealed the area to be unsuitable habitat for *Hibbertia puberula* (refer photos 118 and 119). Dense swathes of exotic grasses and/or herbaceous species dominate the majority of the landscape. Some areas contain wetland and riparian values.

Photo 118: View from Tench Avenue looking east toward Blaikie Road.

Note: area appears to be dominated by a nutrified exotic grassland herbland, unsuitable habitat.

Photo 119: Fields in Tench and Blaikie Roads, Jamisontown.

Note: left photo looking south east toward Anakai Drive, dense swathes of exotic vegetation blanket the landscape. Right photo, exotic weeds dominate the area adjacent to the wetland habitat along School House Creek. Unsuitable habitat for *Hibbertia*.

4.5.2 DETERMINATION OF SPECIES POLYGONS

Based on the available vegetation mapping, site survey and knowledge of the species habitat requirements, the following maps show the polygons of likely habitat and the estimated probability for the species to occur.

Hibbertia puberula subsp. *puberula* was found to be present within the powerline easement, coloured yellow on map 11. This area is outside the footprint.

Areas shown in dark orange on Map 16 are in the proposed transport corridor through the Park, and in the proposed transport corridor to the north of Captain Cook Drive. There is moderate probability for the species to occur here. Areas of the regional park adjacent to the footprint and in the southeastern section also have moderate probability for the species.

In the eastern end of the northern corridor there are sections with low probability.

Map 16: Wianamatta Regional Park potential habitat sites.

Key:

In footprint, moderate probability for the species – dark orange - 1

Proximate to the footprint, moderate probability for the species – pale orange - 2

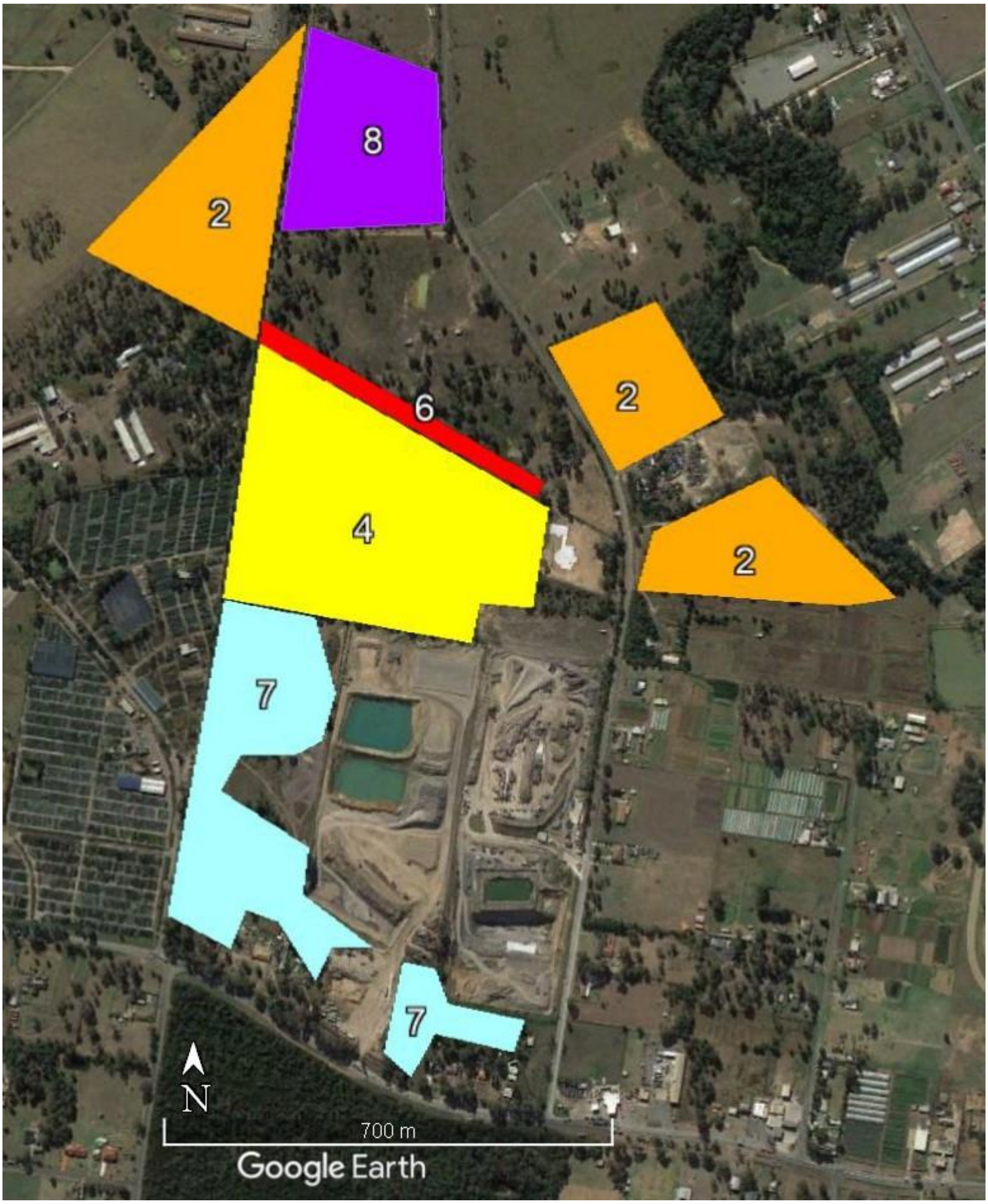
In the footprint, low probability for the species – olive green - 3

Proximate to the footprint, species known to be present – yellow - 4

Map 17: Ropes Creek area potential habitat sites.

Map 18: Shepherd Street Colyton vicinity potential habitat site.

Key: Areas are outside the footprint, low probability of occurrence - peach colour - 5



Map 19. Kemps Creek area potential habitat sites.

Key:

Removed from certification area, species known to be present – red - 6

Proximate to the footprint, species known to be present – yellow - 4

Proximate to the footprint, species moderate probability – pale orange - 2

Proximate to the footprint, species low probability – pale blue - 7

Proximate to the footprint, moderate probability prior to clearing – purple - 8

Map 20: Partially cleared block south of SUEZ landfill site.
Key: Adjacent footprint, moderate probability prior to clearing – purple - 8

4.5.3 ESTIMATE OF AREA OF HABITAT

Greater Penrith to Eastern Creek Urban Release Investigation Area

Wianamatta Regional Park and northern corridor

In footprint, moderate probability, 34 ha.

In footprint, low probability, 3.5 ha.

Proximate to the footprint, moderate probability, 77 ha.

Powerline easement adjacent Wianamatta Regional Park

Outside footprint, species is present, 4 ha.

Ropes Creek vicinity

Outside footprint, low probability, 10 ha.

Colyton vicinity

Outside footprint, low probability, 1.1 ha.

Western Sydney Aerotropolis Growth Area

Kemps Creek area

Removed from certification area, species is present, 1.47 ha

Proximate to the footprint, species is present, 14.4 ha

Proximate to the footprint, moderate potential, 15.6

Proximate to the footprint, low potential, 10.25 ha

Proximate to the footprint, moderate potential prior to clearing, 6.25 ha.

South of SUEZ landfill

Proximate to the footprint, moderate potential prior to clearing, 4.4 ha.

In summary, a total of 37.5 ha of potential habitat for the species lies within the transport corridor.

A further 20 ha where the species is known to be present, and 125 ha of potential habitat, are located within the growth area proximate to potential development and are therefore at risk of edge effects and anthropogenic impacts.

5. Information used in the assessment

Information used in this assessment includes taxonomic papers, BioNet and ALA records of the target species, Critically Endangered Listing, online Threatened Species profile and associated documents, personal observations and site inspections, and the spatial viewer including the layers: survey access and coverage, (BAM plots, polygons and transects), PGA layer and geology and soils.

6. References

CFFIS, 2002. *Compensatory Habitat Assessment of Flora at Rouse Hill, Doonside, Cecil Hills & Kemps Creek for The Western Sydney Orbital*, Report prepared for the NSW RTA.

Eco Logical Australia, 2013. *Lot 3, No 90-145 Clifton Avenue Kemps Creek – Flora and Fauna Impact Assessment,* prepared for Sydney Metro Tree Services Pty. Ltd.

Eco Logical, 2015. *Inspection and review of the Hibbertia sp. Bankstown Population at Bankstown Airport*, report for Bankstown Airport Limited, available at http://www.environment.nsw.gov.au/resources/threatenedspecies/s91ands95/Site_Assessment_ReportA06600-2016.pdf

Ecoplanning, 2015. *Flora and Fauna Assessment and Vegetation Management Plan – 90-145 Clifton Road Kemps Creek NSW,* prepared for TreeServe.

Envirotech (2002). *Flora and Fauna Assessment, 81-83 Clifton Avenue, Kemps Creek,* prepared for the Muhammadi Welfare Association.

Hills District Council website, https://webcache.googleusercontent.com/search?q=cache:-vpeh8rPRVEJ:https://www.thehills.nsw.gov.au/files/assets/public/library-documents/local-studies/aborigines-in-the-hills-district.pdf+&cd=3&hl=en&ct=clnk&gl=au

James, T., 1997. *Urban Bushland Biodiversity Survey, Stage 1 Western Sydney, Native Flora of Western Sydney, Appendices 2 & 3,* published by NSW National Parks and Wildlife Service, Hurstville NSW.

National Parks and Wildlife Service. 2002. *The Native Vegetation of the Cumberland Plain Final Edition*. NSW National Parks and Wildlife Service, Hurstville, available at http://www.environment.nsw.gov.au/resources/nature/cumbPlainMappingInterpguidelines.pdf

NSW Department of Environment, Climate Change and Water, 2010. *Cumberland Plain Recovery Plan*, available at http://www.environment.nsw.gov.au/research-and-publications/publications-search/cumberland-plain-recovery-plan

Price, O. F., Horsey, B. & Jiang, N. (2016). Local and regional smoke impacts from prescribed fires. *Natural Hazards and Earth System Sciences*, 16 (10), 2247-2257, available at http://ro.uow.edu.au/cgi/viewcontent.cgi?article=5192&context=smhpapers

Toelken, H. R. 2000. Notes on *Hibbertia* (Dilleniaceae) 3. *H. sericea* and associated species, *Journal of Adelaide Botanic Gardens* 19 (2000) 1-54.

Toelken, H. R. and Miller, R. T., 2012. Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in *Journal of Adelaide Botanic Gardens* 25 (2012) 71–96 and available at https://data.environment.sa.gov.au/Content/Publications/JABG25P071_Toelken.pdf

Toelken, H. R., 2013. Notes on *Hibbertia* subg. *Hemistemma* (Dilleniaceae) 9. The eastern Australian *H. vestita* group, including *H. pedunculata* and *H. serpyllifolia* Journal of the Adelaide Botanic Gardens 26 (2013) 31–69 and available at https://data.environment.sa.gov.au/Content/Publications/JABG26P031_Toelken.pdf

7. Appendices

Appendix 1. Curriculum Vitae

Robert Miller *Curriculum Vitae*

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Current Position:

Principal of Cumberland Flora & Fauna Interpretive Services

Qualifications:

Associate Diploma Horticulture from the University of Western Sydney (formerly Hawkesbury Agricultural College), conferred on 17 April 1982

Journal Articles

H.R. Toelken & R.T. Miller **2012** Notes on *Hibbertia* (Dilleniaceae) 8. Seven new species, a new combination and four new subspecies from subgen. *Hemistemma*, mainly from the central coast of New South Wales, in Journal of the Adelaide Botanic Gardens, Vol. 25.

Miller J and Miller R **2005** Aquatic macroinvertebrates of headwater streams in the south east forests – diversity and conservation management issues, Wetlands (Australia) 23 (1).

Employment Record

1993 - present

Cumberland Flora and Fauna Interpretive Services

Principal - flora surveys, plant identifications, vegetation assessment, project impact assessment, bush regeneration, rehabilitation, habitat enhancement, seed collection and propagation services.

1990 - 1997 **Sylvan Grove Native Gardens**

Curator of gardens and adjoining bushland - maintenance of and improvement to the plant collection, training and supervision of staff, liaison with other botanic gardens, guided tours, technical advice.

1982 - 1990 **Sylvan Grove Native Gardens**

Horticulturist Specialising in Australian Flora - collection, propagation, identification, and growing of native plants.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES INFORMATION AND RELEVANT EXPERIENCE

Cumberland Flora and Fauna Interpretive Services have provided technical expertise since 1993 to numerous clients including Local Government, NSW Roads and Maritime, NSW Office Environment Heritage NPWS and community groups. Following is a list of some of our projects and clients:

REPORT	CLIENT
Expert advice for Conservation Assessment of *Solanum celatum* Eren Delgado 16/04/2018, Science Division, NSW Office of Environment and Heritage	OEH
Saving our Species (SoS) project for *Pomaderris adnata* a post fire population census Grid D 2018	OEH
Provision of expert advice to update the current ecological data for southern NSW threatened flora species, as part of the review of biodiversity assessments under the Biodiversity Conservation Act 2016.	OEH

REPORT	**CLIENT**
Expert witness in botany Residents Against Intermodal Development Moorebank Incorporated v NSW Minister for Planning and Anor – NSW Land & Environment Court Class 1 Proceedings No. 2017/81889. Review of project documentation, in particular the various biodiversity assessments including the BAM assessment for the project and Individual Expert Witness report of Dr David Robertson 15 October 2017; Site inspections to identify the location of and/or potential habitat for *Hibbertia fumana*, *Hibbertia puberula*, *Grevillea parviflora*, *Persoonia nutans*, *Acacia bynoeana*, provision of an expert report in accordance with Division 2 of Part 31 of the UCPR; confer with the other parties experts at a joint conference and produce a joint expert report; and f appear at the section 34 conciliation conference	EDO
Saving our Species (SoS) project for *Pomaderris adnata* a population census 2017	OEH
Central Coast Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Great Lakes Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2016 – Vegetation Consultant	OEH
Northern Beaches Creek Monitoring Evaluating and Reporting 2015 – Vegetation Consultant	OEH
Clarence Colliery Discharge Investigation April 2015	OEH
Vegetation Assessment as part of the Lachlan Wetlands Condition Assessment Project October 2013 – May 2014	Lachlan Catchment Management Authority
Field expertise and guidance in the Sydney basin to PhD candidate Karen Muscat studying the molecular phylogenetics and morphology of the genus Dianella with close scrutiny of the variation in the D. *caerulea* group of species in eastern Australia	Volunteer to University of Melbourne
Survey for *Pomaderris adnata* to determine population size, structure, occupancy and threats 2014	NPWS Illawarra Region
Survey of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats. Collection of voucher herbarium material for taxonomic review June 2014	OEH
Survey of the southern populations of *Hibbertia stricta* subsp. *furcatula* (Hibbertia species 'Menai') to determine population size, structure, occupancy and threats May 2014	OEH
Investigation of works within the Sublime point precinct Illawarra Escarpment State Conservation Area February 2014.	NPWS Illawarra Region
Identification of Hibbertia species in proposed control burn sites Victoria Road precinct Dharawal National Park.	NPWS Illawarra Region
Assessment of impact of infrastructure upgrade Victoria Road, Dharawal National Park – location of threatened species.	NPWS Illawarra Region
APPEAL IN RESPECT OF PROPERTY AT Lot 1 and 2 DP 224431 Site 2 Sturdee Avenue, Bulli	Roy 'Dootch' Kennedy

REPORT	**CLIENT**
Expert Witness Report Relating to Some Environmental Issues Land & Environment Court of New South Wales PROCEEDINGS NO 10982 of 2012	Roy 'Dootch' Kennedy
Field surveys, collection, pressing, curation of botanical specimens and contributions of notes in association with the manuscript "Notes on Hibbertia subgen. Hemistemma (Dilleniaceae) 7. Eight new species, a new combination and four new subspecies from mainly central New South Wales H.R. Toelken & R.T. Miller 2006 - 10 July 2012	Volunteer to Adelaide Botanic Gardens
Vegetation Surveys and assessments & input into the preparation of REF for proposed car-park and amenities Victoria Road Precinct Dharawal National Park November 12.	NPWS Illawarra Region
Office of Environment and Heritage – Priority Action Statement Expert Consultant Interviews June 2012 – January 2013	OEH
Vegetation Surveys and assessments & input into the preparation of REF for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking track re-alignment Maddens Falls in Dharawal National Park 2011 – 12.	NPWS Illawarra Region
Vegetation Surveys and assessments for proposed walking tracks in Dharawal National Park input into conservation risk assessments 2011 – 12.	NPWS Illawarra Region
Nomination to list Prostanthera saxicola R. Br. S. Str. as an Endangered Species under the NSW TSC Act September 2011	
Field surveys, collection, pressing and curation of botanical specimens of undescribed Kunzea to assist in the taxonomic circumscription of previously presumed extinct, rare and/or poorly known taxa for Dr. H.R. Toelken Honorary Research Associate State Herbarium Science Resource Centre Department of Environment and Natural Resources SA 2011	Volunteer to Adelaide Botanic Gardens
Significant Plant Survey – Maddens Plains Forest Path to Mount Mitchell Precinct IIllawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Significant Plant Survey – Wongawillii Precinct Illawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Significant Plant Survey – Kembla State Forest Precinct Illawarra Escarpment State Conservation Area Cumberland Flora & Fauna Interpretive Services June 2011	NPWS Illawarra Region
Site Inspections and Vegetation Survey of Proposed Minor Track Re-Alignments: Forest Path to Woodward Track & Sublime Point to Austinmer Track Maddens Plains To Sublime Point Precinct Illawarra Escarpment State Conservation Area August 2010	NPWS Illawarra Region

REPORT	CLIENT
Sandon Point Aboriginal Place and Kuradji Lands Vegetation Management Plan April 2010	Illawarra Aboriginal Land Council, Wollongong Council, Southern Rivers Catchment Management Authority.
Forest Path to Woodward Track Precinct Track-head Realignment Maddens Plains IESCA Vegetation Survey April 2010.	NPWS Illawarra Region
Bushland Conservation Project 95 Glendiver Road, The Oaks 2008	A & S Fitzsimmons / Hawkesbury Nepean Catchment Management Authority
Significant Plant Survey – Maddens Plains Forest Path to Woodward Track Precinct Illawarra Escarpment State Conservation Area June 2007	NPWS Illawarra Region
Nomination of Hibbertia "Bankstown Airport" (R.T. Miller & C.P. Gibson s.n. 18/10/2006) as Critically Endangered under the Environment Protection and Biodiversity Conservation Act	Bankstown Bushland Society
Proposal to Demolish A Derelict Amenities Block at Deepwater Park Webster Street Milperra Environmental Assessment of Impacts	Bankstown City Council
Significant Plant Survey – Sublime Point to Panorama House Precinct Illawarra Escarpment Conservation Area August – September 2006	NPWS Illawarra Region
A Consultant for Priority Action Statement Workshop July 2005	NPWS
PHD research assistance – 'The Benefits of Riparian Vegetation in Maintaining Water Quality as Assessed Using Biological Indicators".	UNSW
Plan of Management for Part Lot 11 DP 1049307 Kurrajong Road Prestons January 2005	Sule College
Preliminary Investigation & Vegetation Survey of Lands At Prestons Bounded By Maxwells Creek, Kurrajong Road, Ash Road & The Western Sydney Orbital December 2003	Sule College
Supply and collection of seed for a research project entitled: Factors Affecting Seed Germination and Mycorrhizal Development of the Epacrid: *Woollsia pungens* (2001-2003)	UNSW
Compensatory Habitat Assessment Western Sydney Orbital March 2004	RTA
Compensatory Habitat Assessment Western Sydney Orbital July 2002	RTA
Compensatory Habitat Assessment of Flora at Rouse Hill, Doonside, Cecil Hills & Kemps Creek for The Western Sydney Orbital March 2002	RTA
Compensatory Habitat Assessment Western Sydney Orbital November 2001	RTA
Preliminary Vegetation Survey Between Lawson Rd & Alfords Point Rd, Menai as Part of The Proposed Bangor Bypass 2001	RTA
8-Part Tests for The Proposed Bangor Bypass 2000	RTA
Preliminary Vegetation Survey for The Proposed Bangor Bypass 2000	RTA
Species Impact Statement for the Western Sydney Orbital 2000	Sinclair Knight Mertz

REPORT	CLIENT
Review of Environmental Assessments – Proposed Cricket Ground - Louisa Reserve, The Crest of Bankstown 2000	Bankstown Bushland Society
Review of Environmental Assessments – Proposed Olympic Criterium Circuit the Crest Statement of Environmental Effects	Bankstown Bushland Society
Vegetation Survey – 60 Yanderra Road, Yanderra 1999	Mr. Brian Timmis
Review and Comments on Environmental Assessment – Bankstown City Council - Proposed Cricket Ground – 8 – Part Test- The Crest 1999	Bankstown Bushland Society
Vegetation Survey and Review of Proposed Sand Mining Restoration Works – Howard Park, Lansvale 1999	Chipping Norton Lakes Authority
Rare Species Survey – Blue Mountains & Central Western Slopes 1999	National Parks & Wildlife Service
Vegetation Survey - Kookaburra Road and Camden Valley Way Intersection 1999	Roads & Traffic Authority
Chullora Detention Basin Wetlands Habitat Enhancement 1998	Business Land Group DUAP
Vegetation Study Maxwells Creek Trunk Drainage Stage 1 Vegetation Assessment 1998	Bewsher Consulting
Vegetation Study Prestons Urban Release Area Part 3 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 2 1998	Liverpool City Council
Vegetation Study Prestons Industrial Release Area Part 1 1998	Liverpool City Council
Survey of Remnant Flora for Proposed Nth Liverpool Rd to Edensor Rd Interim Transitway 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management 1998	Roads & Traffic Authority
Beverly Grove Bushland Plan of Management Discussion Paper 1998	Roads & Traffic Authority
Eastern and Western Alignments WSO Cecil Hills Flora Study 1998	Roads & Traffic Authority
Valmay Road Development Vegetation Study 1998	LesryK Pty Ltd
Western Sydney Orbital Prestons To West Baulkham Hills Descriptive Inventory of Remnant Bushland 1998	Roads & Traffic Authority
Vegetation Survey River Road M5 East 1998	Roads & Traffic Authority
Tree Survey, Great Western Highway, Faulconbridge 1998	Roads & Traffic Authority
Eve & Marsh Street Wetlands M5 East 1997	Roads & Traffic Authority
Beverley Grove Bush M5 East 1997	Roads & Traffic Authority
Vegetation Survey - Salt Pan Creek Bridge Duplication M5 East 1997	Roads & Traffic Authority

REPORT	CLIENT
Survey of Flora: Trees and Shrubs, Princes Highway Interchange M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Adjacent to Proposed Exhaust Stack Henderson Avenue, M5 East 1997	Roads & Traffic Authority
Survey of Remnant Vegetation Illoura Reserve, Adjacent to Air Intake Vent M5 East 1997	Roads & Traffic Authority
Lansdowne Reserve Survey of Remnant Flora 1997	Bankstown City Council
Villawood Drain Vertebrate Fauna Survey 1997	Bankstown City Council
Kelso Wetlands Survey of Remnant Flora 1997	Bankstown City Council
Deverall Park Survey of Remnant Flora 1997	Bankstown City Council
Louisa & McClean Reserves Bass Hill Survey of Remnant Flora 1997	Bankstown City Council
The Crest of Bankstown Survey of Remnant Flora 1997	Bankstown City Council
Lawson Bridge Roadworks Survey of Remnant Flora 1997	Roads & Traffic Authority
Davidson Street Scrub Survey of Remnant Flora 1997	Strathfield Council
Freshwater Creek Bushland Survey of Remnant Flora 1996	Bankstown Bushland Society for the EPA
Vegetation Survey Forest Lawn Cemetery Roadworks, Leppington 1996	Roads & Traffic Authority
Vegetation Survey Catherine Fields Road Intersection, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Springfields Road Intersection and Camden Valley Way, Catherine Field 1996	Roads & Traffic Authority
Vegetation Survey Deepfields Road Intersection Camden Valley Way, Catherine Fields 1996	Roads & Traffic Authority
Picnic Point Reserve Vegetation Survey 1996	Bankstown City Council
East Hills Park Vegetation Survey 1996	Bankstown City Council
Monash Reserve Vegetation Survey 1995	Bankstown City Council
Vegetation Consultant on Plan of Management for Cox's Creek for the Endangered Green and Gold Bell Frog 1995	Urban Bushland Management
Smith Park Vegetation Survey 1995	Bankstown City Council
Flora and Fauna Survey, Villawood Stormwater Channel 1995	Bankstown City Council
Virginius Reserve Vegetation Survey 1994	Bankstown City Council
Carysfield Park Vegetation Survey 1993	Bankstown City Council

Ongoing research projects:

Private taxonomic research into the Australian plant genera *Prostanthera*, *Westringia*, *Dianella*, *Thelionema*, *Viola* and *Hibbertia*.

Private research into the invertebrate fauna of the Illawarra with particular emphasis on the Mayfly genus *Atalophlebia*

Flora of Bankstown" a botanical inventory

Botanical inventories of the Sublime Point and Maddens Plains precincts in the Illawarra Escarpment State Conservation Area

Other Publications & Reports

Miller, R.T. (1984 to 2006) numerous papers for the Prostanthera and Westringia Study Group Newsletters.

Miller, R.T. (1991) Vegetation Consultant on Eloura Nature Reserve Vegetation Survey: Report to Liverpool City Council, Greening Australia.

Miller, R.T. Vegetation Consultant on Salt Pan Creek Stage 1 Vegetation Survey: Report to Bankstown City Council, Ian Olsen.

Gibson, C.P. & Miller, R.T. Plant Species List for Bankstown's Natural Heritage: McLaughlin, L., BCC.

Gibson, C.P. & Miller, R.T. Flora of Bankstown Scientific Inventory of Botanical Heritage: Report to Australian National Parks and Wildlife Service, Gibson, C.P. and Miller, R.T. (in preparation).

Nomination of *Prostanthera saxicola* R. Br. s. str. As an Endangered Species under the NSW TSC Act November 2011

Special Projects

- "Flora of Bankstown" a botanical inventory
- Founder & Convener Cookson's Landcare Group Bulli (2003 – 2007)
- President, Society for Growing Australian Plants, East Hills Region, 1987-1995.

- Vice President, Society for Growing Australian Plants, East Hills Region, 1996.
- Plant Steward, Society for Growing Australian Plants, East Hills Region, 1987-1996.
- Leader of the Prostanthera Study Group Australian Plant Society, 1992 - 2010.
- Editor and publisher of Prostanthera & Westringia Study Group's Newsletter *The National Mint* and the Study Groups' Journal – *Lasianthos*.
- Vice President and Founding Member, Bankstown Bushland Society.
- Coordinator Grants Application, Bankstown Bushland Society.
- Bushland Regeneration Grants Project Manager, Bankstown Bushland Society:

- Deverall Park Restoration and Rehabilitation Swamp Woodland ($17,880).
- The Crest of Bankstown Restoration and Rehabilitation ($27,850).
- Airport and Ashford Reserves Restoration and Rehabilitation Swamp Woodland ($45,000).

- Co-recipient of Save the Bush grant for Flora of Bankstown by Hon. Ross Kelly, Minister for Arts, Sports and Environment, 1992-93 ($11,050).
- Founding Member of Illawarra Grevillea Park, Bulli.
- Curator, Lamiaceae collection, Illawarra Grevillea Park, Bulli.
- Former Bankstown City Council's Bushfire Taskforce Community Representative.
- Former presenter of an adult education course in gardening at Bankstown Evening College.
- Development and curation of a private regional herbarium.
- Expert Witness for NSW Police murder trial
- Former appointee as Trustee of the Georges River State Recreational Trust by the Minister for the Environment (the Hon. Tim Moore).

Appendix 2. *Hibbertia puberula* subs. *puberula* collection records 2018

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 28/10/2018 **COLLECTING No.**

LOCALITY: -33.681349 150.715089 Opposite the intersection of Smeeton, Taylor and Nutt Roads in bushland Londonderry NSW 2753. North of Fire Trail

HABITAT: PCT No: 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion Castlereagh Scribbly Gum Woodland

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: Localised in heath patch of *Banksia spinulosa*, *Grevillea mucronulata*, *Philotheca salsolifolia*, *Acacia bynoeana*, *Patersonia sericea*, *Cyathochaeta diandra* etc., within *Eucalyptus sclerophylla Angophora bakeri* Woodland

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 28/10/2018 **COLLECTING No.**

LOCALITY: -33.681753 150.716233 Bushland verge Southern Corner Smeeton, Taylor and Nutt Roads bushland Londonderry NSW 2753

HABITAT: PCT No: 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion Castlereagh Scribbly Gum Woodland

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: Disturbed road verge / bushland from recent road works with weedy fill dumping

2 plants noted – population size unknown

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller, Jan Miller & Stephanie Clark

DATE: 1/11/2018 **COLLECTING No.**

LOCALITY: Castlereagh Nature Reserve Powerline Trail vicinity. Opposite the intersection of The Northern Road and Whitegates Road, Berkshire Park. South of North Trail along unnamed track.

-33.671177 150.753032 -33.672284 150.75167 -33.671676 150.75272

HABITAT: Mapped PCT No: 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion Castlereagh Scribbly Gum Woodland

Associated species: *Eucalyptus sclerophylla, Corymbia gummifera*, *Eucalyptus sideroxylon*, *Allocasuarina littoralis*, *Kunzea ambigua*, *Hakea sericea*, *Bossiaea rhombifolia, Micromyrtus minutiflora, Dillwynia tenuifolia*, *Petrophile* sp., *Brachyloma daphnoides*, *Dillwynia tenuifolia*, *Styphelia laeta*, *Dianella revoluta*, *Patersonia sericea*, *Goodenia hederacea*, *Entolasia stricta* etc.

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: Disturbed bushland from historic laterite extraction – extensive laterite deposits observed in the general vicinity

30 plants noted

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller, Jan Miller & Stephanie Clark

DATE: 1/11/2018 **COLLECTING No.**

LOCALITY: Castlereagh Nature Reserve west of the Powerline Trail. Opposite the Northern Wreckers Northern Road Berkshire Park.

-33.680743 150.745126 -33.67895 150.746758 -33.679531 150.745583

HABITAT: Mapped PCT No: 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion Castlereagh Scribbly Gum Woodland

Associated species: *Eucalyptus sclerophylla, Eucalyptus parramattensis*, *Banksia spinulosa*, *Hakea laevipes*, *Callistemon pinifolius*, *Daviesia squarrosa*, *Micromyrtus minutiflora,* forbs and sedges.

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: A few nonflowering plants noted.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 28/10/2018 **COLLECTING No.**

LOCALITY: -33.642716 150.690815 West trail, Agnes Banks Nature Reserve

HABITAT: Open heathy patch in +/- transition vegetation between

PCT 958 Narrow-leaved Apple - Hard-leaved Scribbly Gum heathy woodland on sand at Agnes Banks, Sydney Basin Bioregion

PCT 1067 Parramatta Red Gum woodland on moist alluvium of the Cumberland Plain, Sydney Basin Bioregion

PCT 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: A few nonflowering plants noted.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 1/11/2018 **COLLECTING No.**

LOCALITY: In bushland – In the vicinity of the track. Entrance south of and near the intersection of Spence and Judd Roads, to the west of Government Road Berkshire Park

-33.687696 150.778284 -33.687557 150.778307 -33.687313 150.777579 -33.687223 150.777563

HABITAT: Open heathy patch in +/- transition vegetation between

Mapped as PCT 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion

Associated species: *Eucalyptus sclerophylla*, *E. parramattensis*, *Angophora bakeri*, *Hakea laevipes*, *Leptospermum trinervium*, *Banksia oblongifolia*, *B. spinulosa*, *Melaleuca nodosa*, *M. thymifolia*, *Grevillea mucronulata*, *Acacia lunata*, *Kunzea capitata*, *Pimelea linifolia*, Cryptandra sp., *Dianella revoluta*, *Patersonia sericea*, *Xanthorrhoea minor*?, *Cyathochaeta diandra*, *Lomandra multiflora*, etc.

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: 10 plants noted at one locale and 7 elsewhere. Mostly nonflowering with petal dehiscence by 9.16 (temp 32) and completed by 9.30 am.

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 29/10/2018 **COLLECTING No.**

LOCALITY: -33.733452 150.794676 East of Wianamatta Regional Park, in powerline easement. South of the Corner of Forrester and Palmyra Roads under powerlines

HABITAT: Derived shrubland/grassland /herbland – unmapped significant vegetation with many threatened species adjoining open forest. Mapped as PCT 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion.

Associated species: *Leptospermum parvifolium*, *Melaleuca nodosa*, *Grevillea mucronulata*, *Pimelea linifolia*, *Micromyrtus minutiflora*, *Dillwynia tenuifolia*, *Pultenaea parviflora*, *Hibbertia pedunculata*, *H. diffusa*, *Brachyloma daphnoides*, *Dodonaea falcata*, *Dianella revoluta*, *Lomandra multiflora*, etc.

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: 10 plants noted at one locale. Mostly nonflowering with petal dehiscence already commenced 10.15 am

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller & Jan Miller

DATE: 31/10/2018 **COLLECTING No.**

LOCALITY: -33.733543 150.794597 and -33.733417 150.794474 East of Wianamatta Regional Park, in powerline easement. South of the Corner of Forrester and Palmyra Roads under powerlines

HABITAT: Derived shrubland/grassland/herbland – unmapped significant vegetation with many threatened species adjoining open forest Mapped as PCT 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion

Associated species: *Allocasuarina littoralis, Melaleuca decora, Leptospermum parvifolium*, *Melaleuca nodosa*, *Grevillea mucronulata*, *Pimelea linifolia*, *Micromyrtus minutiflora*, *Dillwynia tenuifolia*, *Pultenaea parviflora*, *Hibbertia pedunculata*, *H. diffusa*, *Brachyloma daphnoides*, *Dodonaea falcata*, *Lissanthe strigosa*, *Acacia elongata*, *A. ulicifolia*, *Astroloma humifusum*, *Patersonia sericea*, *Phyllanthus hirtellus*, *Gompholobium* sp., *Pomax umbellata*, *Dianella revoluta*, *Lomandra multiflora*, *Lepidosperma laterale*, etc.

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: 15+ plants noted in two patches. These are additional patches from the one patch observed on the 29/10/18 brief inspection. Mostly nonflowering with petal dehiscence near complete 12.38

CUMBERLAND FLORA & FAUNA INTERPRETIVE SERVICES

FAMILY: Dilleniaceae

GENUS: *Hibbertia*

SPECIES: *puberula*

DET.: Robert T. Miller

COLLECTOR(s): Robert T. Miller, Jan Miller & Steve Douglas

DATE: 9/11/2018 **COLLECTING No.**

LOCALITY: TreeServe property: Lot 3 DP 812284, 90 Clifton Avenue Kemps Creek

HABITAT: Derived shrubland/grassland at verge of extensive fill mound growing on disturbed soil with laterite nodules often intertwined with *Dillwynia tenuifolia*.

Remnant trees observed in the general vicinity include *Eucalyptus sclerophylla*, *E. fibrosa*,

E. eugenioides, *E. longifolia* and *E. tereticornis.*

Large shrubs: *Allocasuarina littoralis, Melaleuca decora, Melaleuca nodosa*.

Three additional threatened species were noted: *Dillwynia tenuifolia* (common), *Pultenaea parviflora* and *Persoonia nutans* (1 plant).

HABIT: small sprawling subshrub with occasional +/- semierect wiry branches arising from a rootstock.

NOTES: 20+ plants noted. Mostly +/- finished flowering with petal dehiscence near complete at 11 AM.

Two additional plants observed trough the fence within the adjacent property to the south.

Appendix 3. *Hibbertia puberula* subs. *puberula* collection records 2007

Field notes compiled by Miller and Miller & Gibson

Site: Lucas Heights Site 1 16/10/07

Abundance: extremely localised, rare < 12 plants noted.

Field notes: Lucas Heights Soil Landscape, Gentle plateau slope, skeletal soil above first sandstone outcropping +/- intermittent seepage zone. Vegetation sparse and stunted probably from the impact of drought and fire episode > 2 years. All *Hibbertia* appeared to be seedlings at this locale. Open Woodland / heath – Canopy: *Eucalyptus haemastoma*? and Stringybark species. Associated understorey: *Banksia ericifolia, B. oblongifolia, Leptospermum arachnoides, Grevillea sericea, Xanthorrhoea* sp., *Cyathochaeta diandra, Burchardia umbellata, Hypoxis hygrometrica*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 1 Ridgetop Laterite

Field notes: Very disturbed site (past trailbike/FWD and possible laterite extraction but now protected and regenerating. Open Woodland/Laterite Heath: *Eucalyptus punctata.* Associated understorey species: *Exocarpos cupressiformis, Goodenia hederacea, Pomax umbellata, Brachyloma daphnoides, Patersonia sericea, Gompholobium minus, Leptospermum parvifolium, Kunzea ambigua, Persoonia laurina, Micrantheum ericoides.*

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 2 Easterly Plateau slope above Georges River

Abundance: Very localised but locally common c. 20 plants noted.

Field notes: Soil: fine sand with clay component, undisturbed habitat, walking track only. Habit: compact wiry shrub 30-60cm wide with many lax stems arising from a rootstock. In Open Woodland. *Eucalyptus sclerophylla? E. punctata, Angophora bakeri*. Associated understorey: *Melaleuca nodosa, Lambertia formosa, Leptospermum trinervium, Callistemon linearis, Kunzea ambigua, Kunzea capitata, Coronidium oxylepis, Xanthorrhoea sp., Stipa pubescens, Themeda australis*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 3 Upperslope/headwaters of upper drainage line.

Field notes: Undisturbed. *Eucalyptus punctata, E. sclerophylla*? and *Angophora bakeri*. Associated understorey: *Kunzea ambigua, Melaleuca nodosa, Gompholobium minus, Isopogon anemonifolius, Leucopogon, Kunzea capitata, Xanthorrhoea* sp. Dominated by *Kunzea* and *Melaleuca nodosa*.

Site: Simmos Beach Recreation Reserve Macquarie Fields, Habitat 4 Laterite Ridgetop.

Field notes: *Angophora bakeri. Leptospermum parvifolium* (dominates), *Kunzea ambigua, Petrophile sessilis, Micrantheum ericoides, Kunzea capitata, Lambertia formosa, Pimelea linifolia, Stipa pubescens*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 1: Lateritic Heath

Field notes: *Eucalyptus* sp. (Stringybark), *E. squamosa, Allocasuarina littoralis, Angophora hispida*. Associated understorey*: Leptospermum trinervium* (narrow-leaved form), *Petrophile sessilis, Persoonia lanceolata, Isopogon anemonifolius, Hakea laevipes, H. sericea, Grevillea diffusa, Actinotus minor, Cyathochaeta diandra, Entolasia stricta, Caustis flexuous*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 2: Lateritic Heath

Field notes: Soil very fine sandy loam. Habit: low +/- prostrate shrub sprawling through sedges. *Angophora hispida, Corymbia gummifera, Allocasuarina littoralis*. Associated understorey: *Leptospermum trinervium* (narrow-leaved form), *Petrophile sessilis, Persoonia lanceolata, Pultenaea elliptica, Isopogon anemonifolius, Banksia spinulosa, Grevillea diffusa, Actinotus minor, Cyathochaeta diandra, Entolasia stricta*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 3

Field notes: Soil sandy loam with small sandstone outcroppings. Open Forest *Eucalyptus punctata*, E. sp. (Stringybark), and *Corymbia gummifera.* Associated understorey: *Hakea laevipes, Leptospermum parvifolium, Isopogon anemonifolius, Lissanthe strigosa, Grevillea diffusa, Hakea sericea, Acacia linifolia, Themeda australis, Lomandra obliqua, Lomandra cylindrica, Cyathochaeta diandra*.

Site: Keith Longhurst Reserve (formerly The Basin Reserve) Georges River Road Kentlyn Habitat 4

Field notes: Soil: fine sandy loam scattered lateritic fragments. Open Forest with grassy and herbaceous understorey comprised of *Eucalyptus punctata*, E. sp. (Stringybark), and *Corymbia gummifera.* Associated understorey: *Leptospermum parvifolium, Isopogon anemonifolius, Lissanthe strigosa, Grevillea diffusa, Goodenia hederacea, Stipa pubescens, Themeda australis, Entolasia stricta, Hypoxis hygrometrica, Hovea linearis, Cryptandra* sp., *Lobelia dentata, Patersonia sericea, Cyathochaeta diandra* and *Xanthorrhoea* sp.

Site: Peter Meadows Reserve Old Kent Road Kentlyn

Field notes: Soil: sandy, lateritic. Lateritic Ridgetop Heath *Eucalyptus sclerophylla, E. squamosa, Angophora hispida* heath. Lateritic Ridgetop Heath /Woodland interface: *Eucalyptus sclerophylla, E. punctata, Angophora hispida*. Associated understorey species: *Petrophile sessilis, Lambertia formosa, Kunzea capitata, Leptospermum arachnoides, Brachyloma daphnoides, Hakea laevipes, Xanthorrhoea sp., Actinotus minor, Pultenaea elliptica, Hakea sericea, Gompholobium minus, Goodenia hederacea* and *Entolasia stricta*.

Site: Freres Crossing Reserve, Freres Road Kentlyn 2/11/07, Ridgetop slopes

Field notes: *Eucalyptus punctata, Syncarpia glomulifera* Associated understorey: *Hakea laevipes, Persoonia linearis, Leptospermum trinervium, Isopogon anemonifolius, Gompholobium minus,* *Acacia terminalis, Gonocarpus tetragynus, Brachyloma daphnoides, Eriostemon australis, Grevillea diffusa, Hibbertia diffusa, Hypoxis hygrometrica, Xanthorrhoea* sp.*, Themeda australis, Lomandra obliqua, Entolasia stricta.*

Site: Freres Crossing Reserve, Freres Road Kentlyn 2/11/07, Ridgetop

Field notes: *Eucalyptus punctata, Angophora costata*, Stringybark sp. Associated understorey*: Allocasuarina littoralis, Kunzea ambigua, Acacia terminalis, Brachyloma daphnoides, Hypoxis hygrometrica, Themeda australis* and *Stipa pubescens*.

Site: Ella Avenue Barden Ridge (formerly Lucas Heights) 20/11/07 Below Detention Basin

Field notes: Localised in drainage line. Site impacted by housing development – weed invasion occurring due to urban runoff and sedimentation. *Eucalyptus punctata*, E. sp. (Stringybark), *E. haemastoma, Corymbia gummifera, Angophora hispida*. Associated understorey: *Hakea sericea, Banksia oblongifolia, Leptospermum polygalifolia, L. arachnoides, Lambertia formosa, Kunzea ambigua, Grevillea sericea, Epacris pulchella, Banksia spinulosus, B. marginata, Isopogon anemonifolius, Hakea laevipes, Phyllota phylicoides, Actinotus minor, Patersonia sericea, Xanthorrhoea resinosa, Stipa pubescens, Xanthosia tridentata, Lomandra obliqua, Cyathochaeta diandra, Lepyrodia scariosa, Schoenus brevifolius, Lindsaea linearis*.

Site: Ella Avenue Barden Ridge (formerly Lucas Heights) 20/11/07 Downslope of Detention Basin

Field notes: Scattered through sedges - relatively rare at edge of wet heath/swamp. *Eucalyptus haemastoma*, E. sp. (stringybark), *E. punctata*. Associated understorey: Sedges dominate understorey: *Leptocarpus tenax, Schoenus brevifolius, Xanthorrhoea resinosa, Leptospermum polygalifolia, Banksia oblongifolia, Actinotus minor, Dampiera stricta, Epacris pulchella, Entolasia stricta, Deyeuxia decipiens.*

Site: Little Forest Lucas Heights 20/11/07

Field notes: Soil: fine sandy loam with clay content, +/- impeded drainage, Lucas Heights Soil Landscape, Localised in narrow zone in upper drainage line. *Eucalyptus oblonga, E. haemastoma, Corymbia gummifera, Angophora hispida.* Associated understorey: *Callistemon citrinus, Banksia oblongifolia, Leptospermum polygalifolia, L. arachnoides, Lambertia formosa, Kunzea ambigua, Grevillea diffusa, G. sericea, Melaleuca thymifolia, Callistemon linearis, Hakea sericea, H. teretifolia, Acacia linifolia, Mirbelia rubiifolia, Actinotus minor, Patersonia sericea, Xanthorrhoea resinosa, Stipa pubescens, Xanthosia tridentata, Lomandra obliqua, Cyathochaeta diandra, Schoenus brevifolius*.

Site: Voyager Point Adjacent Old Single Mens Quarters

Field notes: Soil: Fine sand atop of lateritic gravels – Surface layer -Well drained, Aspect: easterly Slope: 0-2. Open Woodland: *Eucalyptus sclerophylla, E. parramattensis, Angophora bakeri*. Understorey diverse open to moderately dense with well-developed ground layer. Dominant Associated Shrub Species: *Melaleuca nodosa, Petrophile sessilis, Leptospermum parvifolium, L.*

trinervium, Banksia spinulosa, Hakea laevipes, Kunzea ambigua, Persoonia lanceolata, Callistemon linearis, Hakea sericea, Acacia brownii, Daviesia acicularis. Dominant Associated Ground Layer Species: *Platysace ericoides, Hovea linearis, Lomandra obliqua, Lepyrodia scariosa, Austrostipa pubescens, Austrodanthonia tenuior, Cyathochaeta diandra*.

Site: Voyager Point adjacent Sirius Drive

Field notes: Soil: Fine sand and laterite – Surface layer -Well drained. Aspect northerly slope 0-2. Open Woodland: *Eucalyptus sclerophylla, Angophora bakeri* and *Eucalyptus oblonga*. Understorey diverse, open to moderately dense with well-developed ground layer. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, Banksia spinulosa, Babingtonia densiflora, Brachyloma daphnoides, Kunzea ambigua, Persoonia levis, Grevillea sericea, Hakea sericea, Isopogon anemonifolius, Melaleuca nodosa, Lambertia formosa, Philotheca scaber, Styphelia laeta.* Dominant Associated Ground Layer Species: *Platysace ericoides, Dianella revoluta, Lomandra obliqua, Lepyrodia scariosa, Austrostipa pubescens, Cyathochaeta diandra*.

Site: Yeramba Lagoon 2/1/07 Ridge slopes 1

Field notes: Shelving sandstone terraces. Soil: Sandy loam. Surface layer: Well drained but drainage impeded by sandstone bedrock. Aspect: westerly slope: 5. Open Woodland: *Eucalyptus racemosa, Corymbia gummifera, Eucalyptus oblonga & Angophora bakeri.* Understorey diverse, open grassy site. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum polygalifolium, Banksia oblongifolia, B. spinulosa, B. marginata, Kunzea ambigua, Persoonia levis, Grevillea sericea, Hakea sericea, Grevillea sericea, Hakea laevipes, Leptospermum arachnoides, Epacris microphylla, Hibbertia stricta.* Dominant Associated Ground Layer Species: *Actinotus minor, Schoenus moorei, Austrostipa pubescens, Themeda australis, Entolasia stricta, Lomandra multiflora.*

Site: Yeramba Lagoon 2/1/07 Ridge slopes 2

Field notes: Ridge slopes – shelving sandstone terraces. Soil: Sandy loam. Surface layer: Well drained. Aspect: northwest. Slope: 5. Interface between Woodland*: Eucalyptus oblonga, Corymbia gummifera, Eucalyptus punctata* Open Woodland: *Eucalyptus racemosa, Corymbia gummifera, Eucalyptus oblonga & Angophora bakeri.* Understorey diverse and well developed moderately dense. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, B. marginata, Hibbertia stricta*, *Leucopogon microphyllus, Lambertia formosa, Callistemon linearis, Melaleuca thymifolia, Gompholobium grandiflora, Epacris microphylla, Lasiopetalum ferrugineum.*

Dominant Associated Ground Layer Species: *Themeda australis, Entolasia stricta, Burchardia umbellata*, *Actinotus minor, Lomandra obliqua, Schoenus moorei, Austrostipa pubescens*.

Site: Blackwall 2/1/07 Ridgetop / Plateau

Field notes: Soil: relatively deep sand. Aspect: Northerly Slope: < 2. Open Woodland: *Corymbia gummifera, Eucalyptus racemosa, E. punctata, and E. oblonga.* Understorey diverse. Dominant Associated Shrub Species: *Brachyloma daphnoides, Banksia spinulosa, Petrophile sessilis, Leptospermum trinervium, L. parvifolium, Isopogon anemonifolius, Babingtonia densifolia, Dillwynia* *retorta, Philotheca scabra, Grevillea sericea, Gompholobium glabratum, Xanthorrhoea media, Kunzea ambigua, Bossiaea heterophylla, Acacia myrtifolia.* Dominant Associated Ground Layer Species: *Phyllanthus hirtellus, Pomax umbellata, Austrostipa pubescens, Themeda australis* and *Cyathochaeta diandra.*

Site: Mickeys Point 2/1/07 Ridgetop / Plateau

Field notes: Soil: lateritic. Aspect: North east Slope: < 2. Open Woodland / Heath: *Eucalyptus racemosa, Angophora hispida,* and *Allocasuarina littoralis.* Understorey diverse. Dominant Associated Shrub Species: *Petrophile sessilis, Leptospermum trinervium, Hakea sericea, Persoonia levis, Kunzea ambigua, Styphelia triflora, Isopogon anemonifolius, Brachyloma daphnoides, Babingtonia densifolia, Hemigenia purpurea, Hibbertia stricta*. Dominant Associated Ground Layer Species: *Actinotus minor, Baeckea ramosissima, Poranthera ericoides, Lomandra obliqua, Austrostipa pubescens, Entolasia stricta.*

Appendix 4. *Hibbertia puberula* identification characters

All microscopic photos by Miller 2018.

Photo 120: *Hibbertia puberula* subsp. *puberula* Canoelands.

Photo shows that the hairs are “worn off” on the older growth.

Photo 121: *Hibbertia puberula* subsp. *puberula* Canoelands

Photo shows tomentum characteristics of new shoots, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface.

Photo 122: *Hibbertia puberula* subsp. *puberula* from Lucas Heights.

Photo 123: *Hibbertia puberula* subsp. *puberula* (Lucas Heights)

Photo shows leaf and stem tomentum, revolute margins and bulging broader central vein obscuring the leaf undersurface of new shoot.

Photo 124: *Hibbertia puberula* subsp. *puberula,* Smith's Creek Reserve 4th June 2018.

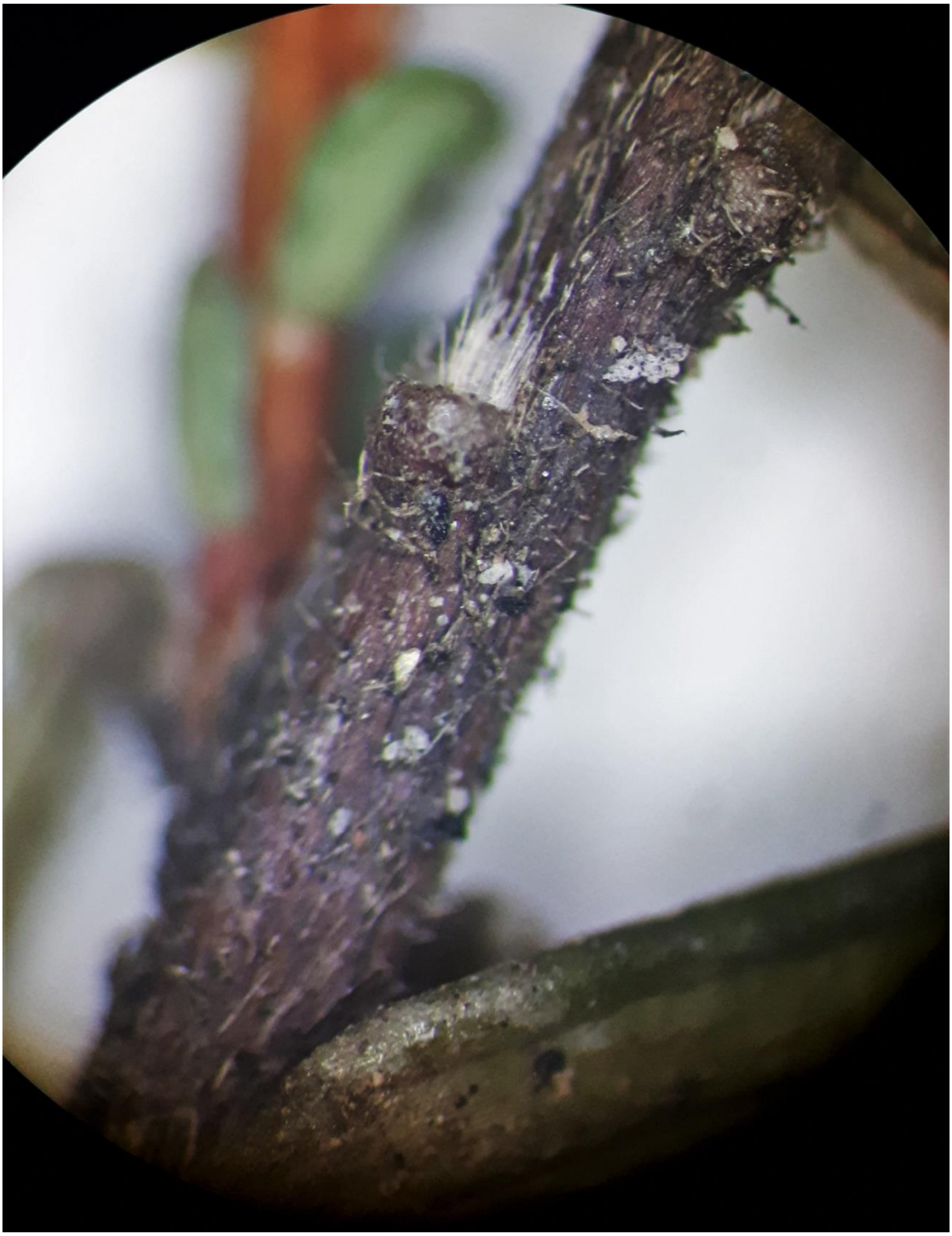


Photo 125: *Hibbertia puberula* subsp. *puberula,* Smith's Creek Reserve 4th June 2018.

Photo 126: *Hibbertia puberula* subsp. *extensa* flower morphology noting four stamens in this specimen.

Photo 127 *Hibbertia puberula* subsp. *extensa* calyces and leaf characteristics 30/11/2018

Photo 128: *Hibbertia puberula* subsp. *extensa* juvenile shoot.

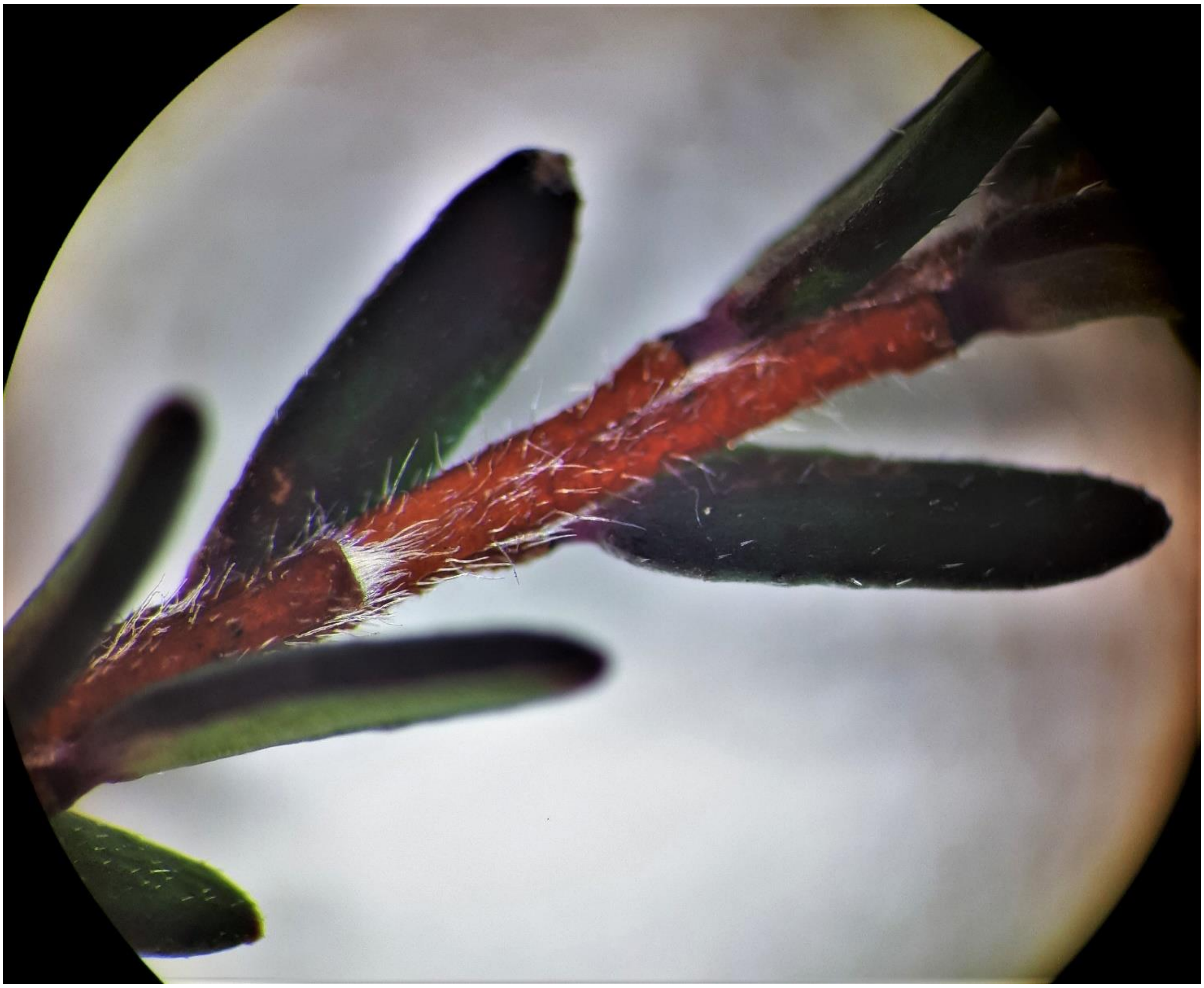


Photo 129: *Hibbertia puberula* subsp. *extensa* juvenile shoot showing tomentum characteristics.

Photo 130: *Hibbertia puberula* subsp. *extensa*

Photo shows typical lateral branching habit and tomentum characteristics of calyxes, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface.

Photo 131: *Hibbertia puberula* subsp. *extensa*

Photo shows tomentum characteristics of stem, revolute leaf margins and bulging broader central vein that obscures the leaf undersurface noting that tomentum has “worn off”.

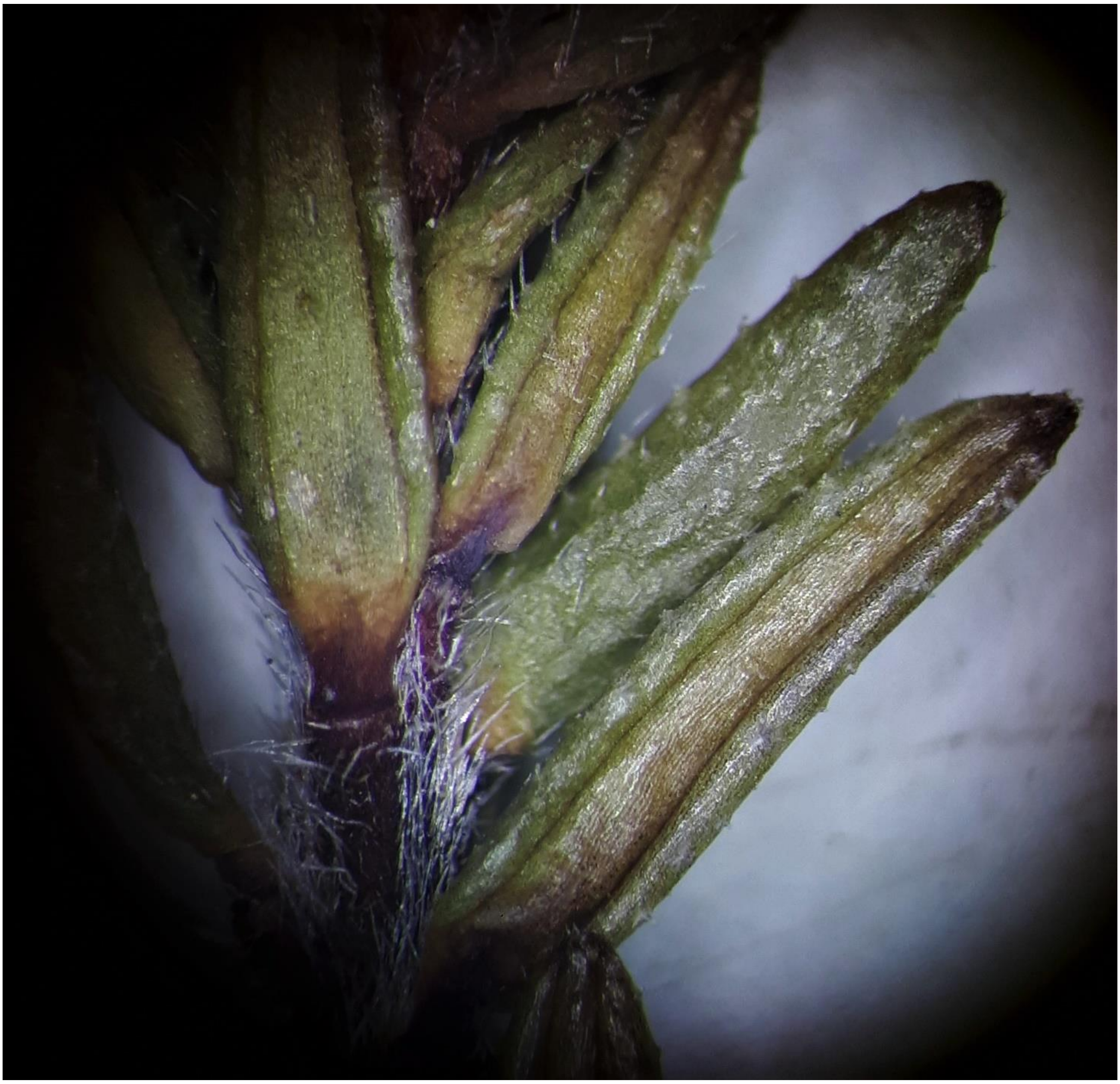


Photo 132: *Hibbertia puberula* subsp. *extensa.*

Photo shows tomentum characteristics of an upper portion of the branchlet, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Note that much of the tomentum has not “worn off”.

Photo 133: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing tomentum characteristics, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 134: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing interpetiolar tuffs, glabrescent tomentum characteristics, revolute margins and recessed to bulging broader central vein that obscures the leaf undersurface. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 135: *Hibbertia puberula* subsp. *glabrescens.*

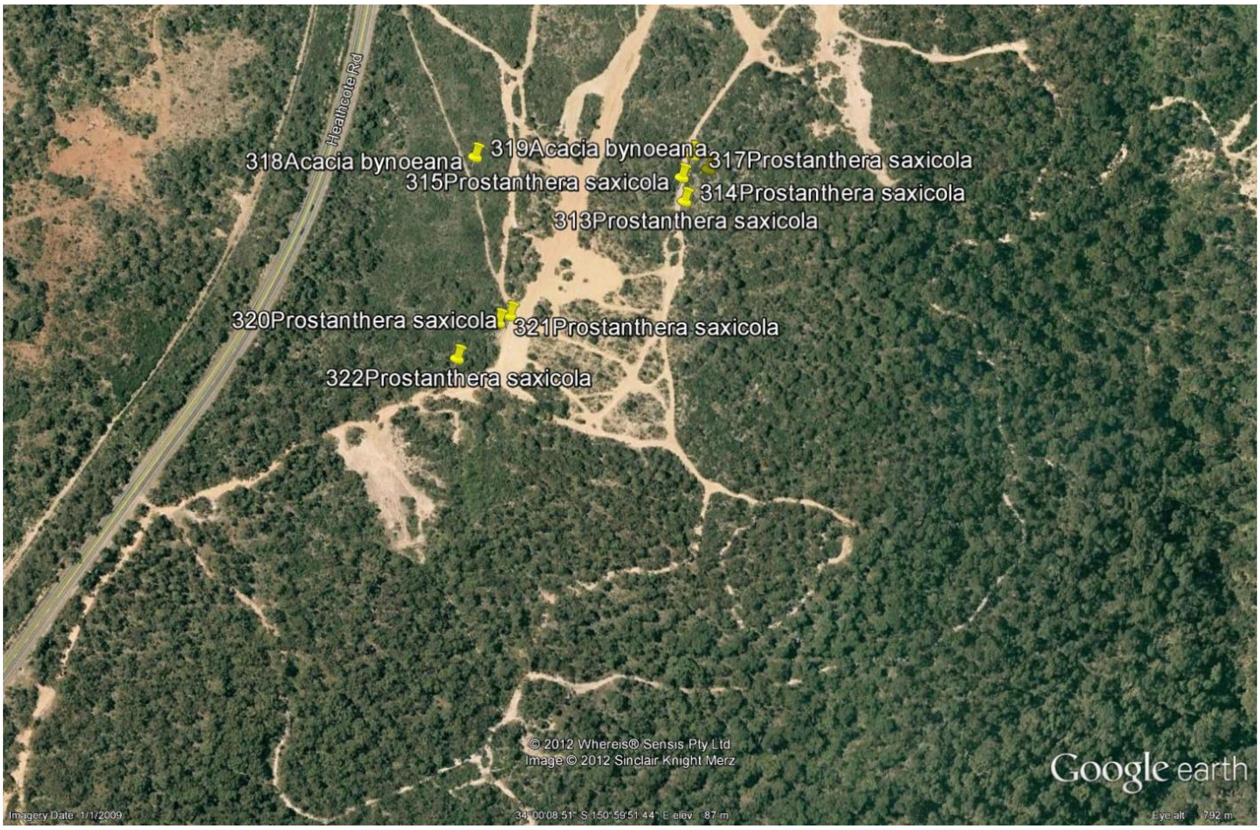
Photo showing interpetiolar tuffs of hair and scattered simple hairs on upper shoot. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Photo 136: *Hibbertia puberula* subsp. *glabrescens.*

Photo showing glabrescent calyces. Specimen collected by C.P Gibson and R.T. Miller 02/01/2007.

Appendix 5. Indicative distribution of *Hibbertia puberula* at Menai.

The following Google Earth images show the indicative distribution of threatened taxa east of Heathcote Road within a Menai proposed development footprint, recorded on two brief CFFIS site inspections.


Heathcote Rd
318Acacia bynoeana
319Acacia bynoeana
317Prostanthera saxicola
315Prostanthera saxicola
314Prostanthera saxicola
313Prostanthera saxicola
320Prostanthera saxicola
321Prostanthera saxicola
322Prostanthera saxicola
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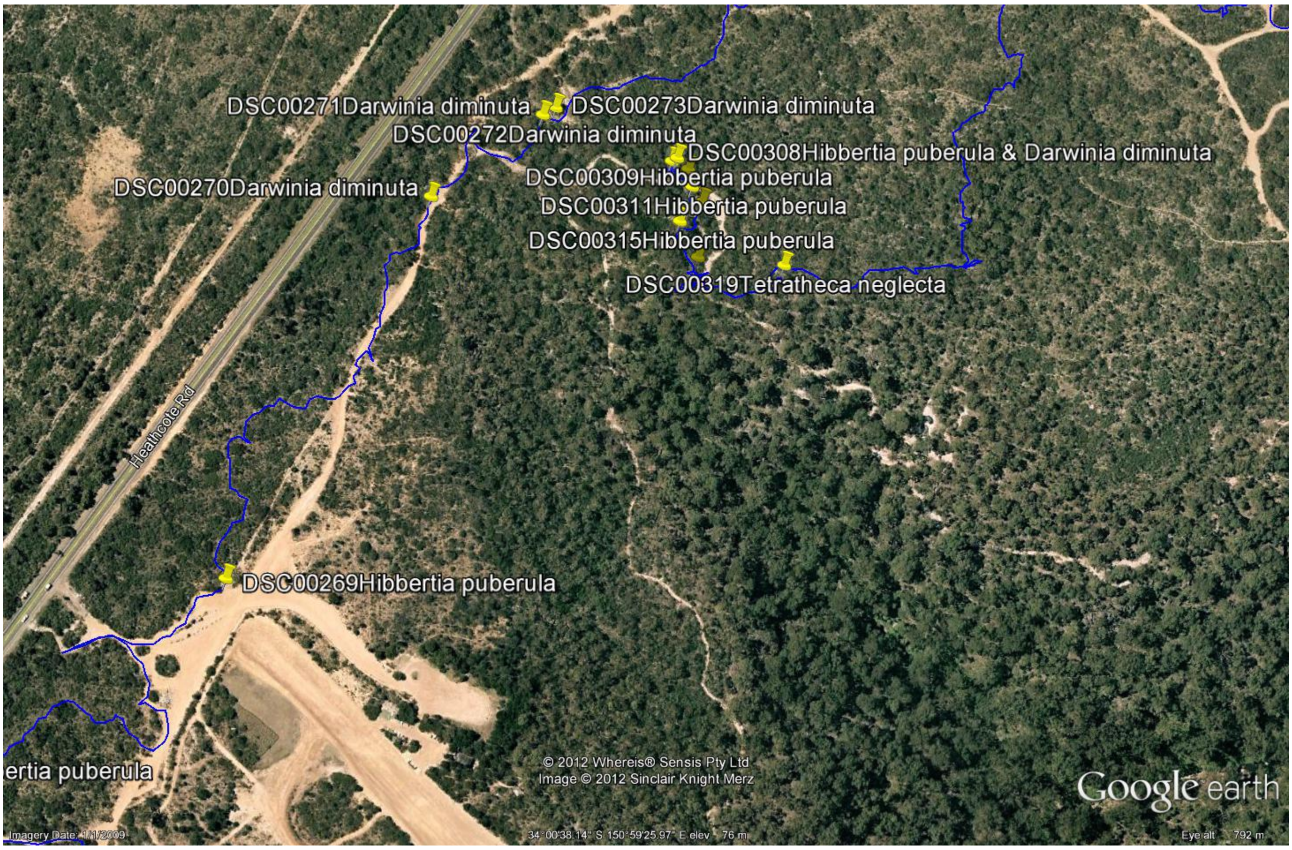
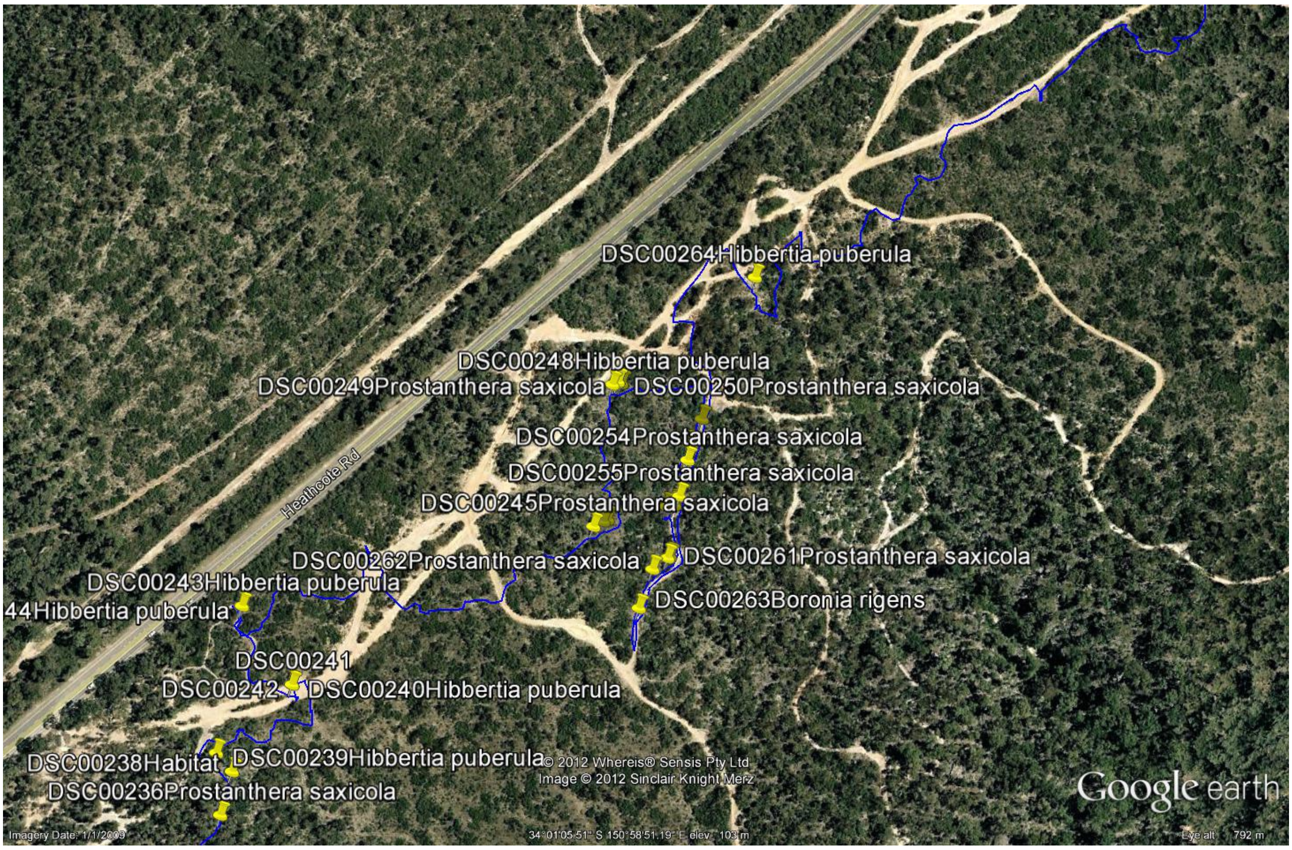
Google earth


311Acacia bynoeana
312Acacia bynoeana
308Hibbertia puberula
310Hibbertia puberula
DSC00321Hibbertia puberula
Survey
DSC00277habitat
DSC00278habitat
DSC00275habitat
DSC00320Acacia bynoeana
DSC00274habitat
DSC00273Darwinia diminuta
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth


DSC00271Darwinia diminuta
DSC00273Darwinia diminuta
DSC00272Darwinia diminuta
DSC00308Hibbertia puberula & Darwinia diminuta
DSC00270Darwinia diminuta
DSC00309Hibbertia puberula
DSC00311Hibbertia puberula
DSC00315Hibbertia puberula
DSC00319Tetratheca neglecta
Heathcote Rd
DSC00269Hibbertia puberula
ertia puberula
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth


DSC00268Hibbertia puberula
DSC00267Hibbertia puberula
DSC00265Hibbertia puberula
DSC00266Hibbertia puberula
© 2012 Whereis® Sensis Pty Ltd
Image © 2012 Sinclair Knight Merz
Google earth
Imagery Date 1/1/2009


DSC00264Hibbertia puberula
DSC00248Hibbertia puberula
DSC00249Prostanthera saxicola
DSC00250Prostanthera saxicola
DSC00254Prostanthera saxicola
DSC00255Prostanthera saxicola
DSC00245Prostanthera saxicola
Heathcote Rd
DSC00262Prostanthera saxicola
DSC00261Prostanthera saxicola
DSC00243Hibbertia puberula
44Hibbertia puberula
DSC00263Boronia rigens
DSC00241
DSC00242
DSC00240Hibbertia puberula
DSC00238Habitat
DSC00239Hibbertia puberula
DSC00236Prostanthera saxicola
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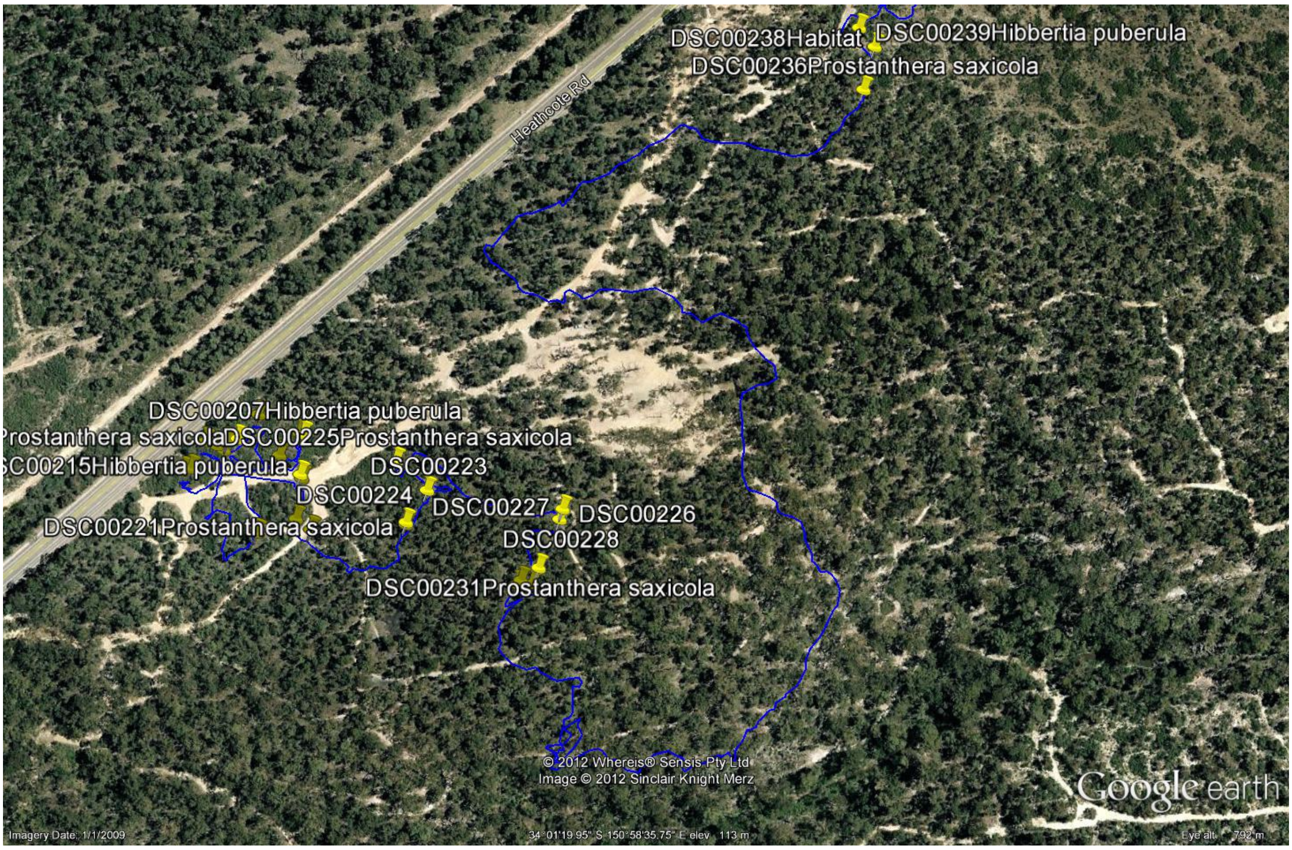
DSC00238Habitat
DSC00239Hibbertia puberula
DSC00236Prostanthera saxicola
Heathcote Rd
DSC00207Hibbertia puberula
rostanthera saxicola
DSC00225Prostanthera saxicola
C00215Hibbertia puberula
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DSC00224
DSC00227
DSC00226
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Image © 2012 Sinclair Knight Merz
Google earth

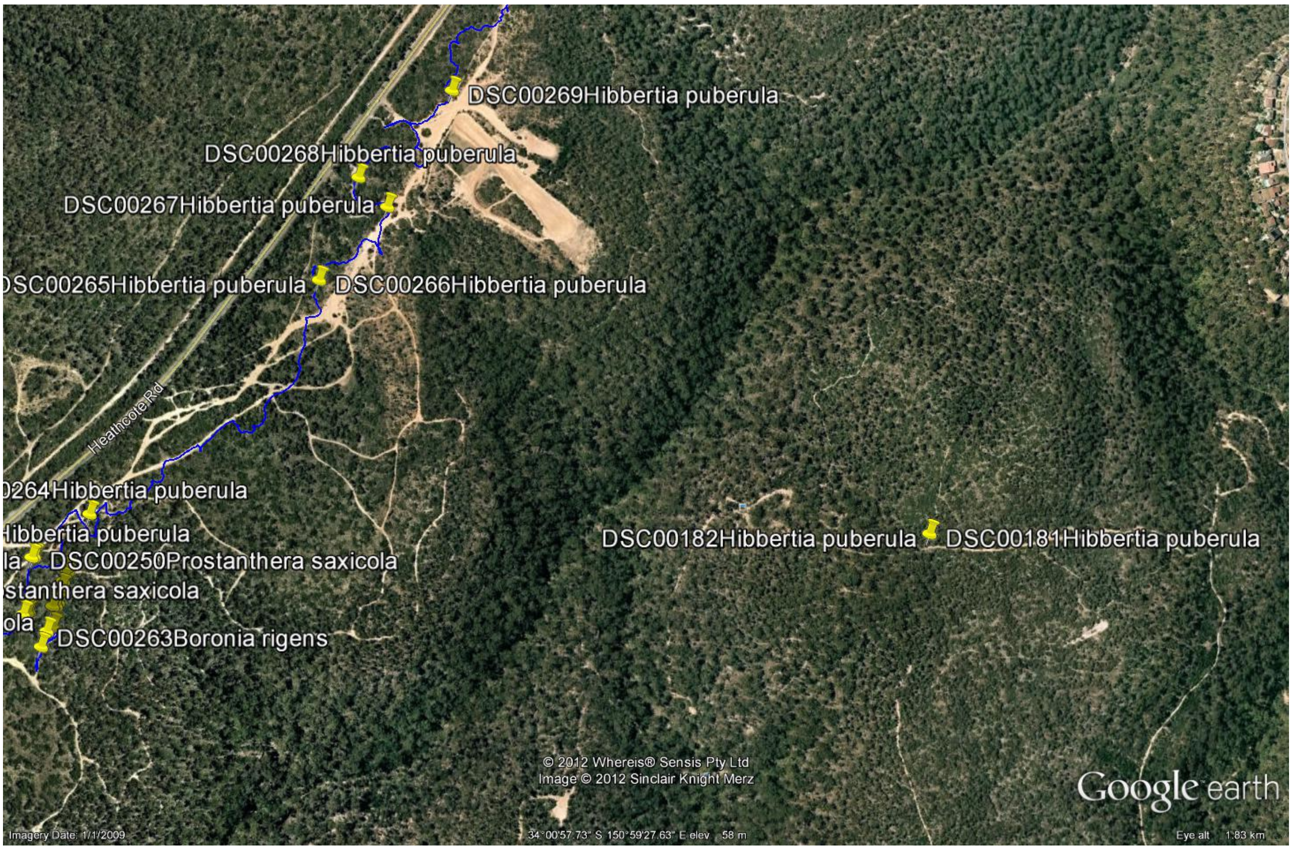
DSC00269Hibbertia puberula
DSC00268Hibbertia puberula
DSC00267Hibbertia puberula
DSC00265Hibbertia puberula
DSC00266Hibbertia puberula
Heathcote Rd
264Hibbertia puberula
Hibbertia puberula
DSC00250Prostanthera saxicola
stanthera saxicola
DSC00263Boronia rigens
DSC00182Hibbertia puberula
DSC00181Hibbertia puberula
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Image © 2012 Sinclair Knight Merz
Google earth

Appendix 6: *Hibbertia pedunculata* cited specimens Toelken 2013

The following table is derived from Toelken (2013) and contains the cited specimens of *Hibbertia pedunculata* examined from Metropolitan Sydney, outlining their current status according to Miller.

Collection Details	Extant	Presumed Extinct at locale	Unknown imprecise locale suitable extant habitat in the area.
J.H.Maiden NSW243240, St Marys Station, South Creek, 24.ix.1887 (NSW);			Yes?
J.L.Boorman NSW85891, St Marys, ix.1920 (NSW);			Yes
W.Woolls MEL35562 & 35565, Parramatta, – (MEL).		Presumed Extinct unless in Parramatta Park	
O.D.Evans NSW85863, Yennora, 13.x.1961 (NSW);		Extinct due redevelopment	
J.J.Fletcher NSW85893/4/5, Cabramatta, 9.xi.1889 (NSW);		Likely to be extinct	
C.P.Gibson & R.T.Miller 26, Shaddock Ave, Villawood (extinct), 26.ix.1990 (AD, NSW);		Extinct	
M.Fuller 304, Chester Hill, x.1927 (CANB);		Likely to be extinct unless the locality refers to Walshaw Park	
C.P.Gibson 61,Walshaw Park, Bass Hill, 12.x.2000 (AD, NSW);	Small population under threat from mismanagement		
C.P.Gibson s.n., Deverall Park at Condell Park, 26.x.2005 (AD, NSW);	Small population under severe threat due in appropriate adjoining development.		
R.T.Miller s.n., Rookwood Cemetery, 16.x.2007 (AD, NSW);	Under threat		

Collection Details	**Extant**	**Presumed Extinct at locale**	**Unknown imprecise locale suitable extant habitat in the area.**
C.P.Gibson 81, Chullora Rail Yards, 9.x.2006 (NSW);	Small population under threat		In part extinct
R.T.Miller & C.P.Gibson 25, Chullora Railway Yards, Muston site 3, 24.x.1990 (NSW);		Likely to be extinct due to development	
A.A.Hamilton NSW85888, Duck River, Clyde, 9.1914 (NSW);	Population under severe threat		
N.King NSW243235, Homebush, 1.ix.1891 (NSW);			Unknown possibly extinct
J.H.Maiden NSW243239, Homebush, x.1893 (NSW);			Unknown possibly extinct
C.P.Gibson & R.T.Miller 24, Smith Park, East Hills, xi.1988 (NSW);	Small population under threat		
R.H.Cambage 828, Peakhurst, xii.1902 (NSW);		No suitable habitat remains	
J.H.Camfield NSW85889, near Kogarah, x.1893 (NSW);		No suitable habitat remains	
J.H.Camfield NSW85892, Bexley, x.1893 (NSW);		No suitable habitat remains	
S.King MEL1009762, near Blue Mountains, 1893 (MEL);			Unknown

Expert report – Little Eagle and Square-tailed Kite

Strategic Assessment for the Little Eagle *Hieraaetus morphnoides* in the Greater Macarthur Growth Area and the Wilton Growth Area, Tony Saunders and Stephen Debus, August 2018

Strategic Assessment for the Square-tailed Kite *Lophoictinia isura* in the Greater Macarthur Growth Area and the Wilton Growth Area, Tony Saunders and Stephen Debus, August 2018

Appendix 1: Habitat descriptions of each site in Greater Macarthur and Wilton Growth Areas

Review of updates to the development footprints of the Greater Macarthur and Wilton urban growth areas in relation to strategic assessments on the Little Eagle and the Square-tailed Kite

Strategic Assessment

for the

Little Eagle *Hieraaetus morphnoides*

in the

Greater Macarthur Growth Area

and the

Wilton Growth Area

Report prepared for the Department of Environment and Planning

Prepared by Tony Saunders and Stephen Debus
Merops Services Pty Ltd

Prepared August 2018

Contents

Figures

Tables

Appendices

Strategic Assessment for the Little Eagle *Hieraaetus morphnoides* in the Growth Areas of Greater Macarthur and Wilton

1. Introduction

Purpose

The purpose of this report is to assess the likelihood of occurrence and potential impacts of the urban growth in the Greater Macarthur and Wilton areas on the Little Eagle *Hieraaetus morphnoides*. In particular, this report will assess the presence of breeding and foraging habitat within these growth areas as required under the Biodiversity Assessment Method. It will also discuss conservation measures required to mitigate potential impacts.

The Little Eagle is listed in New South Wales as vulnerable under the *Biodiversity Conservation Conservation Act* 2016 and is an uncommon species found in open forests and woodlands. It shows a preference for areas containing a mosaic of open woodland and open grasslands with scattered trees, but can also be found along timbered watercourses and the edges of forest remnants. Records for this species exist in and around the area to be impacted by the urban development. However, the species is encountered infrequently in this area and its interactions with local habitat have not been well studied.

The existence of potential habitat for the Little Eagle and of records for the species within the area has meant that a more detailed assessment of the likelihood of impacts from the development in the area is required, particularly of the species' potential for foraging and breeding in the area. Targeted surveys could gather this information, but the survey effort required to collect sufficient data would be great and in the order of hundreds of hours in the appropriate seasons over several years. This would also require tracking of individual birds to gather information on foraging, breeding locations and behaviour at nests etc. Access to several potential habitat areas also proved difficult during the survey period. Knowledge of the habitat structure and plant community types (PCTs) that the Eagle has been recorded in within the growth area and of the ecology of the species can be used as a surrogate for this fieldwork.

Project Context

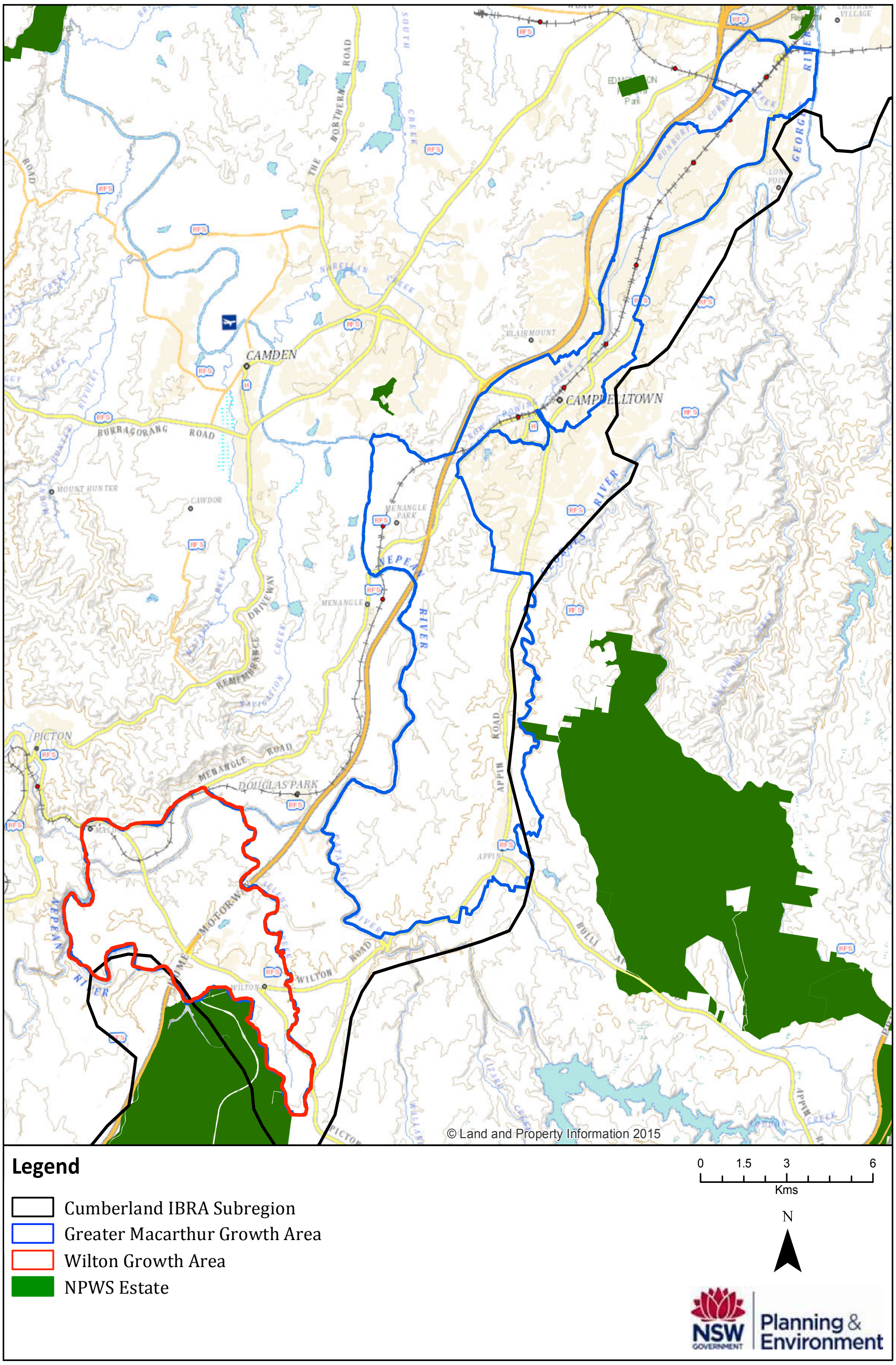
The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

The timeframe for this project, and difficulties in accessing private lands have resulted in some survey challenges for the project. Only 68% of the potential habitat available for this species in the Wilton and Greater Macarthur Growth Areas has been successfully surveyed. Significant areas of the Greater Macarthur Growth Area were unable to be adequately surveyed due to restrictions around land access. Around 900 hectares of potential habitat was not surveyed within this growth area. In particular PCTs 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, 850 Grey Box - Forest Red Gum grassy woodland on shale of the Cumberland Plain, Sydney Basin Bioregion and 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion were unable to be adequately surveyed.

Study Area

The study area is in the Macarthur and Wilton areas, which extend from the southern parts of Liverpool, down to Appin, across to Wilton and then towards the area between Wilton and Picton. The area is within the Cumberland IBRA subregion and the location is shown in Figure 1. The area is bound within a latitude range from -33.88 to -34.33 and a longitude range of 150.55 to 150.97.

Figure 1. Location of Growth Areas and the Cumberland IBRA Subregion.



Survey Methods

Vegetation maps (as supplied by The Department of Planning and Environment NSW) of the Greater-Macarthur Growth Area and the Wilton Growth Area were used to select patches of remnant vegetation that may provide suitable habitat for the Little Eagle. Fifty potential sites were chosen from these maps. Sufficient access was feasible for 40 of these remnants.

The remnants were visited over 4 days from the 18-06-2018 to the 21-06-2018 inclusive. Each site was surveyed for between 0.5 and 1.0 hours. The aim was to collect qualitative data on each of the following:

habitat structure -	tree height range, DBH range, canopy cover, tree maturity, shrub density, grass cover, ground cover
habitat quality -	tree age diversity, shrub layer diversity, presence of woody weeds, evidence of regeneration
connectivity -	degree of connectivity, relative width of corridor to other remnants, presence of gaps in vegetation
aspect and slope -	slope steepness, direction of slope and relationship of site to structural features e.g. watercourses etc.
avian species -	overall diversity, species composition, presence of feral species

The aim was to assess if these sites contained suitable habitat for foraging and breeding and whether they allowed for dispersal of prey and the target species into and out of the remnants. The extent of suitable habitat across the growth areas was then used to estimate the likelihood of the Eagles using the area for foraging and/or breeding.

The Atlas of Living Australia (ALA) and the bird database from the Cumberland Bird Observers Club Inc. (CBOC) were searched for atlas records of the Little Eagle. The records within the Atlas of Living Australia had data mainly from the BioNet Atlas of NSW Wildlife with a few records from un-named individuals contributing directly to the ALA atlas. At the time of access the CBOC bird atlas had over 20,000 survey results for the section of the Cumberland IBRA sub-region that lies within the County of Cumberland. These 2 data sets combined would have captured most of the data on the Eagle for this area.

Justification for Use of an Expert Report

The presence of suitable habitat for foraging and breeding for the Little Eagle combined with the low density for this species and the difficulties with gaining sufficient access for surveys to establish the presence and habitat use by the Eagle in the growth area has meant that survey effort alone has not be able to establish the potential importance of the area for this Eagle.

An expert in the breeding and foraging ecology of the Eagle would be required to assess the importance of the habitat remnants and the likelihood of occurrence within the growth areas. The Eagle is a forest and woodland specialist whose major food in its breeding season is mainly ground foraging mammals, birds and reptiles, although it also takes birds from the tree canopy. Therefore, an expert would also need to also be expert on the avifauna populations occurring in forest and woodland in the Cumberland IBRA Subregion.

The report will address the food resources and foraging space of this raptor as well as the Eagle's potential nest sites and breeding habitat within the growth areas.

Credentials of the Experts Preparing this Report

Dr. Tony Saunders
BSc University of Sydney 1976, PhD University of Western Sydney 2005.

Company Director and Avian Ecologist, Merops Services Pty Ltd 1995 to present.

Relevant experience in surveys and the study of woodland and forest birds of the Cumberland plain:

- Cumberland Plain woodland bird surveys for the NSW Bird Atlas and then for the CBOC Bird Atlas 1982 to the present.
- Cumberland Plain woodland bird surveys on the UWS Hawkesbury Campus 1998 to 2005.
- Woodland bird surveys for Holroyd Council's reserves and parklands 2008 to 2011.
- Survey for threatened woodland birds in proposed urban development of the former ADI site at Penrith 2002.
- Survey for threatened woodland birds in proposed rural subdivision at Badgerys Creek 2006.
- Presented the opening presentation ' Birds of the Cumberland Plain. What was there? What have we lost?' at the ABSA Conference 2016.
- Presented 'Trends in woodland birds of the Cumberland Plain' at the RZS of NSW Conference in 2016.
- Avifauna surveys of sites for development applications and assessment of status of threatened bird species with recommendations for minimising impact of development on these species within the Cumberland Plain and eastern New South Wales. (21 years)
- Bird habitat assessment of managed landscapes and natural habitat areas and recommendations for habitat enhancement and rehabilitation for birds. (21 years)

Relevant publications relating to woodland birds of the Cumberland Plain:

- Saunders, T. (2016). Birds of the Cumberland Plain. What was there? What have we lost? Abstract from 'Birds of the Cumberland Plain: Past distributions, present studies and the outlook for their future' Australian Bird Study Association Conference - 23 January 2016. *Corella* **40**: 46.
- Saunders, T. (in prep.). Trends in woodland bird populations in the Cumberland Plain. *Australain Zoologist.*

Dr. Stephen Debus
Bachelor Arts (Biology/Behavioural. Science), Dip. Natural Resources (Wildlife), MSc. (Zoology), PhD (Zoology)

Adjunct associate lecturer/research associate, Zoology University of New England, Armidale. 2004 to present
Senior Ecologist (casual) Eco Logical Australia 2014 to present

Relevant experience in surveys and the study of the Little Eagle *Hieraaetus morphnoides* and of woodland birds:

- Birds of Prey Monitoring project: nest sites and productivity of threatened raptors on the tablelands – field survey and report (Northern Tablelands Local Land Services 2017-18)
- Regent Honeyeater, Swift Parrot, raptor and woodland bird surveys and reporting (North West Local Land Services 2015-18)
- Co-supervising, and finding all 13 Little Eagle nests and sharing the fieldwork for, a UNE Zoology student Honours project near Armidale in 2017 on the breeding habitat and nest-site characteristics of the Eagle (Candice Larkin, B Zool. Hons thesis duly submitted and awarded)

Relevant publications relating to foraging and breeding biology of the Little Eagle *Hieraaetus morphnoides*:

- Debus, S.J.S. 1993. Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Square-tailed Kite, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.
- Debus, S. 2017. *Australasian Eagles and Eagle-like Birds*. CSIRO Publishing, Melbourne. [The Little Eagle chapter is a 25-year update of the Debus 1993 *HANZAB* Little Eagle account.]
- Debus, S. 2012. *Birds of Prey of Australia: A Field Guide*, 2nd ed. CSIRO Publishing, Melbourne.
- Debus, S.J.S. 1984. Biology of the Little Eagle on the Northern Tablelands of New South Wales. *Emu* 84: 87-92.
- Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007b. Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales. *Australian Field Ornithology* 24: 137-157.
- Debus, S.J.S. & Ley, A.J. 2009. Aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides*. *Australian Field Ornithology* 27: 76-99.
- Olsen, J., Fuentes, E., Judge, D., Rose, A.B. & Debus, S.J.S. 2010. Diets of Wedge-tailed Eagles (*Aquila audax*) and Little Eagles (*Hieraaetus morphnoides*) breeding near Canberra, Australia. *Journal of Raptor Research* 44: 50-61.
- Debus, S.J.S. 2011. Parental time-budgets and breeding behaviour of the Little Eagle *Hieraaetus morphnoides* in northern New South Wales. *Corella* 35: 65-72.
- Debus, S.J.S., Olsen, J., Judge, D. & Butterfield, M. 2013. Numbers of breeding Little Eagles *Hieraaetus morphnoides* near Canberra in relation to atlas counts. *Corella* 37: 30-32.
- Olsen, J., Debus, S.J.S. & Judge, D. 2013. Declining Little Eagles *Hieraaetus morphnoides* and increasing rabbit numbers near Canberra: is secondary poisoning by Pindone the problem? *Corella* 37: 33-35.
- Olsen, J., Debus, S.J.S., Judge, D. & Rose, A.B. 2013. Diets of Wedge-tailed Eagles *Aquila audax* and Little Eagles *Hieraaetus morphnoides* breeding near Canberra, 2008–2009. *Corella* 37: 25-29.

2. Species Information

Species Description

The Little Eagle is a smaller bird than the Wedge-tailed Eagle and about the same size as the Whistling Kite. However, it is more robust than the Whistling Kite with shorter wings and a shorter square-edged tail. It glides and soars on flat wings or slightly raised wings when gaining height. The head is short and broad compared with the Whistling Kite. There is a light morph which is light and dark brown with light rufous underparts. The underwings have a distinctive pale 'M' pattern and the tail is barred (Debus 2012). When observed from underneath they appear to have dark leading and trailing edges to the underwing, compared with the Whistling Kite which only has dark trailing edges to the wing (pers. obs.). The dark morph has a rufous body with slightly darker brown wings, which from the underside appear all dark except for pale inner primaries (Debus 2012).

Life Cycle

Little Eagles will form pairs in breeding territory, but are solitary outside the breeding season (Debus 1993). In New South Wales, nest building or renovation occurs in August, egg laying from August to September, incubation lasts from 37-39 days with hatching from October to December, fledging occurs from December to January and post-fledglings are dependent on adults for 2 or more months after that (Olsen 2014, Olsen et al. 2017, Debus et al. 2007, Debus and Ley 2009, Debus 2011). Banded individuals have been recovered up to 26 years after banding and banding data suggest that birds occupy a home range or wintering range for at least 6-10 years (Debus 2015).

Breeding has been reported during October and November in the Cumberland County from the Royal National Park and Warriewood on the northern beaches of Sydney, but no nests were recorded within the Cumberland Plain (CBOC Atlas accessed 29-06-2018). However, they have bred within the Cumberland Plain at Cobbity in 1978 (Hoskin *et al.* 1991).

Distribution and Abundance

The Little Eagle is endemic to Australia, but is not found in Tasmania (Olsen et al. 1993). The New Guinea form is now a separate species (Debus 2017). The global population is estimated to be a maximum of 80,000 (Debus 2017). It is considered to be resident for at least several consecutive years at nesting sites (Debus et al. 2007, Debus and Ley 2009). It may also be a partial migrant with some movement north in the non-breeding period (Olsen 1995). It is capable of traversing the continent (>2000 km: Debus 2015), and a satellite-tracked breeding male near Canberra wintered in the Top End of the Northern Territory before returning (Dabb 2018).

The Little Eagle is considered moderately common and a partial nomad in New South Wales (Morris et al. 1981). They are found throughout New South Wales, but are more common in the western two-thirds of the state (Cooper et al. 2014). It was rarely noted in lightly timbered country of the Cumberland County prior to the 1950s (Hindwood and McGill 1958) but had become a frequent visitor over the next 30 years (Hoskin 1991). It is often recorded from western Sydney in lightly timbered country away from areas of dense urbanisation (Patrick 2016). It is reported as an uncommon resident of open forest and farmland in the Shoalhaven area and has been reported in the Picton/Wilton area (Chafer *et al.* 1999).

Little Eagles have declined by 14% nationally between the two national bird atlases over an approximately 20-year period (Barrett *et al.* 2003), and declined by 39% in New South Wales over the same period (Barrett *et al.* 2007). The reporting rates in the NSW Bird Atlas declined by 70% since the mid-1980s (Cooper *et al.* 2014).

The CBOC Atlas (accessed 29-06-2018) holds 336 records of the Eagle. Each survey detected mostly a single bird, but sometimes pairs. Four birds, two adults and two fledglings, were recorded in the Royal National Park. Two hundred and seventy nine of the 336 records for the County were recorded from the Cumberland Plain and 35 of those records are from inside the growth areas or within 5 kilometres of the growth area boundaries. The highest reporting rate was 2.2% for the Cumberland Plain for records prior to 1970, but after declining to 0.8% during the 1970s, recovered in the 1990s and the Eagle has been recorded in 1.3% of surveys since the year 2000 (Saunders in prep.).

The declines are thought to be due to loss of woodland habitat (Cooper et al. 2014), disturbance to nests, loss of breeding habitat, urbanisation and high density rural subdivision and subsequent competition for remaining habitat by Wedge-tailed Eagles (Debus et al. 2007, Debus and Ley 2009, Debus 2011, Dabb 2018). Declines in the ACT and NSW may also be due to control of rabbits, which are a major prey item, and the use of Pindone for rabbit control, which possibly affects the predator as well through secondary poisoning from eating baited rabbits (Olsen et al. 2013). Urban encroachment not only affects nesting woodland habitat but also the surrounding open areas used for foraging (Walsh and Beranek 2017) and nesting and foraging areas may become disjunct (ACT Government 2008). They are easily disturbed while nesting (Cupper and Cupper 1981) and will flush from the nest when approached to within 50 to 140 metres (Debus *et al.* 2007).

Breeding density in eastern NSW has been estimated at 1 pair per 1600 hectares in the early 1980s (Debus 1984) and one pair per 2100-3000 hectares since 2000 (Debus 2017). Active nests in eastern NSW are between 2 and 5 kilometres apart and birds will forage up to at least 1.8 kilometres from the nest (Debus 1984, Debus and Ley 2009); average inter-nest distance in contiguous wooded habitat is 3.6 km (Larkin and Debus unpublished data). Walsh and Beranek (2017) found that the Eagles will forage up to 3 kilometres from the nest, which gives a minimum breeding/ foraging territory of 2800 hectares. In the ACT, active nests were on average 5 km apart (Rae *et al.* 2018), and one post-breeding adult male had an elongated foraging range of 6500 hectares, with foraging journeys of 10-20 km, around the outer edge of Canberra (Brawata and Gruber 2016).

Habitat Requirements

Little Eagles prefer open woodland, but are also found along forest edges, timbered watercourses through open country and open grazing country (Hollands 1984, Taylor and Canberra Ornithologists Group 1992, Olsen *et al.* 1993). They hunt over most open habitats and will seek areas where there is a mosaic of treed habitat and open country

(Debus 1993, Cooper et al. 2014). They can also be found in woodland associated with wetlands (Debus 1993, CBOC Atlas accessed 29-06-2018).

They will nest in tall living eucalypts between 5 and 30 metres tall in open forest, woodland, and remnant woodland in farmland (Debus 1993, Debus *et al.* 2007, Debus and Ley 2009). Nests are generally between 13 and 20 metres above ground (Debus 1993, Debus and Ley 2009, T. Saunders pers. obs.). They prefer to nest in dense woodland adjacent to open habitat e.g. grassy woodland for foraging (Debus 1993, Debus and Ley 2009, Debus 2011). Nests are typically in an emergent eucalypt, the tallest in the stand and often with the largest girth, in woodland patches at least 4.8 hectares in size (average 85 ha); mostly within 200 m of an edge; more distant from sealed roads (average 838 m) than gravel roads (average 546 m) than tracks (average 304 m), at least 38 m from the nearest dwelling (average 457 m), and at least 1 km from suburbia (Larkin and Debus unpublished data). Near Canberra, nests were at least 215 m from a dwelling, at least 122 m from an urban edge, and farther from sealed roads (average 710 m) than gravel roads (260 m) or footpaths (average 90 m) (Rae *et al.* 2018). The minimum nesting requirements as per a review of the literature are provided in Tables 1 and 2 below.

Table 1. Minimum distances of active Little Eagle nests from developments in 2 studies:

Parameter	Armidale (C. Larkin et al. unpubl.)	Canberra (Rae et al. 2018)
Dwelling	38 m	215 m
Urban area	1 km	122 m
Industrial building	–	65 m
Sealed road	65 m	31 m
Unsealed road	135 m	29 m
Track/path	34 m	24 m

Table 2. Minimum criteria for active Little Eagle nest-site characteristics (Armidale, C. Larkin *et al.* unpublished data):

Parameter	Measurement
Woodland patch size	4.8 ha
Nest-tree height	20.5 m
Reference tree height*	14.6 m
Nest-tree DBH**	37 cm
Reference tree DBH*	54 cm
Nest height	15 m

*Reference trees are other trees within the nest stand (within 25 m of the eagle's nest tree)
**Diameter at breast height

Foraging requires open woodland areas and open grasslands adjacent to woodlands because the preferred prey includes mainly ground foraging prey species. These are across a broad range of prey species and include insects, reptiles, birds, mammals and carrion. The prey types that have been recorded for the Little Eagle are listed as follows:

Insects	grasshoppers, beetles, cicadas (Debus 1993, 2017)
Reptiles	Bearded Dragon, Eastern Blue-tongue, Cunningham's Skink, goannas (Debus 1993, Debus *et al.* 2007, Debus 2017)
Birds	Crimson and Eastern Rosellas and other parrots, Galah, Australian Magpie-lark, Peaceful Dove, Common Starling, ducks, pigeons, small to large passerines (Debus 1993, Debus *et al.* 2007, Olsen *et al.* 2010, Debus 2017, Rae *et al.* 2018)
Mammals	Rabbit, Hare, Mouse, Rat, Cat, *Antechinus*, bandicoot, possums (Debus 1993, Debus *et al.* 2007, Walsh & Beranek 2017)
Carrion	macropods, Hare, Sheep, Fox (Debus 1993, Olsen *et al.* 2010, Debus 2017)

There is some information on local vegetation types within the Cumberland County that are preferred by the Little Eagle. One hundred and twenty-six records out of the 325 records held with the CBOC Atlas (accessed 29-06-2018) contain information about the habitat type where the Eagle was encountered. In order of most to least common they were:

Pastureland with Scattered Trees	27%
Cumberland Plain Woodland	22%
Heath	15%
Urban Parkland	10%
Tall Forest	8%
Sandstone Woodland	8%
Rainforest	8%
Swamp and River Woodland	2%

The OEH Threatened Species Data Collection indicates that the Little Eagle has the potential to inhabit the following plant communities within the Wilton and Greater Macarthur Growth Areas:

830	Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain
850	Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain
883	Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain
1800	Wetlands

The habitat requirements discussed above have been used in this report to identify important habitat areas. They have been grouped into the habitat criteria listed below. The greater the number of criteria that are met the more likely it is that the remnant will provide habitat for Little Eagle.

1. Site contains tall open forest or woodland.
2. Site is near or along a timbered watercourse.
3. Site contains one or more of the following PCTs: -
   830, 835, 849, 850, 883 and 1395.
4. Site contains a mosaic of open grazing land and woodland.
5. Site contains ground foraging prey species
   e.g. rabbits, hares, mice, passerines, parrots and pigeons.
6. Site has open grassy areas around the edges of remnants, timbered corridors and watercourses.
7. Site has tall or emergent trees suitable for nesting.

3. Description of the Study Area's Relevance to the Little Eagle

Land Use History

Much of the northern half of the Greater Macarthur growth area has been developed as residential, commercial and industrial land decades ago and any remaining habitat can only be found along watercourses and on steep slopes where these developments are not appropriate. Much of this area would have been a mix of cleared grazing land and bushland prior to this stage of development.

The southern half of the Greater Macarthur and the Wilton growth areas contain older small towns, which now have a few larger new residential developments. These occupy only a small area within the growth areas. Much of the land consists of small to medium rural holdings and grazing agricultural land that was cleared for farming decades ago. Throughout this area there are many watercourses that are tributaries to either the Georges or Nepean rivers and the forests along these watercourses has largely been left intact with some clearing or thinning at the edges. Many of the remnant patches and forested watercourses have been affected by woody weed invasion since development in the area.

Landscape Context

The growth areas follow the transport corridor along the Hume Motorway that connects the area to the south-western areas of greater Sydney to the north. The area abuts intact, contiguous, forested areas to the east and to the south. These are in water catchments or national park reserves, which cover hundreds of square kilometres. The western edge abuts mostly cleared rural holdings either side of the Nepean River and then further west to the Warragamba Dam water catchment area.

Much of the region is in the western half of the Cumberland IBRA subregion, which contains most of the remaining large woodland remnants and is an important area for this reason. The woodlands of the Cumberland Plain are threatened ecological communities and have been prioritised by the Office of Environment and Heritage for habitat protection and enhancement (DECCW 2010).

Native Vegetation

The remnant native vegetation within the growth areas is mainly eucalypt forest and woodland. Forested areas on steep slopes and along watercourses have largely been left intact and often contain a structurally and species diverse understorey. Woodland areas remaining on flat or gently undulating land have a few scattered dense patches of understorey, but are mostly open woodland with a grassy understorey. Many of the remnant patches have been invaded by woody weeds and many woodland remnants are subjected to grazing pressure and are clear of any understorey. Some of the remnants have also been thinned and have only scattered paddock trees along their edges.

The following plant community types are found in these remnants within the growth areas:

PCT Codes and Names

- 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- 850 Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 877 Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1081 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion
- 1292 Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion
- 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion

Potential Habitat

Most of the uncleared areas in the northern half of the Greater Macarthur growth area are remnant forest patches along watercourses that were unsuitable for development. They are small, often isolated and mostly surrounded by urban development with little or no open areas surrounding each remnant to act as buffers. Some have open areas within them that have mown grass and are now parkland. Few of the reserves have open edges or grazing areas around them and as such do not provide suitable foraging habitat. This area has a major watercourse near the eastern edge, which is the Georges River. This river would provide access to the reserves that provide some suitable resources for the Eagle.

The southern half of the Greater Macarthur and the Wilton growth areas have small areas of urban development and larger areas of open grazed pastureland and rural holdings. There are very large remnants of forest and woodland that mainly follow watercourses that are connected to either the Georges or Nepean Rivers. In the south and east sections of the growth areas many of these forest remnants are also part of contiguous habitat into water catchment reserves or national parks. The forest remnants often border open areas with scattered trees and provide good edge habitat for the Eagle. There are many areas, which have a mosaic of open grazed land and small patches of open forest and woodland.

Some 40 sites, scattered over the whole length of the growth areas, were sampled for habitat quality and their ability to provide foraging and nesting resources for the Eagle. Fifty potential sites were selected based on the vegetation maps of the area but access into much of the area was difficult. The habitat requirements for the Eagle are described in detail in Section 2 of the report and are grouped into seven different criteria for assessing suitable habitat. Details of each site's location, their PCTs and which of the criteria were satisfied are listed below (see Table 3) and a more-detailed description of each site can be found in Appendix 1. All of the sites met at least one of the criteria and 20 of the sites meet at least 5 of the 7 criteria. The PCTs where the Eagle has been observed from previous records (BioNet Atlas of NSW Wildlife, accessed 29-06-2018) include 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion, 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, 850 Grey Box - Forest Red Gum grassy woodland on shale of the Cumberland Plain, Sydney Basin Bioregion, 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion and 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, which were recorded on many sites.

These sites represent only a small portion of the forest remnants within the growth areas, yet nearly all sites satisfied many of the criteria used to assess whether suitable habitat existed on-site for the Eagle. This implies that most of the remaining forest and woodland habitat in the area is potential Eagle habitat, especially as the remnants are tall, have open edges and follow watercourses. Open areas that exist adjacent to the forest and woodland remnants, and especially where there is a mosaic of open grazing areas and woodland remnants provide potential habitat. All forest, woodland and open areas that provide potential habitat will be shown as species polygons in Section 4 of this report. It should be noted that some of the important open areas adjacent to forest and woodland remnants overlap with the proposed urban development footprint.

Although there is much potential breeding habitat within the growth areas, BAM defines breeding habitat as live (occasionally dead) large old trees within suitable vegetation AND the presence of an adult with nesting material; or an individual on a large stick nest in the top half of the tree canopy. Adults with nesting material or their presence on a large stick nest were not observed during surveys. These criteria would need to be met to confirm the presence of breeding habitat within the growth areas.

Table 3. Criteria relating to habitat resources for the Little Eagle that were satisfied for each of the study sites.

Site No.	Latitude	Longitude	PCTs	Criteria Satisfied
1	-33.96801	150.90682	849	1,2,3,5,6,7
2	-33.97577	150.90994	835, 849	1,2,3,4,5,6,7
3	-33.98336	150.89717	1395	1,2,3,4,5,6,7
4	-33.99160	150.87588	835	1,2,3,5,6,7
5	-33.99667	150.87933	849	3,5
6	-33.00763	150.86866	835	2,3
7	-34.01357	150.85682	835, 1395	1,2,3,7
8	-34.01049	150.84202	849	3,7
9	-34.00402	150.83964	1395	3
10	-34.03953	150.84055	849	2,3,5,6
11	-34.05475	150.83743	1081, 1181	1,2,3,7
12	-34.05460	150.81757	850	1,3
13	-34.05984	150.79926	850	2,3,7
14	-34.05677	150.80422	850	2,3
15	-34.06471	150.79735	835	1,2,3,7
16	-34.07929	150.80041	849	3
17	-34.07103	150.79253	835	1,2,3,7
18	-34.07175	150.78816	849	1,2,3,7
19	-34.07426	150.77886	849	1,2,3,7
20	-34.09521	150.75699	835	1,3,4,5,6,7
21	-34.10223	150.75169	1395	1,2,3,4,5,6,7
22	-34.09795	150.74683	849	1,3,5,6,7
23	-34.09972	150.7786	830	1,3,7
24	-34.11215	150.77988	835	1,2,3,5,6,7
25	-34.12015	150.79354	1395	3,4,5,6,7
26	-34.12996	150.78533	1395	1,3,4,5,6,7
27	-34.14001	150.79018	1395	1,3,6,7
28	-34.15692	150.78909	1395	1,3,4,5,6,7
29	-34.19165	150.78422	1395	1,2,3,6,7
30	-34.20653	150.76729	850	1,3,4,5,6,7
31	-34.20109	150.75721	1395	2,3,4,5,6
32	-34.22262	150.7522	1395	3,4,5,6
33	-34.26687	150.71363	1395	3,4,5,6
34	-34.24750	150.70141	1395	1,2,3,6,7
35	-34.23376	150.69217	1395	1,2,3,4,5,6,7
36	-34.23014	150.68057	1395	3,5,6,7
37	-34.21825	150.66305	849	1,2,3,4,5,6,7
38	-34.22517	150.64112	1395	1,2,3,4,5,6,7
39	-34.23169	150.63132	1395	1,2,3,4,5,6,7
40	-34.20781	150.63328	1081	1,2,4,5,6,7

Criteria:
1. Site contains tall open forest or woodland.
2. Site is near or along a timbered watercourse.
3. Site contains one or more of the following PCTs - 830, 835, 849, 850, 883, 1181 and 1395.
4. Site contains a mosaic of open grazing land and woodland.
5. Site contains ground foraging prey species e.g. rabbits, hares, mice, passerines, parrots and pigeons.
6. Site has open grassy areas around the edges of remnants, timbered corridors and watercourses.
7. Site has tall or emergent trees suitable for nesting.

4. Assessment of Species Presence and Suitable Habitat

Species Records for the Greater Macarthur and Wilton Growth Areas

There were 78 records for the Little Eagle from the area containing the urban development area (ALA Atlas and CBOC Atlas, accessed 29-06-2018). The list of records is shown in Table 4 and the distribution of these records is shown in Figure 2.

Table 4. Records of the Little Eagle *Hieraaetus morphnoides* in and around the Greater Macarthur and Wilton Growth Areas.

Location Name	Latitude	Longitude	Date	Source
Mount Annan Botanical Gardens	-34.06250	150.7708333	27-03-1999	CBOC Inc.
Macdonald Road, Ingleburn	-33.98444	150.8563889	10-04-1999	CBOC Inc.
Macquariedale Road, Appin	-34.17083	150.7711111	01-07-1999	CBOC Inc.
Macquariedale Road, Appin	-34.17083	150.7711111	01-08-1999	CBOC Inc.
Riverside Reserve, Elderslie	-34.05389	150.7008333	01-06-1993	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	30-09-2000	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	19-08-2000	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	27-05-2000	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	17-10-1999	CBOC Inc.
Georges River, Macquarie Fields	-33.99611	150.9030556	26-06-2000	CBOC Inc.
Mount Annan Botanical Gardens	-34.06944	150.7677778	07-04-2001	CBOC Inc.
Mt Annan Botanic Gardens	-34.07500	150.775	17-05-2001	CBOC Inc.
Long Point, Macquarie Fields	-34.01778	150.9036111	20-04-2002	CBOC Inc.
Mt. Annan Botanical Gardens	-34.07194	150.7666667	11-05-2003	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	16-12-2000	CBOC Inc.
Mount Annan Botanical Gardens	-34.05389	150.7694444	15-12-2001	CBOC Inc.
Varroville, NSW- St Andrews Rd (Glendallo)	-33.95778	150.8375	09-11-2003	CBOC Inc.
Leppington NSW - Lawn Cemetery (eastern remnant)	-33.95778	150.8377778	10-01-2002	CBOC Inc.
Harrington Park, NSW - Narellan Creek	-34.03472	150.7402778	21-01-2005	CBOC Inc.
Raby, NSW - Raby Road.	-34.01500	150.8036111	27-01-2005	CBOC Inc.
Rossmore, NSW - South Creek, Rossmore Grange	-33.92806	150.7580556	13-02-2005	CBOC Inc.
Leppington NSW - Lawn Cemetery (eastern remnant)	-33.95778	150.8377778	08-03-2005	CBOC Inc.
Mt Annan Botanic Gardens	-34.06583	150.7694444	08-04-2006	CBOC Inc.
Glen Alpine	-34.08472	150.7763889	07-11-2009	CBOC Inc.
Mount Annan Botanic Gardens	-34.07000	150.7708333	19-11-2013	CBOC Inc.
Mt Annan Botanic Gardens	-34.06583	150.7694444	19-11-2013	CBOC Inc.
Mt.Annan Botanic Gardens, Campbelltown	-34.07250	150.7672222	01-11-1996	CBOC Inc.
Lieutenant Cantello Reserve, Hammondville	-33.95111	150.9669444	08-06-2014	CBOC Inc.
Mt Annan Botanic Gardens	-34.05389	150.7677778	23-10-2016	CBOC Inc.
Mt Annan Botanical Gardens	-34.07000	150.7705556	01-01-2017	CBOC Inc.
Mt Annan Botanical Gardens	-34.07000	150.7705556	23-01-2017	CBOC Inc.
Mt Annan Botanic Gardens	-34.07000	150.7705556	27-07-2017	CBOC Inc.
Mt Annan Botanic Gardens	-34.07000	150.7705556	24-08-2017	CBOC Inc.
Mt Annan Botanic Gardens	-34.07000	150.7705556	13-10-2017	CBOC Inc.
Mt Annan Botanic Gardens	-34.07000	150.7705556	31-10-2017	CBOC Inc.
	-34.16283	150.790372		BioNet Atlas of NSW Wildlife
	-34.16018	150.793163		BioNet Atlas of NSW Wildlife
	-34.16205	150.792898		BioNet Atlas of NSW Wildlife
	-34.16283	150.790372		BioNet Atlas of NSW Wildlife

	-34.16205	150.792898		BioNet Atlas of NSW Wildlife
	-34.16018	150.793163		BioNet Atlas of NSW Wildlife
	-33.99842	150.867836	26-12-1986	BioNet Atlas of NSW Wildlife
	-34.25867844	150.5614166		
CAMPBELLTOWN	-33.99841943	150.8678364	26-12-1986	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.92865874	150.8590417	22-01-1985	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.92865874	150.8590417	03-02-1985	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.92865874	150.8590417	21-04-1985	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.06231705	150.7817252	30-10-1994	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.18931555	150.7186366	13-09-2007	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.10632606	150.7259794	01-01-1998	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.10632606	150.7259794	01-01-1999	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.10632606	150.7259794	01-01-2000	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.10632606	150.7259794	01-01-2001	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.91688232	150.962082	09-02-1996	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.96674653	150.8716143	23-09-1998	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.08870094	150.7392383	14-03-2003	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.09695161	150.7314649	14-03-2003	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.93513506	150.8426533	31-05-2004	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.08812956	150.737097	14-09-2008	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-33.97527778	150.8630556	19-04-2013	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.30863396	150.6021486	20-02-2013	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.19170843	150.5864347	30-07-2013	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.11952649	150.6010416	06-03-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.972419	150.8475765	13-05-2014	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.00694444	150.8336111	13-06-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.923655	150.945471	28-05-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.952063	150.964321	08-06-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.95874478	150.9292539	02-05-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.92452167	150.9405973	28-05-2014	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.068907	150.776461	08-12-2014	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.15753198	150.6856719	23-05-2006	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.9655606	150.8459273	18-03-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.9743899	150.8453699	31-03-2014	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.90482214	150.852501	31-08-2007	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-33.97454806	150.824829	31-08-2007	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-33.99418471	150.8044648	26-04-2007	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.9589684	150.8806809	18-01-1999	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.31134794	150.6040053	01-03-2015	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.94682494	150.866701	15-03-2001	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.94002463	150.8754603	11-07-2006	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.31388162	150.5806545	21-04-2004	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.90600632	150.7990515	20-01-2004	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.93060527	150.9631288	06-06-2003	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.97654526	150.9587325	28-04-2006	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.16861374	150.609128	01-01-1994	BioNet Atlas of NSW Wildlife

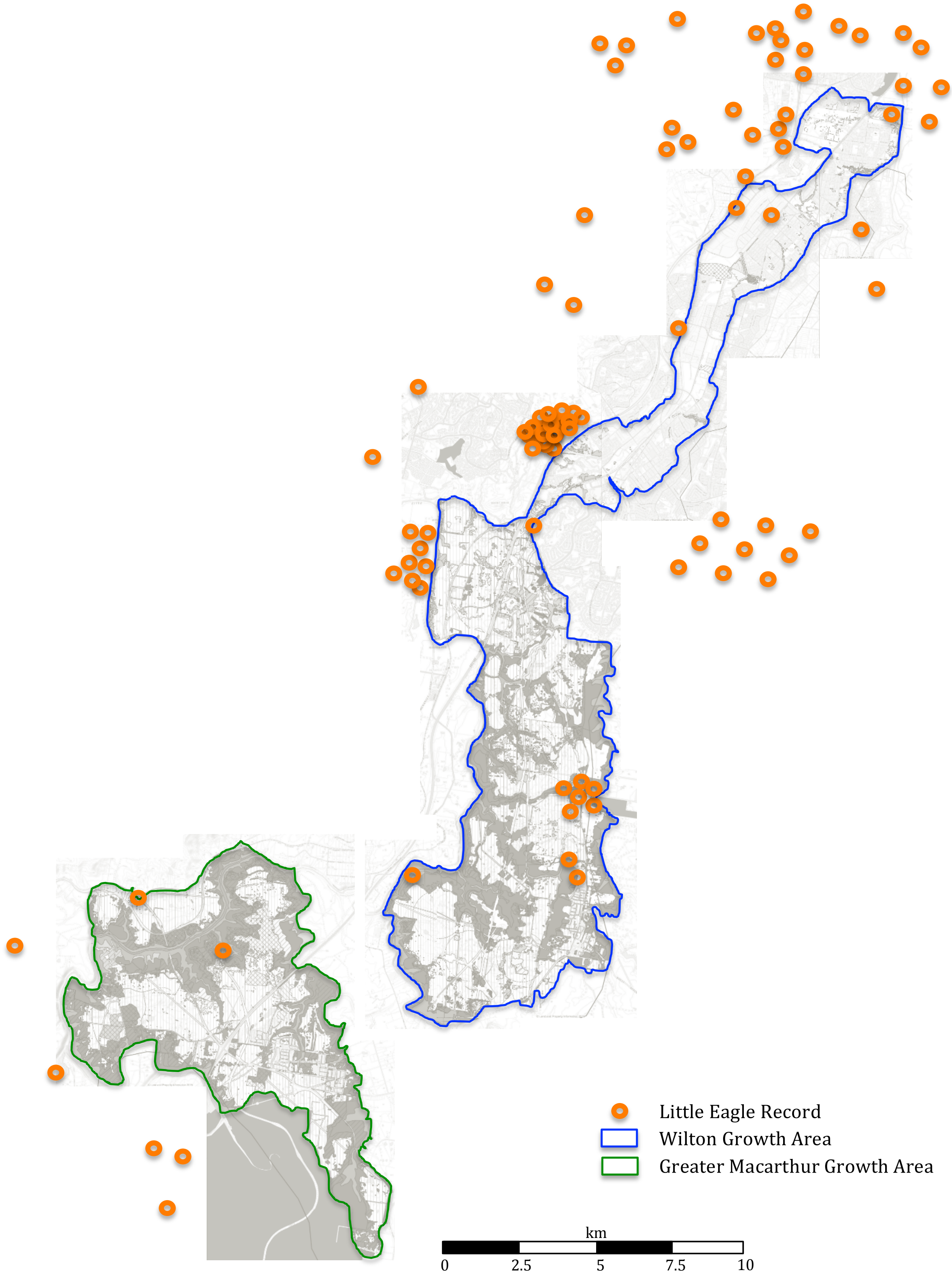


Figure 2. Species records for the Little Eagle *Hieraaetus morphnoides* in and around the Greater Macarthur and Wilton Growth Areas (source ALA and CBOC Inc.).

Of these 78 records, 15 were within the Greater Macarthur growth area and the Wilton growth area. The other 63 records are within 5 kilometres of the boundaries of the growth areas. There was no discernible seasonality in the records, although they were slightly more common from January through to May (the post-breeding dispersal phase). Records from August to December raise the possibility of the Eagle breeding in the vicinity of the growth areas or within 10 km. For instance, possible breeding behaviour (mating) was observed near Camden where a pair was regularly seen, although no nest was found on the site (a 1600 ha agricultural research station: Starr *et al.* 2004). Most of the Eagle records are associated with large patches of open woodland that occur within open grassland areas, such as pastureland and parkland; some are found in forest along watercourses and were obtained close to the edges of remnant forest. A few records were from woodlands associated with wetlands. The records support the conclusion that a mosaic of open woodland and open grassland with scattered trees provides important habitat for the Eagle. We are not aware of any previous habitat assessments for the Little Eagle in the study area.

Assessment of Suitable Habitat in the Growth Areas, Distribution Polygons and Justification for Determination

The areas of potential breeding and foraging habitats for the Greater Macarthur growth area are shown in maps 1 to 7 in Figure 3. The areas of potential breeding and foraging habitats for the Wilton Growth Area are shown in maps 1 to 3 in Figure 4. The existing remnant patches containing potential habitat for the Eagle are shown as an overlay over the vegetation maps. Sites where the habitat structure, plant community type and placement in the landscape all indicate potential breeding habitat breeding and foraging habitat for the species are shown in red. Some areas have potential as foraging habitat but a low likelihood for breeding and these are shown in orange. Some of these areas are within the proposed urban development footprint and have been included because they satisfy several of the following conditions. They contain good edge habitat adjacent to an existing habitat remnant e.g. open areas with scattered trees, provide good foraging habitat, provide connectivity between existing remnants, contain a mosaic of woodland patches and open grassland, broaden a connecting corridor or protect an edge habitat (shown in yellow). They also provide a buffered foraging area between habitat areas and the urban development footprint. Other areas, which also satisfied any of these same conditions and that are not within the urban development footprint, are included as they are areas where habitat enhancement would improve the Eagle's access to resources within the growth areas (shown in green).

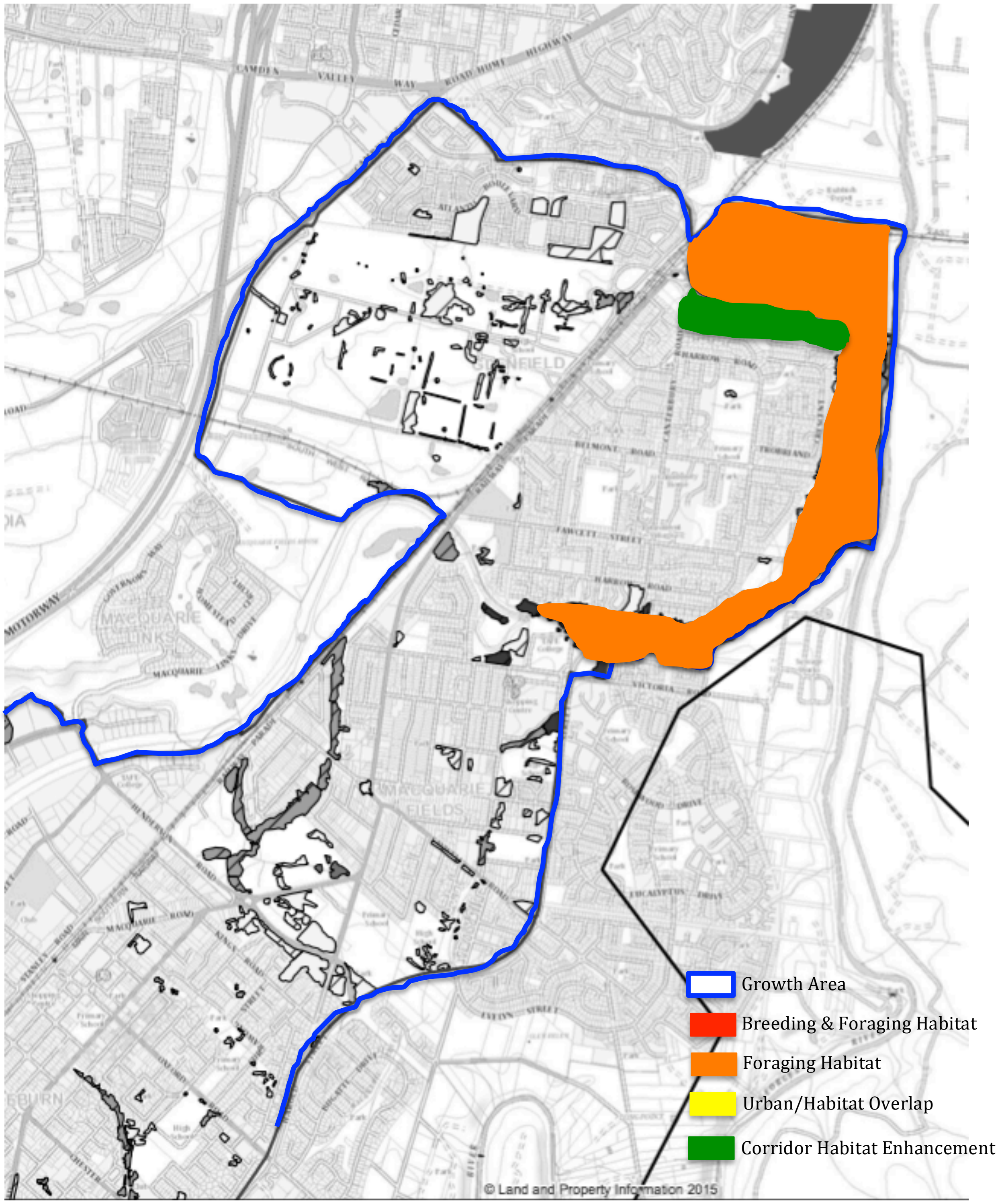


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 1). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

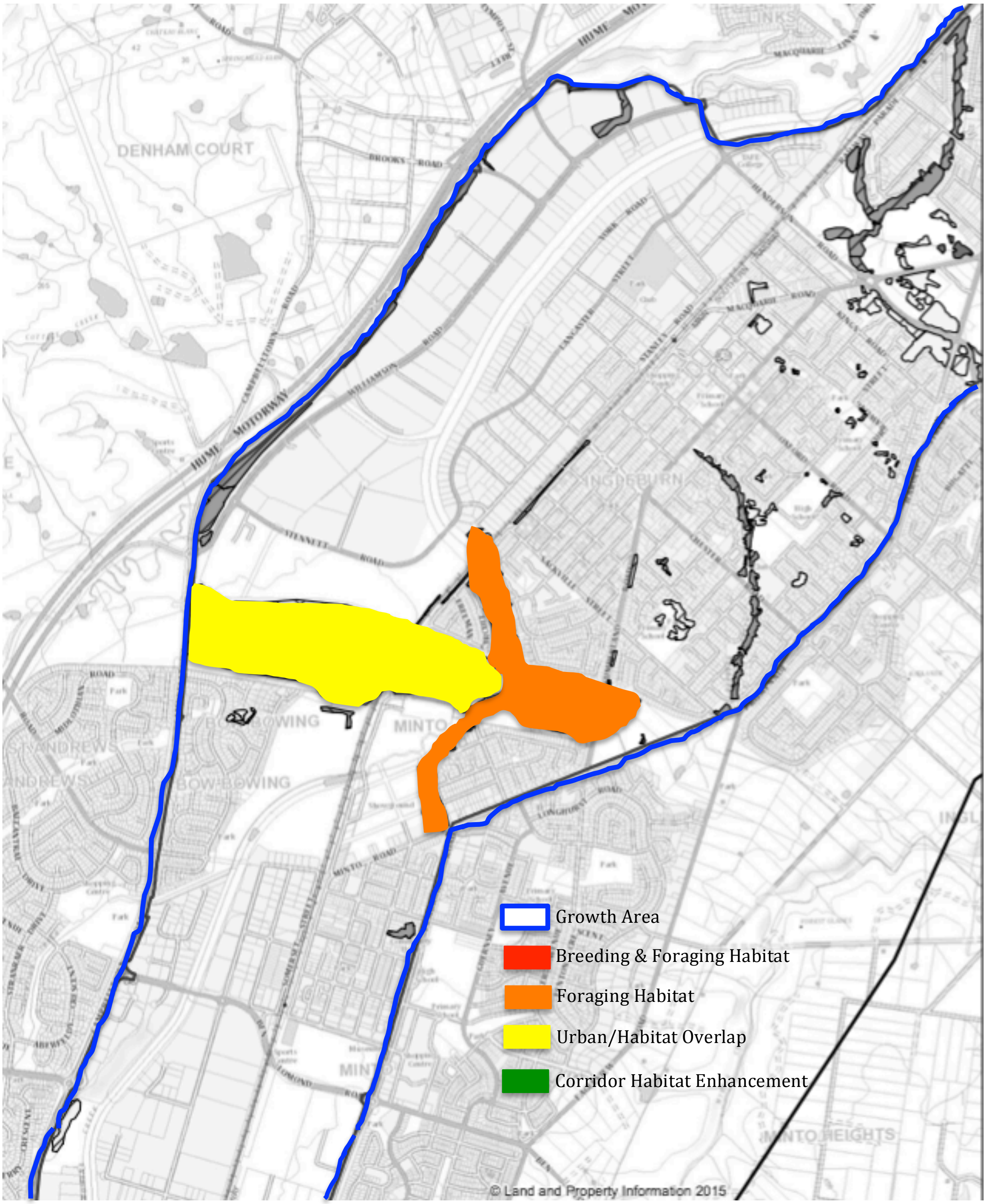


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 2). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

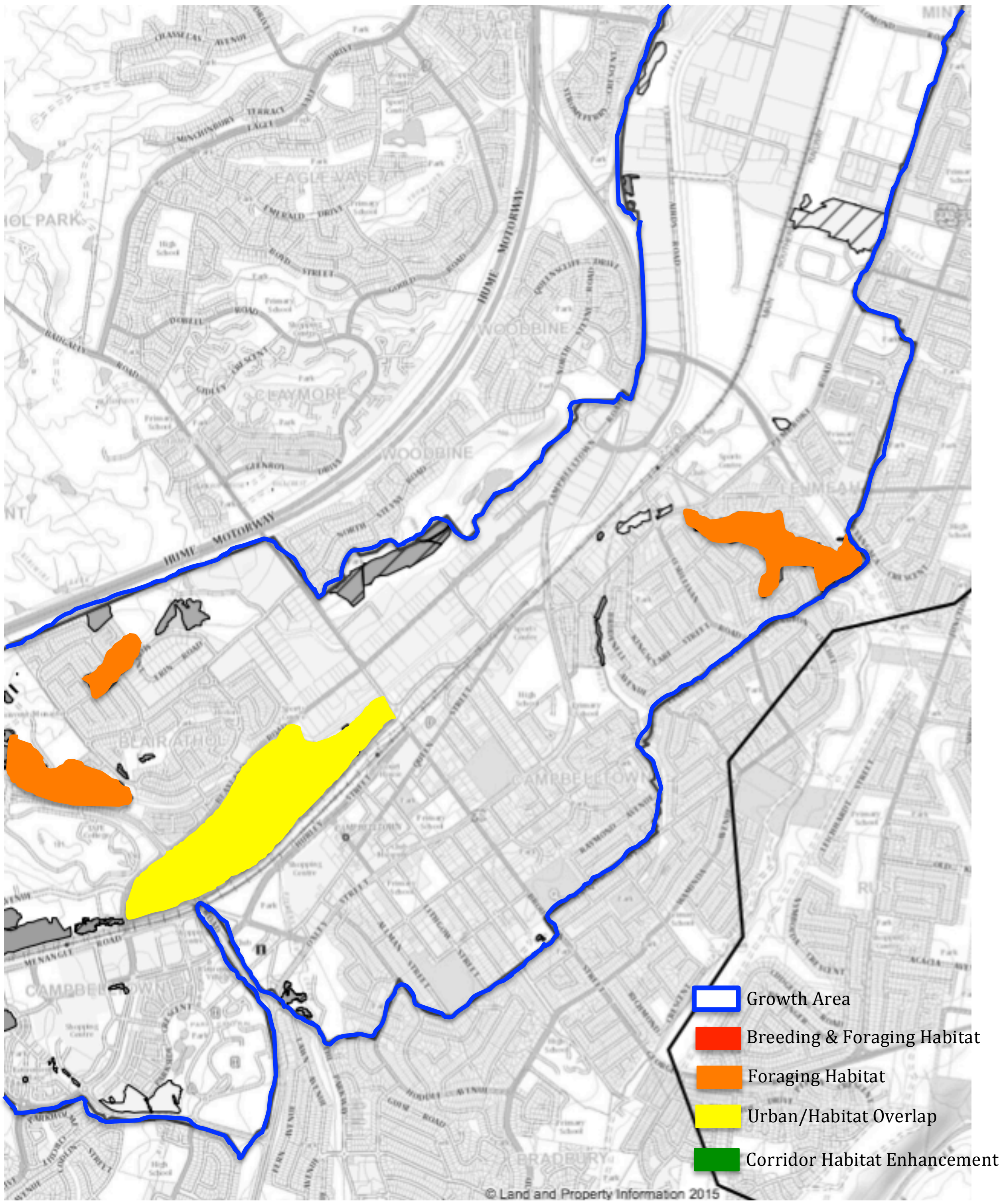


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 3). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

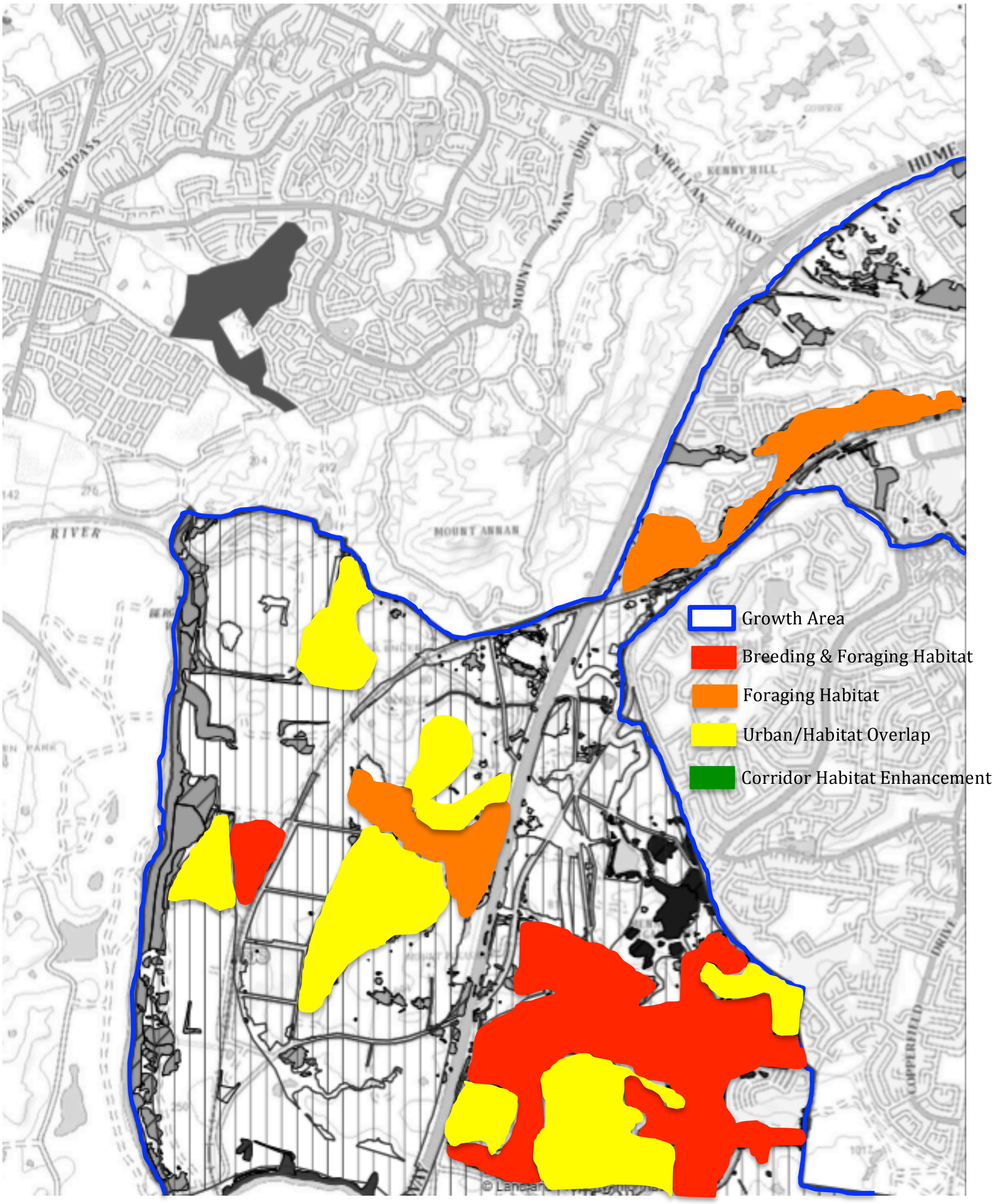


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 4). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

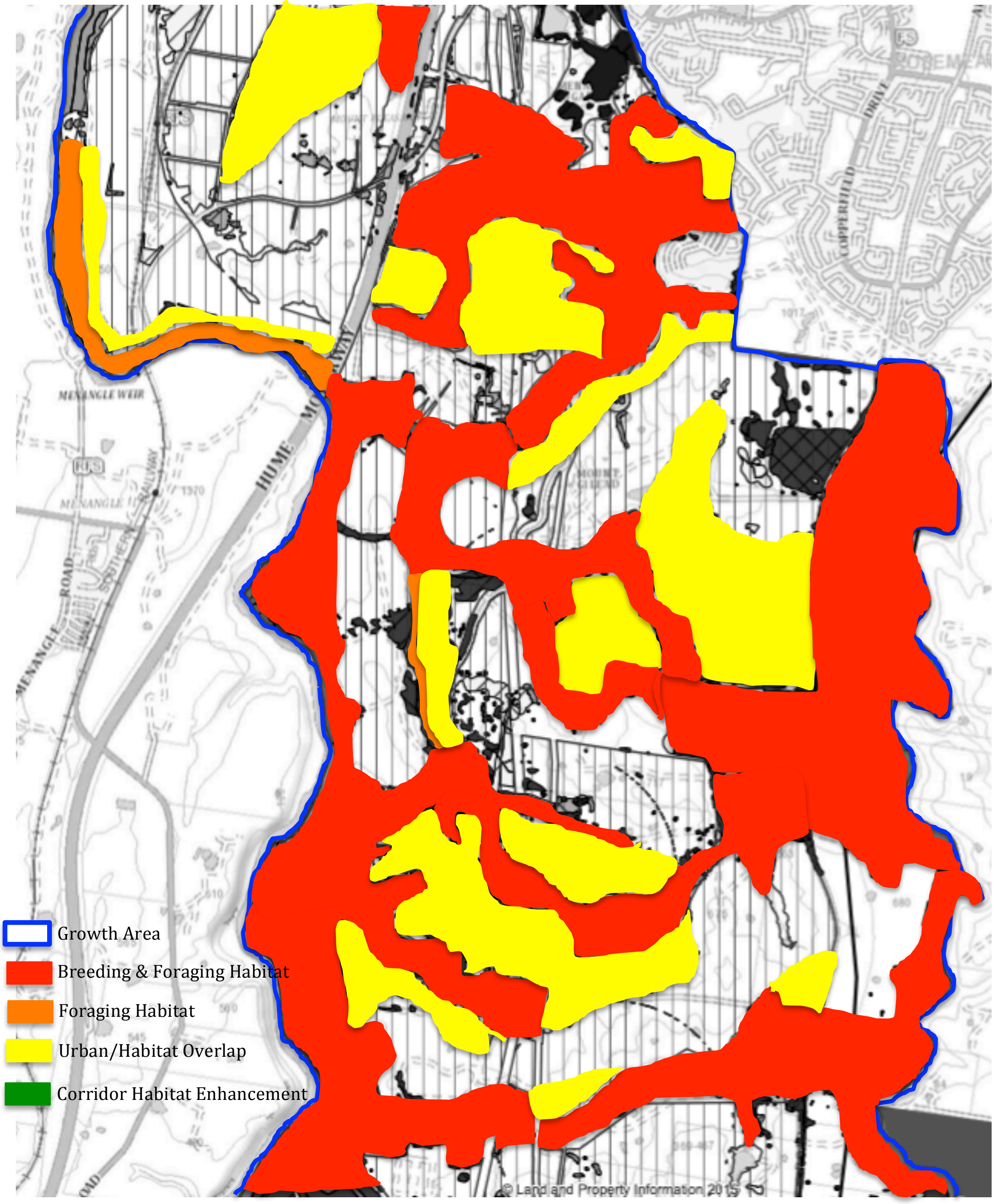


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 5). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

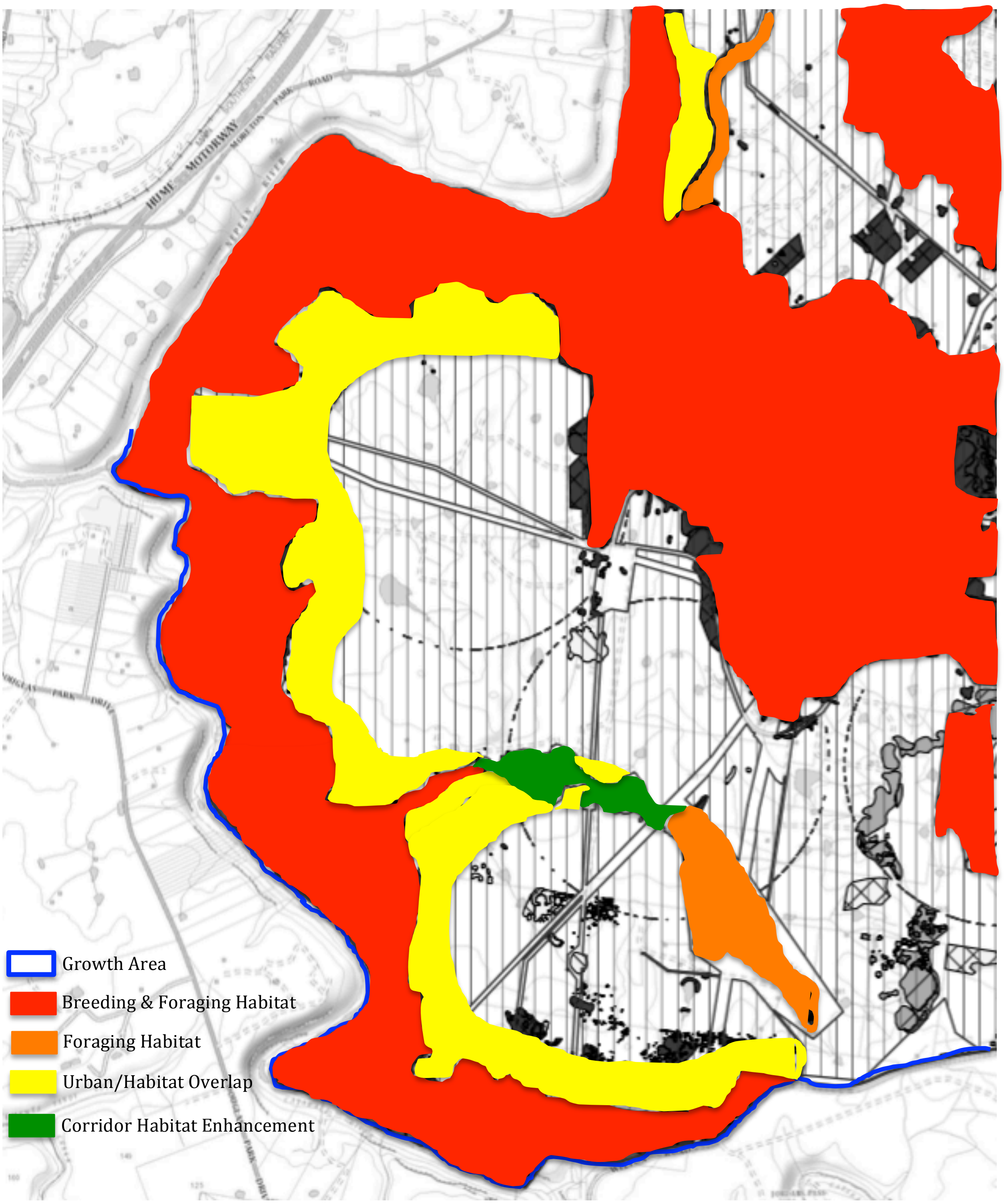


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 6). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

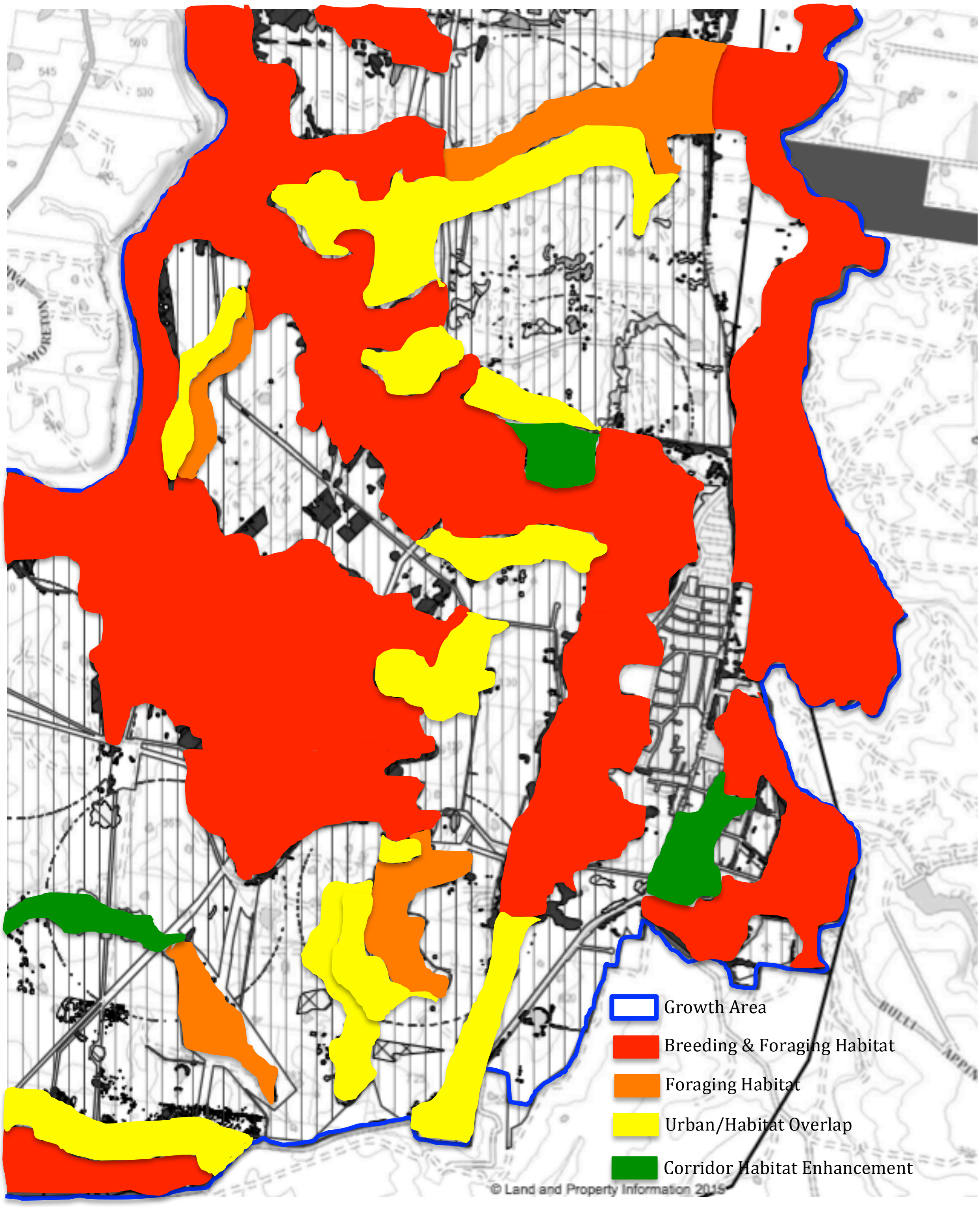


Figure 3. Potential breeding and potential foraging habitat for the Little Eagle in the Greater Macarthur growth area (Map 7). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

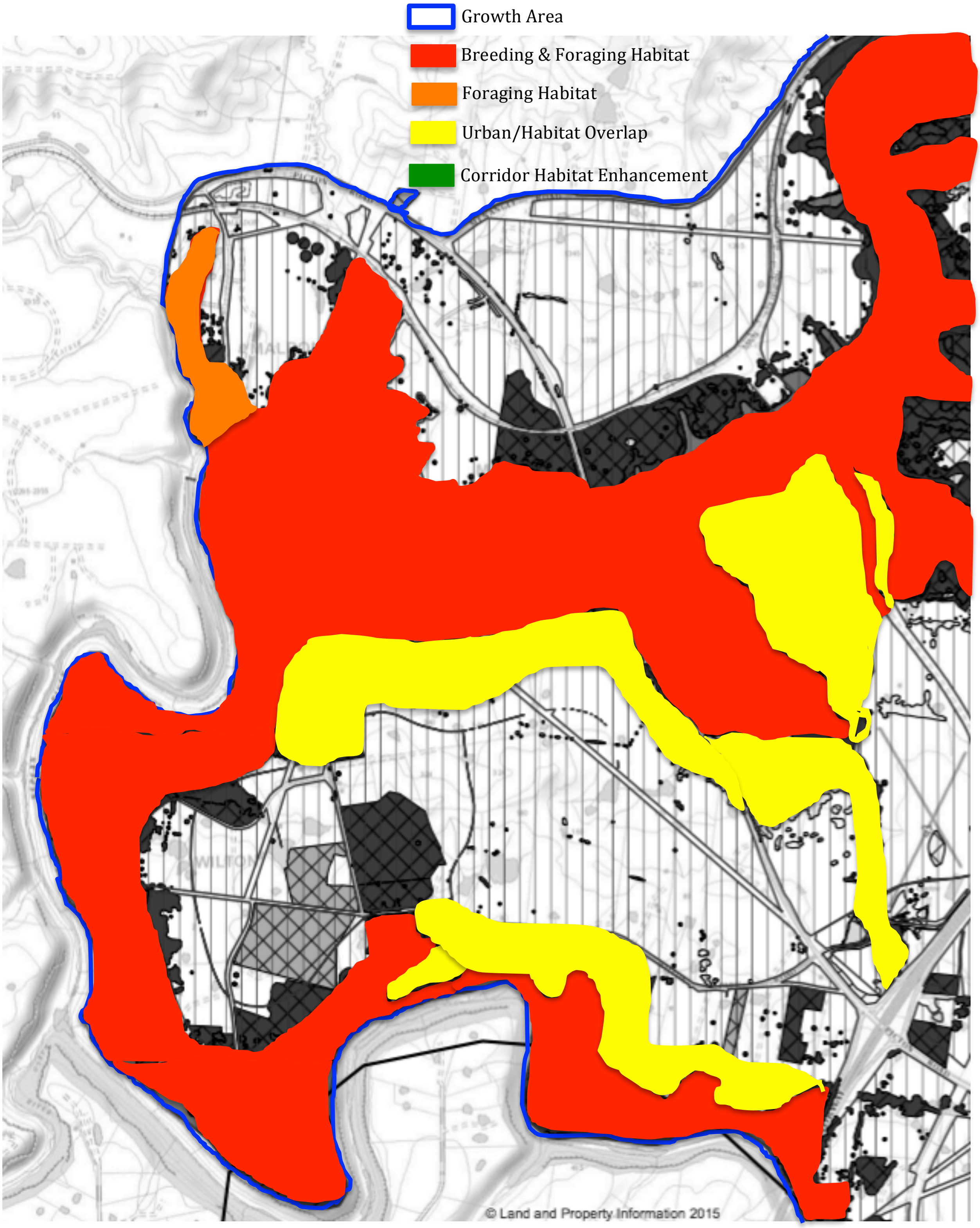


Figure 4. Potential breeding and potential foraging habitat for the Little Eagle in the Wilton growth area (Map 1). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

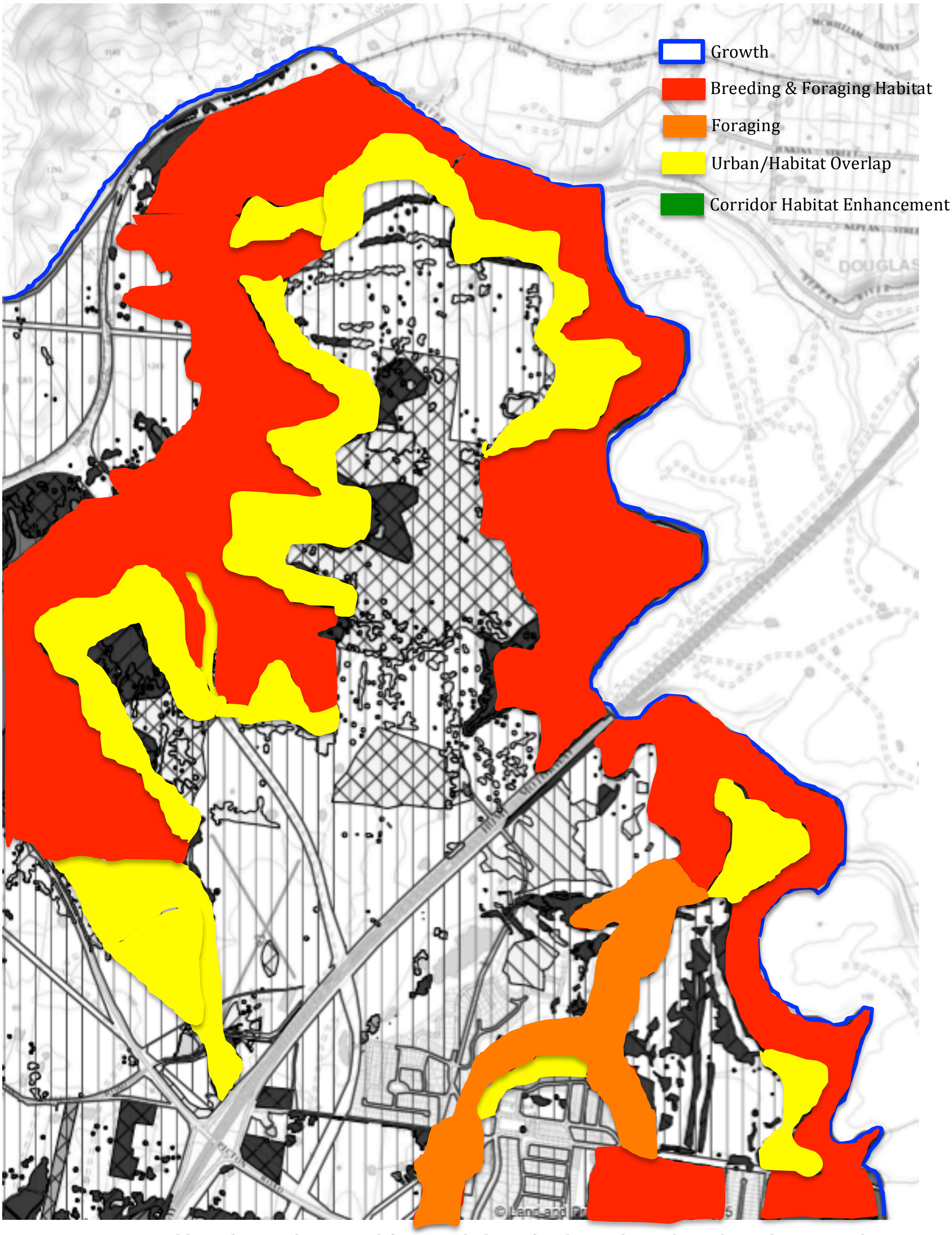


Figure 4. Potential breeding and potential foraging habitat for the Little Eagle in the Wilton growth area (Map 2). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

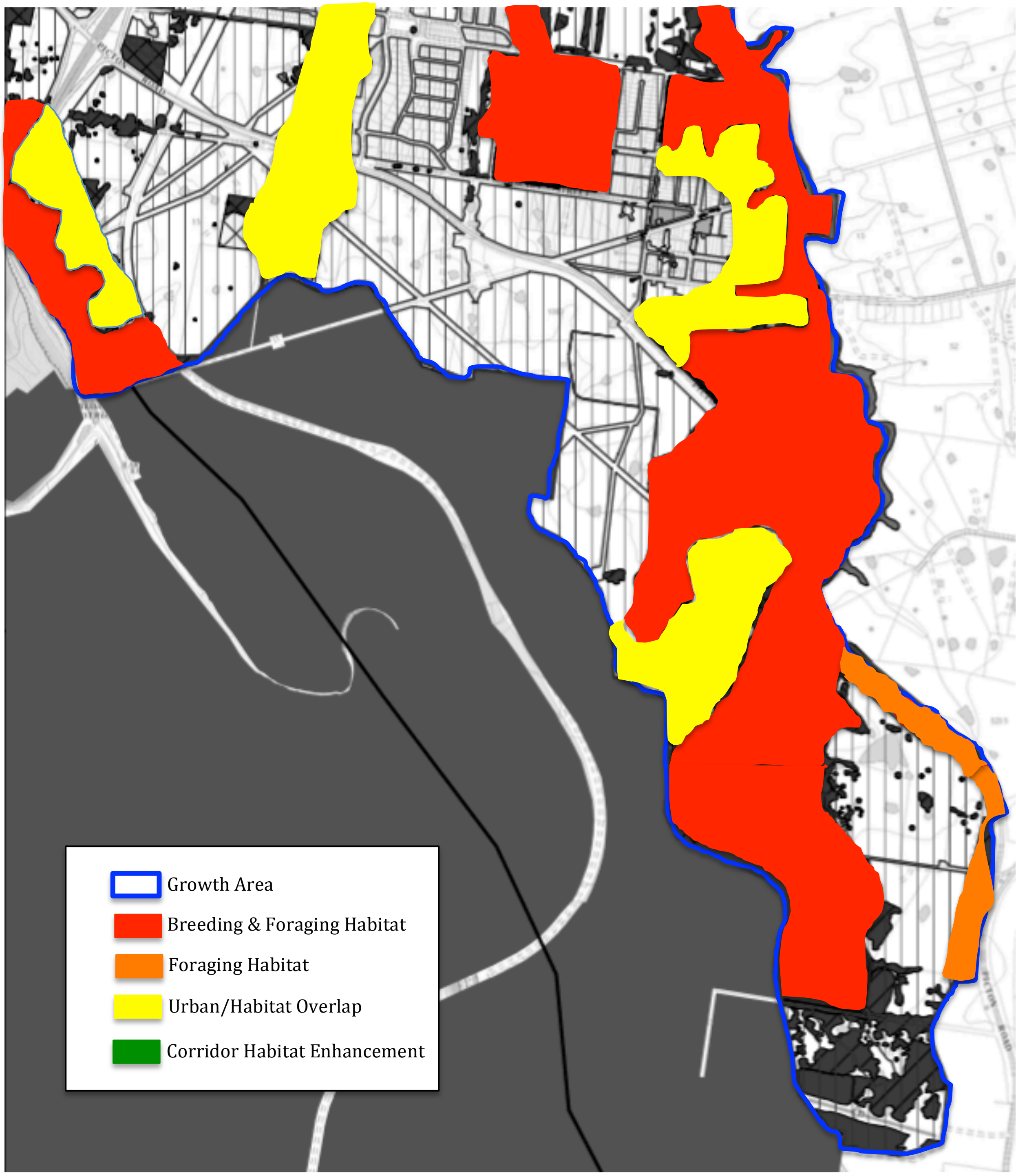


Figure 4. Potential breeding and potential foraging habitat for the Little Eagle in the Wilton growth area (Map 3). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

Assessment of the Likelihood of Species Presence in the Growth Areas, Distribution, Population Estimate and Justification for Determination

There is a very high likelihood of Little Eagles occurring within the growth areas at any time of the year. The habitat remnants within the growth areas are tall open forests and woodland, are mostly along watercourses and have abundant edges. There are also areas of open woodland dispersed through open grazing land with scattered trees. These factors provide good foraging habitat for the Eagle. The Eagle has also been recorded in most of the plant community types that occur within the growth areas, and again this aspect supports a high likelihood of Little Eagles occurring in the site.

No nests have ever been recorded in the growth areas and no evidence of breeding was observed during surveys by Biosis or by the authors. Although breeding has not been observed within the growth areas it is very likely that they forage in the area while breeding outside the growth areas. As the Little Eagle is considered to be resident for at least several consecutive years while nesting it is likely that if nesting has occurred within the growth areas it should have been detected. However, the Eagle has nested in similar situations elsewhere and nesting within the growth areas would also be possible as there is suitable nesting habitat within the growth areas. This view is supported by the occurrence of records for the Eagle within and around the growth areas in the breeding season, and the mating pair observed by Starr *et al.* (2004) near Camden.

The minimum requirements for Little Eagle nests are described in Tables 1 and 2. The Greater Macarthur and Wilton growth areas are more similar to Canberra than to Armidale. Armidale is a large town surrounded by a mosaic of remnant patches of vegetation and cleared grazing pastureland, whereas, Canberra and the growth areas are more spread-out and scattered along transport corridors. This implies that the minimum nesting requirements for Canberra in Table 1 are more relevant to this study.

The distribution of records and the size of a breeding territory at about 3 kilometres radius, as reported in the literature (see above), suggest that there are likely to be 4 to 6 breeding pairs in the area. There is likely to be a pair at the north end of the Greater Macarthur growth area as there are 36 records from this area. The sightings are associated with the large rural subdivision areas with scattered woodland remnants around Kemps Creek and with the Georges River woodland corridor. Sightings within the growth area suggest that the Eagles come in for foraging. It is possible that more than one pair is associated with this area.

The next important area is towards the middle of the Greater Macarthur growth area with another 34 records from this area. The sightings are centred on the Mount Annan Botanical Gardens and the area of woodland mosaic between Camden Park and the Nepean River. These two areas are 5 kilometres apart and there is sufficient habitat to support another 2 pairs of Eagles here. There is also much suitable foraging habitat east of these two locations within the growth area that provide foraging habitat. Although there was only one sighting within this part of the growth area it is likely that they would have been detected more frequently with more survey effort.

The next important area is in the south of the Greater Macarthur growth area along the forest edges found along Appin Road and around Appin. There is likely to be another pair here that could nest within or adjacent to the growth area. There are open grassland areas on the edges of forest remnants and along watercourses associated with the Nepean River that provide good foraging and breeding habitat. There is also likely to be another pair associated with the Nepean River around the Wilton to Pheasants Nest area. There were 7 sightings in this area and 2 of them were within the Wilton growth area.

In summary, the evidence suggests that the Little Eagle is found within the growth areas of Greater Macarthur and Wilton and that there are likely to be 4 to 6 pairs resident in the area. However, no evidence of breeding as defined by the presence of a bird on a nest or by the presence of pairs of birds in suitable habitat was observed within the growth areas. The presence of suitable foraging habitat within these growth areas means that protection of habitat within them may be critical to the continued presence of the Eagle in the area. It will also be important to provide a 100 m to 200 m buffer of open grassy woodland between any urban development and forest remnants to not only provide foraging habitat but also to prevent disturbance during nesting attempts within the growth areas.

5. Information Used in the Assessment

Data:

Atlas of Living Australia - occurrences of Little Eagle and Square-tailed Kite in Liverpool, Campbelltown and Wollondilly LGAs. (accessed 29-06-2018). <https://biocache.ala.org.au/occurrences/search>

BioNet Atlas of NSW Wildlife (accessed 29-06-2018).

Biosis - vegetation mapping and field survey data (supplied by the Department of Environment and Planning 21-05-2018).

Cumberland Bird Observers Club Inc. Bird Database (accessed 29-06-2018).

References:

ACT Government 2008 Action Plan No. 35 Little Eagle *Hieraaetus morphnoides*
Atlas of Living Australia - occurrences of Little Eagle and Little Eagle in Liverpool, Campbelltown and Wollondilly LGAs. accessed 29-06-2018. <https://biocache.ala.org.au/occurrences/search>

Barrett, G.W., Silcocks, A.F., Cunningham, R., Oliver, D.L., Weston, M.A. and Baker, J. 2007 Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species. *Australian Zoologist* 34(1): 37-77.

Brawata, R. and Gruber, B. 2016 Movements of the Little Eagle (*Hieraaetus morphnoides*) surrounding the proposed Riverview Development Area, Australian Capital Territory. Report by the Institute for Applied Ecology, University of Canberra, Canberra.

Chafer, C.J., Brandis, C.C.P. and Wright, D. 1999 *A Handbook of Birds Found in the Illawarra, Shoalhaven and Adjacent Tablelands.* Illawarra Bird Observers Club, Wollongong.

Cooper, R.M., McAllan, I.A.W. and Curtis, B.R. 2014 *An Atlas of the Birds of NSW & the ACT. Volume 1. Emu to Plains-Wanderer.* NSW Bird Atlassers Inc., Sydney.

Cupper, J. and Cupper, L. 1981 *Hawks in Focus: A Study of Australia's Birds of Prey.* Jaclin Enterprises, Mildura.

Dabb, G. 2018 An inconvenient eagle. Canberra Bird Notes 43: 132-137.

Debus, S.J.S. 1984 Biology of the Little Eagle on the Northern Tablelands of New South Wales. *Emu* 84: 87-92.

Debus, S.J.S. 1993 Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Little Eagle, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.

Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007 Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales. *Aust. Field Ornithology* 24: 137-157.

Debus, S.J.S. & Ley, A.J. 2009 Aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides*. *Australian Field Ornithology* 27: 76-99.

Debus, S.J.S. 2011 Parental time-budgets and breeding behaviour of the Little Eagle *Hieraaetus morphnoides* in northern New South Wales. *Corella* 35: 65-72.

Debus, S.J.S. 2012 *Birds of Prey of Australia: A Field Guide (2nd ed.).* CSIRO Publishing, Clayton South.

Debus, S.J.S., Olsen, J., Judge, D. & Butterfield, M. 2013 Numbers of breeding Little Eagles *Hieraaetus morphnoides* near Canberra in relation to atlas counts. *Corella* 37: 30-32.

Debus, S.J.S. 2015 Assessment of band recoveries for three Australian eagle species. *Corella* 39: 67-72.

Debus, S.J.S. 2017 *Australasian Eagles and Eagle-like Birds.* CSIRO Publishing, Clayton South.

Ferguson-Lees, J. and Christie, D.A. 2005 *Raptors of the World, a Field Guide.* Helm, London

Garnett, S. (ed) 1993 *Threatened and Extinct Birds of Australia RAOU Report Number 82.* Royal Australasian Ornithologists Union and Australian National Parks and Wildlife Service, Moonee Ponds, Victoria.

Hindwood, K.A. and McGill, A.R. 1958 *The Birds of Sydney (County of Cumberland) New South Wales.* Royal Zoological Society of N.S.W., Sydney.

Hollands, D. 1984 *Eagles, hawks and falcons of Australia.* Nelson, Melbourne.

Hoskin, E.S. (Hindwood, K.A. and McGill, A.R.) 2nd ed. 1991 *The Birds of Sydney, County of Cumberland, New South Wales, 1770-1989*. Surrey Beatty & Sons, Chipping Norton.

Morris, A.K., McGill, A.R. and Holmes, G. 1981 *Handlist of Birds in New South Wales*. New South Wales Ornithologists Club, Sydney.

Olsen, P., Crome, F. and Olsen, J. 1993 *National Photographic Index of Australian Wildlife Volume 8 Birds of prey and ground birds of Australia*. Angus & Robertson, Sydney.

Olsen, P.D. 1995 *Australian Birds of Prey.* University of New South Wales Press, Sydney.

Olsen, J., Fuentes, E., Judge, D., Rose, A.B. & Debus, S.J.S. 2010 Diets of Wedge-tailed Eagles (*Aquila audax*) and Little Eagles (*Hieraaetus morphnoides*) breeding near Canberra, Australia. *J. Raptor Research* 44: 50-61.

Olsen, J., Debus, S.J.S. & Judge, D. 2013 Declining Little Eagles *Hieraaetus morphnoides* and increasing rabbit numbers near Canberra: is secondary poisoning by Pindone the problem? *Corella* 37: 33-35.

Olsen, J., Debus, S.J.S., Judge, D. & Rose, A.B. 2013 Diets of Wedge-tailed Eagles *Aquila audax* and Little Eagles *Hieraaetus morphnoides* breeding near Canberra, 2008–2009. *Corella* 37: 25-29.

Olsen, J. 2014 *Australian High Country Raptors*. CSIRO Publishing, Melbourne.

Olsen, J., Trost, S., Gruber, B. and Long, T. 2017 Home-range and behaviour of a fledgling Little Eagle *Hieraaetus morphnoides* in the Australian Capital Territory. *Corella* 41: 88-98.

Patrick, A. 2016 *Birds of Sydney.* A. Patrick, Winston Hills.

Rae, S., Fletcher, D,. Mulvaney, M,. Davies, M,. Roberts, D. and Olsen, P. 2018 Notes on the breeding ecology of Little Eagles in the ACT in 2017/2018. *Canberra Bird Notes* 43: 186-193.

Saunders, T. in prep. Trends in woodland bird populations on the Cumberland Plain.

Starr, M., Starr, M.J. and Wilson, S.C. 2004 Raptor populations at an agricultural site featuring sustainable farming practices near Sydney, New South Wales. *Australian Field Ornithology* 21: 67-71.

6. Curriculum Vitae

Dr Tony Saunders

Name: Anthony Stephen John Saunders

Contact Details: 1878 Taralga Road Laggan NSW 2583 0409 399 849

Academic Qualifications:

BSc University of Sydney 1976
Dip Ed Sydney Teachers College 1977
PhD University of Western Sydney 2005

Other Qualifications:

LR Drivers Licence
Public Vehicle Driver Authority
Work Health & Safety General Construction Induction (White Card)
Chemical Use and Handling Certificate
Resuscitation Certificate
Emergency Care Certificate
Anaphylaxis Training Certificate
Drone Essentials Certificate

Fields of expertise:

Bird habitat assessment on reserves, lands in production and potential offset property.
Bird monitoring in natural, modified and managed habitats.
Assessment of likelihood of threatened woodland bird species occurrence on development sites.
Coordinating projects between government and non-government organisations.
Coordination of volunteers collecting wildlife data.
Ecotourism: guiding general interest and specialists groups in flora and fauna.
Environmental and science education at high school, TAFE, and university levels.
Habitat management for terrestrial woodland birds and other wildlife.
Presentations on ecology to public interest groups and at professional workshops.
Remote area wildlife atlassing.
Wildlife database design and management.
Land for Wildlife assessments and habitat enhancement planning.

Professional positions held:

2010 - 2018	Merops Services Pty Ltd (director, avifaunal ecologist). Environmental and landscape consultant and contractor, flora and fauna surveys, habitat enhancement plans.
2013 - 2018	Land for Wildlife Assessor for Community Environment Network
1995 - 2010	Merops Services (avifaunal ecologist). Environmental and landscape consultant and contractor.
2006 - 2018	Part-time teacher, mainly science, but also industrial arts, English and maths, Crookwell High School, Goulburn High School and Trinity Grammar School.
1997 - 2005	Part-time bird guide and ecotourism bus driver.
1993 - 2004	Part-time lecturer, supervisor and demonstrator, University of Western Sydney (biology, ecology and field survey techniques).
2001 - 2004	Atlas Facilitator, Birds Australia (organising remote atlassing, facilitating data exchange and communication between Birds Australia, state government organizations and other non-government organisations).
1997	Field Technical Officer, Birds Australia (monitoring breeding success of endangered bird species).
1996	Field Technical Officer, University of Western Sydney (reptile, bird and plant survey techniques and data analysis).
1978 - 1994	High School Science Teacher at Marsden, Heathcote, Penrith and Kingswood High Schools.

Other volunteer positions held:

2014 - 2017	Assistant to Co-ordinator of the Sydney Bird Fair.
2009 – 2018	President - Crookwell Native Flora and Fauna Club.
2013 - 2018	Secretary - Grabine/Foggs Crossing Landcare Group
2001 - 2018	Avifaunal Advisor and Education Officer for Oolong Sanctuary, Dalton.
1997 - 2010	Project Manager for Atlas of Birds of the County of Cumberland.
2010 - 2018	Technical advisor to the Cumberland Bird Observer's Club's Atlas Databasae Management Committee.
1996 - 2009	Committee Member - CBOC (Cumberland Bird Observers Club Inc.).
1998 – 2014	CBOC representative to Bird Interest Group Network (BIGnet).
1997 - 2002	Faunal Advisor for the Hawkesbury Rainforest Network.
1999 - 2002	Member of Steering Committee of Birds in Backyards for Birds Australia.
1998 - 1999	Consultant to Birds Australia Birds for Birds in Backyards Project.
1998 - 2003	Regional Organiser for Sydney and the Blue Mountains, NSW facilitator and NSW/ACT representative on the Steering Committee for the National Bird Atlas for Birds Australia.
2002	Representative on NSW NPWS Wildlife Issues Advisory Panel for Birds Australia.

Relevant experience:

Co-ordination, facilitation and organization of exhibits and presentations at field-day events and indoor venues. This has involved allocating space, providing necessary facilities and setting-up audio-visual equipment for exhibitors and presenters (18 years)

Co-ordinator of volunteers for the CBOC Inc. and the Birds Australia national birds atlas. (13 years)

Facilitated the BIGnet data exchange agreement between Birds Australia, NSW Bird Atlassers, Canberra Ornithologists Group and the Cumberland Bird Observers Club. Facilitated bird data exchanges between Birds Australia, NSW State Forests and NSW DECC. (4 years)

Presenter at seminars for Bushcare, Landcare, Greening Australia, Wires and local councils, conservation societies and garden clubs on habitat management for birds and bird survey techniques. (32 years)

Educator at public, tertiary and secondary levels in the area of bird habitat management and bird survey methodology. (23 years)

Ecotourism and bird guiding (19 years).

Undertaking avifauna surveys of sites for development applications and assessment of status of threatened bird species on sites and making recommendations for minimising impact of development on these species.

Bird habitat assessment of managed landscapes and natural habitat areas and recommendations for habitat enhancement and rehabilitation for birds. (21 years)

Design, building and management of the bird database for the birds of the County of Cumberland on behalf of CBOC Inc. (16years)

Membership and professional affiliations:

Australian Bird Study Association
Australian Bush Heritage
Birdlife Australia
Crookwell Native Flora and Fauna Society
Cumberland Bird Observers Club
Ecological Consultants Association of NSW
Grabine/Foggs Crossing Landcare Group
Greening Australia
NSW Bird Atlassers
Royal Zoological Society (Scientific member)
Wildlife Preservation Society of Queensland

Papers, Articles and Reports:

Saunders, T. 1985. Common Bronzewings at Round Hill Nature Reserve. *CBOC Newsletter* Vol. 6 No. 6 : 5

Saunders, T. 1986. Eastern Bristlebird at Ku-Ring-Gai Chase National Park. *CBOC Newsletter* Vol. 8 No. 2 : 1

Saunders, T. 1990. Sooty Oystercatcher. *CBOC Newsletter* Vol. 11 No. 3 : 3

Saunders, T. 1991. Keeping Records of Bird Observations. *CBOC Newsletter* Vol. 12 No. 5 : 6-7.

Saunders, T. 1997. Birdscaping Gardens *CBOC Newsletter* Vol. 18 No. 4 : 6

Saunders, A.S.J. 1993. Seasonal variation in the distribution of the Noisy Friarbird *Philemon corniculatus* and the Red Wattlebird *Anthochaera carunculata* in eastern New South Wales. *Australian Bird Watcher* 15: 49-59.

Saunders, A.S.J., Ambrose, S.J. & Burgin, S. 1995. Gape width and prey selectivity in the Noisy Friarbird *Philemon corniculatus* and Red Wattlebird *Anthochaera carunculata*. *Emu* 95: 297-300.

Whelan, H. (ed.) 1997. *Australian Geographic Birdwatcher's Journal.* Australian Geographic. Chapters 'How to Watch Birds' and 'Bringing Birds into Your Garden'.

Healey, J. (ed.) 1997. *Encyclopaedia of Australian Wildlife.* Reader's Digest, Sydney. Chapters on Honeyeaters and Chats.

Saunders, A.S.J. & Burgin, S. 2001. Selective foliage foraging by Red Wattlebirds, *Anthochaera carunculata*, and Noisy Friarbirds, *Philemon corniculatus*. *Emu* 101: 163-166.

Saunders, T. 2002 *Bird Monitoring of Federal Park and White's Creek Valley Park, Annandale*. Leichhardt Council, Unpublished Report.

Saunders, T. 2002 Bird Habitat Issues and Management of Urban Bushland. *Caring For Our Bushland and Waterways: Forum Proceedings*. 2002 Wollondilly Catchment Landcare Forum.

Saunders, A.S.J., Burgin, S. & Jones, H. 2003 The importance of eucalypt nectar in the diet of large honeyeaters. *Corella* 27: 1-12.

Saunders, T. 2003 *Managing Avian Biodiversity in the Leichhardt Local Government Area.* Leichhardt Council, Unpublished Report.

Saunders, T. 2003 *Breeding Waterbird Study at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2004 *Bush Bird Status at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2005 *Bush Bird Project at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2005 *Habitat Survey of Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2006 *Flora and Fauna Assessment of Badgerys Creek.* Unpublished Report.

Saunders, T. 2007 *Bird Habitat Management within Holroyd Local Government Area.* Holroyd City Council, Unpublished Interim Report.

Burgin, S. & Saunders, T. 2007 Parrots of the Sydney region: population changes over 100 years. Pp. 185-194 in *Pest or Guest; The Zoology of Overabundance*, edited by Lunney, D., Eby, P., Hutchings, P. & Burgin, S. Royal Zoological Society of NSW, Mosman.

Saunders, T. 2008 *Avian Biodiversity Monitoring and Bird Habitat Management within the Leichhardt LGA.* Leichhardt Council, Unpublished Report.

Saunders, T. 2009 *Bird Habitat Management within Holroyd Local Government Area.* Holroyd City Council, Unpublished Report.

Saunders, T. 2009 *Sydney Olympic Park Bush Bird Survey* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2010 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Interim Report.

Saunders, T. 2010 *Bird Monitoring at Sydney Olympic Park 1999 to 2009* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2011 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Interim Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Heathfield' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Girragirra' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Garrallan' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Garraroo' Binda*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Watervale' Boorowa*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Wookie Hills' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Orchre Arch' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Raintree-Marra' Cowra*, Unpublished Report.

Saunders, T. 2011 *Criteria for Ranking Priorities for Habitat Enhancement for Lachlan Catchment Management Authority*, Unpublished Report.

Saunders, T. 2012 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Final Report.

Saunders, T. 2013 Birdscaping Gardens. p 16 *Our Gardens* Volume 55, The Garden Clubs of Australia.

Saunders, T. 2014 *Habitat Survey of Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Mitchell' Binda*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Douglass' Binda*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Holmes' Peelwood*, Unpublished Report.

Saunders, T. 2015 *Habitat Assessment and Enhancement Plan for 'Ollis' Bigga*, Unpublished Report.

Saunders, T. 2015 *Habitat Assessment and Enhancement Plan for 'Flat Rocks' Bigga*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Gunthori' Yass*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for Lot3 DP 789337 Taralga*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for Lot 57 Bevendale*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 48541Abercrombie for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 48016 Abercrombie for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 823525 Binda for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 753055 Binda for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for DP 1217631 Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'Callarah' Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'The Angle' Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'Bobbins' Reids Flat*, Unpublished Report.

Saunders, T. 2016 Birds of the Cumberland Plain. What was there? What have we lost? Abstract from 'Birds of the Cumberland Plain: Past distributions, present studies and the outlook for their future.' Australian Bird Study Association Conference - 23 January 2016. *Corella* 40: 46

Saunders, T. 2016 *Bird surveys, likelihhood for threatened birds and habitat description for Syerston Mine Project, Fifield,* Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Tanjenong' Abercrombie*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bohara' Breadalbane*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Greendale' Breadalbane*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bunduluk' Laggan*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 48618 Windellama for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 1185604 Windellama for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 823489 Cullulla for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Bird surveys, likelihhood for threatened birds and habitat description for Vickery Mine Project, Boggabri,* Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bimbimbie' Bigga*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for 'Tanjenong' Abercrombie*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for DP 1162296 Crookwell*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for 1206394 Red Ground*, Unpublished Report.

Saunders, T. 2018 *Bird surveys, likelihhood for threatened birds and habitat description for Maxwell Mine Project, Jerrys Plains,* Unpublished Report.

Saunders, T. in prep. Trends in woodland bird populations on the Cumberland Plain.

Thesis:

Saunders, A.S.J. 2006 Comparative Foraging Ecology of the Noisy Friarbird *Philemon corniculatus* and the Red Wattlebird *Anthochaera carunculata* in central eastern New South Wales.

Dr Stephen Debus

Abridged CV: Stephen John Stewart DEBUS

BA (Biol./Behav. Sc.), Dip. Natural Resources (Wildlife), Dip. Ed. (Sci.), MSc. (Zool.), PhD (Zool.)

Contact details:

Ph: 02 6773 2510 (BH), 02 6772 1710 (AH), mobile: 0409 779 766

Addresses: Zoology, University of New England, Armidale NSW 2351 (business)
PO Box 1015 (6 Holloway St), Armidale NSW 2350 (private)

Website www.une.edu.au/staff-profiles/ers/sdebus

Professional capacities:

Vertebrate fauna surveys. Research and survey of threatened forest and woodland birds, particularly raptors and owls. Ecology/biology/behaviour of birds, especially predatory species. Conservation and management of threatened bird species. Distribution, status and biology/ecology of NSW birds. Reviews and biological profiles of bird species. Editing ornithological papers. Peer review of ornithological documents/EISs/species impact statements. Impact assessment (avifauna). Review of conservation status of NSW fauna.

Computer skills:

Proficient in Word and Excel, limited experience with GIS and ArcView

Employment:

Eco Logical Australia 2011-18 (casual; senior ecologist: fauna survey and report)

EA Systems (now EnviroAg Australia) 2000-14 (casual; ecologist: fauna survey and assessment)

Research assistant, Zoology, UNE, casual 1984-2014 (field ornithology: bird banding, bird surveys/censusing, ecological studies)

Tutor/demonstrator, Zoology UNE (casual), 2007-13

NSW Dept Environment & Climate Change, 2008-09 (temporary) (threatened species officer: Project Officer, NSW Scientific Committee)

Research Assistant, Ecosystem Management UNE (casual), 2008-09 (bird survey)

Post-doctoral research fellow, Zoology, UNE, 2005-07 (ecology of woodland birds)

Junior research fellow, Zoology, University of New England, 1990-1993, 1998-2004 (ecology of rare forest owls in relation to habitat and forest management; ecology and management of birds)

Technical officer, University Partnerships Pty Ltd (UNE), 1995-1996 (fauna survey and report, Eastlink EIS)

Casual assistant demonstrator, Depts Zoology and Ecosystem Management, UNE, 1988-2002 (field practical classes on population ecology and behavioural ecology of birds)

Casual teacher, New England Institute of TAFE, 1987-1993 (bird biology: including laboratory and field practical classes on classification, identification and ecology)

Field technician, National Parks & Wildlife Service Armidale, 1986 (fauna inventory, vegetation sampling and analysis)

Research assistant, Department of Ecosystem Management, University of New England, casual 1986-1987 (field survey of vegetation and fauna)

Honorary position:

Adjunct associate lecturer/research associate, Zoology UNE, 2004-2017 (includes collaborative research and publication, co-supervision of Honours/Masters/PhD students)

Consultant biologist:

Whitehaven Coal 2018 (field survey, assessment and report on potential BioBank site for Regent Honeyeater)

Northern Tablelands Local land Services 2017-18 (Birds of Prey Monitoring project: nest sites and productivity of threatened raptors on the tablelands – field survey and report)

North West Local Land Services 2015-18 (Regent Honeyeater, Swift Parrot, raptor and woodland bird surveys and reporting)

28 South Environmental 2013-2018 (threatened fauna survey/assessment and report)

Fenner School of Environment and Society, Australian National, University 2016-17 (Regent Honeyeater surveys and data submission)

3E Environmental 2012-17 (flora & fauna survey and reporting)

BirdLife Australia – Northern NSW (for Bundarra-Barraba Operations Group of the Regent Honeyeater Recovery Team), 2007-17 (Regent Honeyeater/woodland bird survey and monitoring)

Southern New England Landcare 2014-16 (fauna surveys on farms, data submission, landholder workshop, report review)

James Warren & Associates 1997-2016 (fauna survey and reporting)

Conacher Environmental Group 2008, 2015 (fauna survey and report)

Ecotone Environmental Services 2012-13 (peer review of threatened fauna assessment; targeted fauna survey: federally listed birds)

NSW National Parks & Wildlife Service/Dept Environment & Conservation/DECC 1987-2013 (fauna survey, review of avifaunal component of environmental impact statements/ fauna impact statements/fauna reports, preparation of recovery plans and species profiles for threatened species)

Australian Museum, 1995, 2012 (review of fauna impact statement, avifauna; feather sampling of wild-caught birds for DNA analysis)

Cumberland Ecology 2004-2012 (fauna survey and report)

Arnhem Environmental 1996-2012 (fauna survey)

Eco Logical Australia 2010-2011 (threatened bird research, fauna database compilation)

Warkworth Mining Ltd 2008, 2011 (avifauna survey and report)

Terra Consulting/Geolyse/Orogen 2004-11 (fauna survey and assessment)

State Forests of NSW 1987-2009 (fauna survey, review of avifaunal component of environmental impact statements/fauna impact statements/fauna reports, fauna survey worskhop)

TransGrid 2009 (investigation and report: bird-related outages on 500 kV transmission lines)

Earth Services 2007-08 (fauna survey and report)

Armidale Dumaresq Council 2006-08 (fauna assessment)

Tamworth Regional Council 2007-08 (starling control/raptor assessment)

PLACE Environmental 2006-07 (fauna assessment)

ACT Planning & Land Authority 2005-06 (fauna survey and assessment)

Greenloaning Biostudies 1996-2004 (fauna survey)

Burnett Shire Council 2003 (fauna survey and assessment)

Inverell Shire Council 2003 (fauna assessment)

HWR Ecological 2003 (fauna survey)

WBM Oceanics 1999-2002 (fauna survey)

Resource Strategies 1999 (fauna survey)

Network Design & Construction Ltd, 1999 (fauna survey)

Woodward-Clyde Pty Ltd, 1994-1999 (fauna survey)

Telstra Environmental Evaluation Team 1998 (fauna survey and report)

Maunsell Pty Ltd, 1995-97 (fauna survey, review of environmental assessment)

Austeco Pty Ltd, 1990-1997 (fauna survey)

North-west Ecological Services 1997 (fauna survey)

ANCA 1995-1996 (fauna survey, Jervis Bay National Park)

SA National Parks & Wildlife Service, 1995 (fauna survey)

Grants and awards:

Search for Red Goshawk in NSW: $1,000 from the Australian Bird Environment Fund (Bird Observers Club of Aust.), 1987.

Distribution, status and habitat requirements of the Sooty Owl in northern NSW: $2,000 as a Cayley Memorial Scholarship (Gould League of NSW) 1990-93; with Associate Professors Hugh Ford & Harry Recher (UNE), $34,280 from WWF Australia and $64,835 from ANPWS (Endangered Species Program) 1990-93.

Will wildlife corridors work for sedentary birds?: with Professor Hugh Ford, $42,565 from the NSW Environmental Trust 2005, $43,359 in 2006-07.

Bird Observers Club of Australia: Distinguished Service Award, 2005 (editing the *Australian Bird Watcher*/*Australian Field Ornithology* for 21 years 1984-2005).

Royal Zoological Society of NSW Whitley Award, 2013 (*Birds of Prey of Australia: A Field Guide*, 2nd edn, best vertebrate guide in 2012)

BirdLife Australia's D.L. Serventy Medal for publication in ornithology, 2015

Voluntary work:

Editor: *Australasian Raptor Association News* 1980-1989 and *Boobook* (re-named) 2004-17 (biannual journal for bird-of-prey enthusiasts); *Australian Field Ornithology* 1984-2015 (quarterly journal)

Sub-editor: *Corella* Wedge-tailed Eagle special issue, 2007; White-bellied Sea-Eagle special issue, 2009; rare raptors special issue, 2011

Committee member: Australian Bird Study Association 1981-1988, 2005-17; Birds Australia Northern NSW Group 1996-99, 2004-12, 2015-17; Australasian Ornithological Conference 2009 organising committee 2008-09; ABSA/BirdLife Southern NSW conference organising committee 2013-14

Regent Honeyeater Recovery Team: Bundarra-Barraba Operations Group rep, 2008-18

Red Goshawk National Recovery Team 2014-18

Publications:

~130 refereed papers (selection appended), books and book contributions, theses: see appended list

Refereed publications (selected titles):

Debus, S.J.S. 1984. Biology of the Little Eagle on the Northern Tablelands of New South Wales. *Emu* 84: 87-92.

_____, Ley, A.J., Trémont, S. & Trémont, R. 1991. Breeding behaviour and diet of the Australian Hobby *Falco longipennis* in northern New South Wales. *Aust. Bird Watcher* 14: 123-137.

Debus, S.J.S. 1992. A survey of diurnal raptors in north-east New South Wales, 1987-1990. *Aust. Birds* 25: 67-77.

Debus, S.J.S. 1993a. The mainland Masked Owl *Tyto novaehollandiae*: a review. *Aust. Bird Watcher* 15: 168-191.

_____ 1993b. The status of the Red Goshawk *Erythrotriorchis radiatus* in New South Wales, in Olsen, P.D. (Ed.), *Australian Raptor Studies*, pp. 182-191. Australasian Raptor Association, RAOU, Melbourne.

Debus, S.J.S., Ley, A.J., Trémont, S.M., Trémont, R.M. & Collins, J.L. 1993. Breeding behaviour and diet of the Collared Sparrowhawk *Accipiter cirrhocephalus* in northern New South Wales. *Aust. Bird Watcher* 15: 68-91.

Debus, S.J.S., McAllan, I.A.W. & Mead, D.A. 1993a,b. Museum specimens of the Red Goshawk *Erythrotriorchis radiatus*. I. Annotated list of specimens; II. Morphology, biology and conservation status in eastern Australia. *Sunbird* 23: 5-28; 75-89.

Debus, S.J.S., McAllan, I.A.W. & Morris, A.K. 1993. The Square-tailed Kite *Lophoictinia isura* in New South Wales. *Aust. Birds* 26: 104-118.

Peake, P., Conole, L.E., Debus, S.J.S., McIntyre, A. & Bramwell, M. 1993. The Masked Owl *Tyto novaehollandiae* in Victoria. *Aust. Bird Watcher* 15: 124-136.

Ford, H.A., Davis, W.E., Debus, S., Ley, A., Recher, H. & Williams, B. 1993. Foraging and aggressive behaviour of the Regent Honeyeater *Xanthomyza phrygia* in northern New South Wales. *Emu* 93: 277-281.

Debus, S.J.S. 1994. The Sooty Owl *Tyto tenebricosa* in New South Wales. *Aust. Birds* 28 supplement: 4-19.

_____ & Chafer, C.J. 1994. The Powerful Owl *Ninox strenua* in New South Wales. *Aust. Birds* 28 supplement: 21-38.

_____ & Rose, A.B. 1994. The Masked Owl *Tyto novaehollandiae* in New South Wales. *Aust. Birds* 28 supplement: 40-64.

Debus, S.J.S. 1995. Surveys of large forest owls in northern New South Wales: methodology, calling behaviour and owl responses. *Corella* 19: 38-50.

Kavanagh, R.P., Debus, S., Tweedie, T. & Webster, R. 1995. Distribution of nocturnal forest birds and mammals in north-eastern New South Wales: relationships with environmental variables and management history. *Wildlife Research* 22: 359-377.

Debus, S.J.S. 1997a. A survey of the raptors of Jervis Bay National Park. *Aust. Birds* 30: 29-44.

_____ 1997b. The Barking Owl in New South Wales. *Aust. Birds* 30: 53-80.

_____ 1997c. Aspects of the biology of captive-bred, hack-released Masked Owls *Tyto novaehollandiae*. In Czechura, G. & Debus, S. (Eds), *Australian Raptor Studies II*, pp. 14-33. Birds Australia Monograph 3, Birds Australia, Melbourne.

_____ 1997d. Vocal behaviour of the Southern Boobook *Ninox novaeseelandiae* and other nocturnal birds. In Czechura, G. & Debus, S. (Eds), *Australian Raptor Studies II*, pp. 71-85. Birds Australia Monograph 3, Birds Australia, Melbourne.

Mathieson, M.T., Debus, S.J.S., Rose, A.B., McConnell, P.J. & Watson, K.M. 1997. Breeding diet of the Letter-winged Kite *Elanus scriptus* and Black-shouldered Kite *Elanus axillaris* during a House Mouse plague. *Sunbird* 27: 65-71.

Debus, S.J.S., Maciejewski, S.E. & McAllan, I.A.W. 1998. The Grass Owl in New South Wales. *Aust. Birds* 31: 29-45.

Brigham, R.M., Debus, S.J.S. & Geiser, F. 1998. Cavity selection for roosting, and roosting ecology of forest-dwelling Australian Owlet-nightjars (*Aegotheles cristatus*). *Aust. J. Ecol.* 23: 424-429.

Bischoff, T., Lutter, H. & Debus, S. 2000. Square-tailed Kites breeding on the mid-north coast of New South Wales. *Aust. Bird Watcher* 18: 233-240.

Brown, B., Brown, F. & Debus, S.J.S. 2000. Further observations on a pair of Square-tailed Kites nesting near Grafton, New South Wales. *Aust. Bird Watcher* 18: 270-273.

Debus, S.J.S. & Rose, A.B. 2000. Diet of Grey Falcons *Falco hypoleucos* breeding extralimitally in New South Wales. *Aust. Bird Watcher* 18: 280-281.

Harrington, G.N. & Debus, S.J.S. 2000. Dietary items of the Rufous Owl *Ninox rufa* on the Atherton Tableland, north Queensland. *Aust. Bird Watcher* 18: 251-252.

Debus, S.J.S. 2001. Surveys of the Barking Owl and Masked Owl on the North-west Slopes of New South Wales. *Corella* 25: 5-11.

Barnes, C.P., Zillmann, E.E., Rose, A.B. & Debus, S.J.S. 2001. Diet and biology of the Square-tailed Kite *Lophoictinia isura* in south-eastern Queensland: nest-building to post-fledging. *Aust. Bird Watcher* 19: 28-43.

Debus, S.J.S., Agnew, L.R. & Schulz, M. 2001. Surveys of the Grass Owl *Tyto capensis* in coastal New South Wales. *Aust. Bird Watcher* 19: 94-102.

Debus, S.J.S. 2002. Distribution, taxonomy, status and major threatening processes of owls of the Australasian Region. In Newton, I., Kavanagh, R., Olsen, J. & Taylor, I. (Eds), *Ecology and Conservation of Owls*, pp. 355-363. CSIRO, Melbourne.

Griffiths, H., Lutter, H., Rose, A.B. & Debus, S.J.S. 2002. Breeding and diet of a pair of Square-tailed Kites *Lophoictinia isura* on the mid-north coast of New South Wales. *Aust. Bird Watcher* 19: 184-193.

Debus, S.J.S. & Rose, A.B. 2003. Diet of a Barking Owl *Ninox connivens* in the channel country of south-west Queensland. *Corella* 27: 18-19.

Lutter, H., Dinnie, R. & Debus, S.J.S. 2003. Square-tailed Kites breeding in northern coastal New South Wales: post-fledging diet and behaviour. *Aust. Field Ornithology* 20: 94-104.

Debus, S.J.S., Olsen, J. & Rose, A.B. 2004. Diet of the Barn Owl *Tyto alba* near Lake Frome in arid South Australia. *Corella* 28: 40-42.

Debus, S.J.S. & Rose, A.B. 2004. Diet of the Barn Owl *Tyto alba* near Tamworth, New South Wales. *Corella* 28: 95.

Lutter, H., Lutter, M., Rose, A.B. & Debus, S.J.S. 2004. Breeding biology and diet of the Square-tailed Kite on the mid-north coast of New South Wales. *Aust. Field Ornithology* 21: 141-157.

Olsen, J., Debus, S., Rose, A.B. & Hayes, G. 2004. Breeding success, cliff characteristics, and diet of Peregrine Falcons at high altitude in the Australian Capital Territory. *Corella* 28: 33-37.

Barnes, C.P., Rose, A.B. & Debus, S.J.S. 2005. Breeding behaviour and diet of a family of Barking Owls *Ninox connivens* in south-eastern Queensland. *Aust. Field Ornithology* 22: 182-195.

Debus, S.J.S. 2005. White-bellied Sea-Eagles breeding in the Australian Capital Territory? *Canberra Bird Notes* 30: 146-147.

Debus, S.J.S., Ford, J.A. & Rose, A.B. 2005. Breeding-season diet of a pair of Barking Owls near Armidale, New South Wales. *Corella* 29: 15-16.

Debus, S.J.S. & Lollback, G. 2005. Breeding behaviour of the Restless Flycatcher near Armidale, New South Wales. *Aust. Field Ornithology* 22: 22-28.

Debus, S.J.S. & Rose, A.B. 2005. Spring diet of Pied Currawongs at Imbota Nature Reserve, Armidale, New South Wales. *Corella* 29: 19-21.

Debus, S.J.S., Hatfield, T.S., Olde, G.S. & Rose, A.B. 2005. Breeding behaviour and diet of a pair of Black Falcons *Falco subniger* in northern New South Wales. *Aust. Field Ornithology* 22: 165-181.

Courtney, J. & Debus, S.J.S. 2006a. Breeding habits and conservation status of the Musk Lorikeet *Glossopsitta concinna* and Little Lorikeet *G. pusilla* in northern New South Wales. *Aust. Field Ornithology* 23: 109-124.

_____ & _____ 2006b. Observations on the post-fledging period of the Barn Owl *Tyto alba*. *Aust. Field Ornithology* 23: 159-162.

Debus, S.J.S. 2006a. Breeding and population parameters of robins in a woodland remnant in northern New South Wales, Australia. *Emu* 106: 147-156.

_____ 2006b. Breeding biology and behaviour of the Scarlet Robin *Petroica multicolor* and Eastern Yellow Robin *Eopsaltria australis* in remnant woodland near Armidale, New South Wales. *Corella* 30: 59-65.

_____ 2006c. Breeding habitat and nest-site characteristics of Scarlet Robins and Eastern Yellow Robins near Armidale, New South Wales. *Pacific Conservation Biology* 12: 261-271.

_____ 2006d. The role of intense nest predation in the decline of Scarlet Robins and Eastern Yellow Robins in remnant woodland near Armidale, New South Wales. *Pacific Conservation Biology* 12: 279-287.

Debus, S.J.S. & Rose, A.B. 2006. Supplementary data on breeding and diet of the Northern Forest Raven *Corvus tasmanicus boreus*. *Aust. Field Ornithology* 23: 96-101.

Debus, S.J.S., Ford, H.A. & Page, D. 2006. Bird communities in remnant woodland on the New England Tablelands, New South Wales. *Pacific Conservation Biology* 12: 50-63.

Debus, S.J.S., Ford, H.A. & Trémont, S.M. 2006. Bird communities in remnant woodland on the upper North-west Slopes of New South Wales. *Aust. Zoologist* 33: 519-529.

Debus, S.J.S., Lollback, G., Oliver, D.L. & Cairns, S.C. 2006. The birds of Bulgunnia and Mulyungarie Stations in the pastoral zone of arid South Australia. *South Australian Ornithologist* 35: 27-37.

Debus, S.J.S., Olde, G.S., Marshall, N., Meyer, J. & Rose, A.B. 2006. Foraging, breeding behaviour and diet of a family of Black-shouldered Kites *Elanus axillaris* near Tamworth, New South Wales. *Aust. Field Ornithology* 23: 130-143.

Lutter, H., McGrath, M.B., McGrath, M.A. & Debus, S.J.S. 2006. Observations on nesting Brahminy Kites *Haliastur indus* in northern New South Wales. *Aust. Field Ornithology* 23: 177-183.

Debus, S.J.S. 2007a. Avifauna of remnant bushland in south-east Queensland I: Brisbane and hinterland. *Sunbird* 37(2): 14-24.

_____ 2007b. Avifauna of remnant bushland in south-east Queensland II: The Gold Coast hinterland. *Sunbird* 37(2): 25-32.

_____ 2007c. Avifauna of remnant bushland in south-east Queensland III: The Sunshine Coast and hinterland. *Sunbird* 37(2): 33-44.

_____ 2007d. Avifauna of remnant bushland on the Tweed Coast of New South Wales. *Sunbird* 37(2): 45-55.

Debus, S.J.S. & Wood, C. 2007. Growth of a nestling Masked Owl *Tyto novaehollandiae*. *Aust. Field Ornithology* 24: 49-53.

Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007a. Breeding biology and diet of the Wedge-tailed Eagle *Aquila audax* in the New England region of New South Wales. *Aust. Field Ornithology* 24: 93-120.

Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007b. Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales. *Aust. Field Ornithology* 24: 137-157.

Debus, S.J.S., Ley. A.J. & Rose, A.B. 2007. Winter diet of a Barn Owl and a Nankeen Kestrel in Diamantina National Park, western Queensland. *Sunbird* 37: 1-8.

Debus, S.J.S. 2008a. The effect of Noisy Miners on small bush birds: an unofficial cull and its outcome. *Pacific Conservation Biology* 14: 185-190.

Debus, S.J.S. 2008b. Biology and diet of the White-bellied Sea-Eagle *Haliaeetus leucogaster* breeding in northern inland New South Wales. *Aust. Field Ornithology* 25: 165-193.

Debus, S.J.S., Ley, A.J. & Rose, A.B. 2008. Further dietary items of the Eastern Barn Owl *Tyto javanica* in Diamantina National Park, Queensland. *Australian Field Ornithology* 25: 149–152.

Trost, S., Olsen, J., Rose, A.B. & Debus, S.J.S. 2008. Winter diet of Southern Boobooks *Ninox novaeseelandiae* in Canberra 1997-2005. *Corella* 32: 66-70.

Debus, S.J.S. & Ley, A.J. 2009. Aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides*. *Australian Field Ornithology* 27: 76-99.

Cherriman, S.C., Foster, A. & Debus, S.J.S. 2009. Supplementary notes on the breeding behaviour of Wedge-tailed Eagles *Aquila audax*. *Australian Field Ornithology* 27: 142-147.

Ford, H.A., Walters, J.R., Cooper, C.B., Debus, S.J.S. & Doerr, V.A.J. 2009. Extinction debt or habitat change? – Ongoing losses of woodland birds in north-eastern New South Wales, Australia. *Biological Conservation* 142: 3182-3190.

Debus, S.J.S., Ley, A.J. & Rose, A.B. 2010. Diet of the Eastern Barn Owl *Tyto (javanica) delicatula* in Diamantina National Park, south-western Queensland, in 2008–2009. *Australian Field Ornithology* 27: 179-183.

Olsen, J., Fuentes, E., Judge, D., Rose, A.B. & Debus, S.J.S. 2010. Diets of Wedge-tailed Eagles (*Aquila audax*) and Little Eagles (*Hieraaetus morphnoides*) breeding near Canberra, Australia. *J. Raptor Research* 44: 50-61.

Debus, S.J.S. 2011. Parental time-budgets and breeding behaviour of the Little Eagle *Hieraaetus morphnoides* in northern New South Wales. *Corella* 35: 65-72.

Debus, S.J.S. & Olsen, J. 2011. Some aspects of the biology of the Black Falcon *Falco subniger*. *Corella* 35: 29-36.

Debus, S.J.S. & Tsang, L.R. 2011. Notes on Black Falcons *Falco subniger* breeding near Tamworth, New South Wales. *Australian Field Ornithology* 28: 13-26.

Barnes, C.P. & Debus, S.J.S. 2012. A snapshot in the post-fledging period of the Black Falcon. *Australian Field Ornithology* 29: 86-88.

Debus, S.J.S. 2012. Hunting behaviour of Black Falcons. *Australian Field Ornithology* 29: 83-85.

Debus, S.J.S. & Ford, H.A. 2012. Responses of Eastern Yellow Robins *Eopsaltria australis* to translocation into vegetation remnants in a fragmented landscape. *Pacific Conservation Biology* 18: 194-202.

O'Donnell, W.B. & Debus, S.J.S. 2012. Nest-sites and foraging of the White-bellied Sea-Eagle *Haliaeetus leucogaster* on the subtropical eastern Australian coast. *Australian Field Ornithology* 29: 149-159.

Debus, S.J.S. 2013. Breeding of the Hooded Robin *Melanodryas cucullata* in native and exotic woodlands near Armidale, New South Wales. *Corella* 37: 49-56.

Debus, S.J.S. & Zuccon, A.E. 2013. Observations on hunting and breeding behaviour of the Black Falcon *Falco subniger*. *Sunbird* 43: 12-26.

Debus, S.J.S., Olsen, J., Judge, D. & Butterfield, M. 2013. Numbers of breeding Little Eagles *Hieraaetus morphnoides* near Canberra in relation to atlas counts. *Corella* 37: 30-32.

Olsen, J., Debus, S.J.S. & Judge, D. 2013. Declining Little Eagles *Hieraaetus morphnoides* and increasing rabbit numbers near Canberra: is secondary poisoning by Pindone the problem? *Corella* 37: 33-35.

Olsen, J., Debus, S.J.S., Judge, D. & Rose, A.B. 2013. Diets of Wedge-tailed Eagles *Aquila audax* and Little Eagles *Hieraaetus morphnoides* breeding near Canberra, 2008–2009. *Corella* 37: 25-29.

Olsen, J., Debus, S.J.S., Rose, A.B. & Judge, D. 2013. Diets of White-bellied Sea-Eagles *Haliaeetus leucogaster* and Whistling Kites *Haliastur sphenurus* breeding near Canberra, 2003–2008. *Corella* 37: 13-18.

Trainor, C.R., Debus, S.J.S., Olsen, J., Norman, J.A. & Christidis, L. 2013. Bonelli's Eagle *Aquila fasciata renschi* in the Lesser Sundas, Wallacea: distribution, taxonomic status, likely origins and conservation status. *Forktail* 29: 100-106.

Barnes, C.P. & Debus, S.J.S. 2014. Observations on the post-fledging period of the Collared Sparrowhawk (*Accipiter cirrocephalus*). *Sunbird* 44: 12-23.

Charley, D., Lutter, H. & Debus, S.J.S. 2014. Breeding behaviour and prey of Black Falcons, *Falco subniger*, including food-caching. *South Australian Ornithologist* 40: 11-30.

Debus, S.J.S. & Searle, J.B. 2014. Surveys of the Red Goshawk and other raptors on the Weipa Plateau, Cape York Peninsula. *Sunbird* 44: 36-51.

Debus, S.J.S., Baker, G., Owner, D. & Nottidge, B. 2014. Response of White-bellied Sea-Eagles *Haliaeetus leucogaster* to encroaching human activities at nest sites. *Corella* 38: 53-62.

Baylis, T., van Gessel, F.W. & Debus, S.J.S. 2015. Some vocalisations of the Grey Falcon *Falco hypoleucos*. *Corella* 39: 73-76.

Debus, S.J.S. 2015. Assessment of band recoveries for three Australian eagle species. *Corella* 39: 67-72.

Debus, S.J.S., Baker-Gabb, D.J. & Aumann, T.A. 2015. Parental time-budgets, breeding behaviour and affinities of the Red Goshawk *Erythrotriorchis radiatus*. *Corella* 39: 87-93.

Aumann, T.A., Baker-Gabb, D.J. & Debus, S.J.S. 2016. Breeding diets of four raptor species in the Australian tropics. *Corella* 40: 13-16.

Bishop, D., Diamond, J., Hornbuckle, J. & Debus, S. 2016. New breeding, distribution and prey records for the Pygmy Eagle *Hieraeetus weiskei*. *Australian Field Ornithology* 33: 224-226.

Rourke, J. & Debus, S.J.S. 2016. The breeding cycle of a pair of Brahminy Kites *Haliastur indus* in New South Wales. *Australian Field Ornithology* 33: 151-155.

Whelan, D.J., McRitchie, B.W., Pickering, L.J. & Debus, S.J.S. 2016. Observations on a breeding pair of Black Falcons *Falco subniger* in southern Victoria. *Australian Field Ornithology* 33: 159-166.

Debus, S.J.S., Bauer, A.L. & van Gessel, F.W. 2017. Calls and vocal behaviour of the Black Falcon *Falco subniger*. *Corella* 41: 83-87.

Debus, S.J.S., Bauer, A.L. & Mitchell, G.I. 2017. Breeding biology, behaviour and foraging ecology of the Black Falcon *Falco subniger* near Tamworth, New South Wales. *Corella* 41: 71-82.

Debus, S.J.S., Martin, W.K. & Lemon, J.M. 2017. Changes in woodland bird communities as replanted woodland matures. *Pacific Conservation Biology* 23: 359-371.

Olsen, J., Judge, D., Trost, S., Rose, A.B. & Debus, S.J.S. 2018. Diets of breeding Brown Goshawks *Accipiter fasciatus* and Collared Sparrowhawks *A. cirrocephalus* near Canberra, Australia: comparisons with other regions and raptor species. *Corella* 42: 18-28.

Debus, S.J.S., McAllan, I.A.W. & Schodde, R. Submitted. *Circus assimilis* Jardine & Selby, 1828 and *Circus approximans* Peale, 1848 (Aves, Accipitriformes): conservation of usage by designation of a neotype for *Circus assimilis* Jardine & Selby, 1828. *Bulletin of Zoological Nomenclature*.

Palmer, R., Rose, A.B. & Debus, S.J.S. Submitted. Diet of the Peregrine Falcon *Falco peregrinus* in inland south-western Australia. *Australian Field Ornithology*.

Schoeb, M., Werner, R., Janetzki, H. & Debus, S.J.S. In prep. Black Falcons *Falco subniger* breeding near Mackay in coastal Queensland. *Australian Field Ornithology*.

Books:

Debus, S.J.S. 1993. Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Square-tailed Kite, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.

_____ 1994. Australasian raptor species texts in del Hoyo, J., Elliott, A. & Sargatal, J. (Eds), *Handbook of the Birds of the World* vol. 2. Lynx, Barcelona.

_____ 1996. Turnicidae, buttonquail species texts in del Hoyo, J., Elliott, A. & Sargatal, J. (eds), *Handbook of the Birds of the World* vol. 3. Lynx, Barcelona.

Czechura, G. & Debus, S. (Eds) 1997. *Australian Raptor Studies II*. Birds Australia Monograph 3, Birds Australia, Melbourne.

Debus, S. 1998. *The Birds of Prey of Australia: A Field Guide*. Oxford University Press, Melbourne.

Debus, S.J.S. (Ed.) 1999. Strigiformes, Caprimulgiformes species accounts in Higgins, P.J. (Senior Ed.), *Handbook of Australian, New Zealand and Antarctic Birds, Volume 4, Parrots to Dollarbird*, Oxford University Press, Melbourne.

Debus, S. 1999. Red Goshawk, Barking Owl species accounts in Ayers, D., Nash, S. & Baggett, K., *Threatened Species of Western New South Wales*, National Parks & Wildlife Service, Sydney (revised edition).

Olsen, P., Debus, S., Shea, C.J., Bildstein, K.L. & Ellis, S. (Eds) 2000. *Selected Australasian Falconiformes Conservation Assessment and Management Plan*. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley (MN, USA).

Debus, S. 2009. *The Owls of Australia: A Field Guide to Australian Night Birds*. Envirobook, Sydney.

_____ 2009. Australasian crow/raven species texts in del Hoyo, J., Elliott, A. & Christie, D. (Eds), *Handbook of the Birds of the World* vol. 14. Lynx, Barcelona.

Curtis, L.K., Dennis, A.J., McDonald, K.R., Kyne, P.K. & Debus, S.J.S. (Eds) 2012. *Queensland's Threatened Animals* (Debus: Powerful Owl, Rufous Owl, Masked Owl species accounts). CSIRO Publishing, Melbourne.

Debus, S. 2012. *Birds of Prey of Australia: A Field Guide*, 2nd edn. CSIRO Publishing, Melbourne.

Debus, S. 2017. *Australasian Eagles and Eagle-like Birds*. CSIRO Publishing, Melbourne.

Debus, S. Submitted. Grey Falcon and Black Falcon chapters in Leonardi, G. (Ed), *Falcons of Arid Environments* (in prep.). To be published privately, Catania, Italy.

Theses:

Debus, S. 1994. Aspects of the biology, conservation and management of threatened forest owls and raptors in northern New South Wales. MSc thesis, University of New England, Armidale.

Debus, S. 2004. The impact of habitat fragmentation on woodland birds: A test of some hypotheses in New England. PhD thesis, University of New England, Armidale.

Strategic Assessment

for the

Square-tailed Kite *Lophoictinia isura*

in the

Greater Macarthur Growth Area

and the

Wilton Growth Area

Report prepared for the Department of Environment and Planning

Prepared by Tony Saunders and Stephen Debus
Merops Services Pty Ltd

Prepared August 2018

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Strategic Assessment for the Square-tailed Kite *Lophoictinia isura* in the Growth Areas of Greater Macarthur and Wilton

1. Introduction

Purpose

The purpose of this report is to assess the likelihood of occurrence and potential impacts of the urban growth in the Greater Macarthur and Wilton areas on the Square-tailed Kite *Lophoictinia isura*. In particular, this report will assess the presence of breeding and foraging habitat within these growth areas as required under the Biodiversity Assessment Method. It will also discuss conservation measures required to mitigate potential impacts.

The Square-tailed Kite is listed in New South Wales as vulnerable under the *Biodiversity Conservation Act 2016* and is an uncommon species found in coastal and sub-coastal forests and woodlands. Inland, it shows a preference for timbered watercourses, though not necessarily strictly so near the coast, and is a summer breeding migrant to south-eastern Australia, arriving in September and leaving by March. Records for this species exist in and around the area to be impacted by the development. However, the species is encountered infrequently in this area and its interactions with local habitat have not been well studied.

The existence of potential habitat for the Square-tailed Kite and of records for the species within the area has meant that a more detailed assessment of the likelihood of impacts from the development in the area is required, particularly of the species' foraging and breeding use of the area. Targeted surveys could gather this information, but the survey effort required to collect sufficient data would be great and in the order of hundreds of hours in the appropriate seasons over several years. This would also require tracking of individual birds to gather time budgets and breeding locations and behaviour at nests etc. Access to several potential habitat areas also proved difficult during the survey period. Knowledge of the habitat structure and plant community types (PCTs) that the Kite has been recorded in within the development area and of the ecology of the species can be used as a surrogate for this fieldwork.

Project Context

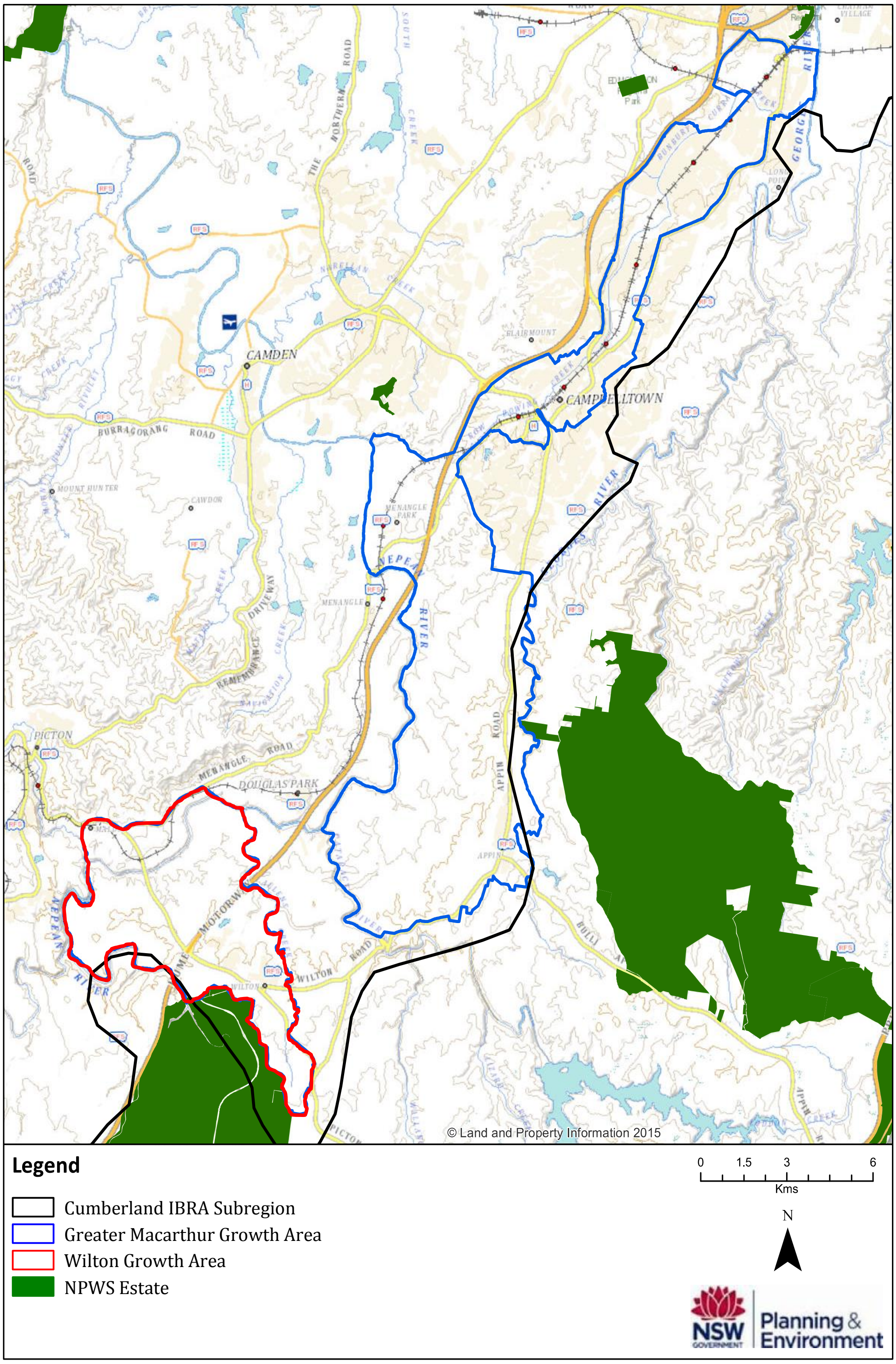
The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

The timeframe for this project, and difficulties in accessing private lands have resulted in some survey challenges for the project. Only 68% of the potential habitat available for this species in the Wilton and Greater Macarthur Growth Areas has been successfully surveyed. Significant areas of the Greater Macarthur Growth Area were unable to be adequately surveyed due to restrictions around land access. Around 363 hectares of potential habitat was not surveyed within this growth area, and only 35% of PCT 850 Grey Box-Red Gum grassy woodland on shale of the southern Cumberland Plain within this growth area was successfully accessed for survey.

Study Area

The study area is in the Macarthur and Wilton areas, which extend from the southern parts of Liverpool, down to Appin, across to Wilton and then towards the area between Wilton and Picton. The area is within the Cumberland IBRA subregion and the location is shown in Figure 1. The area is bound within a latitude range from -33.88 to -34.33 and a longitude range of 150.55 to 150.97.

Figure 1. Location of Growth Areas and the Cumberland IBRA Subregion.



Survey Methods

Vegetation maps (as supplied by The Department of Planning and Environment NSW) of the Greater-Macarthur Growth Area and the Wilton Growth Area were used to select patches of remnant vegetation that may provide suitable habitat for the Square-tailed Kite. Fifty potential sites were chosen from these maps. Sufficient access was feasible for 40 of these remnants.

The remnants were visited over 4 days from the 18-06-2018 to the 21-06-2018 inclusive. Each site was surveyed for between 0.5 and 1.0 hours. The aim was to collect qualitative data on each of the following:

habitat structure -	tree height range, DBH range, canopy cover, tree maturity, shrub density, grass cover, ground cover
habitat quality -	tree age diversity, shrub layer diversity, presence of woody weeds, evidence of regeneration
connectivity -	degree of connectivity, relative width of corridor to other remnants, presence of gaps in vegetation
aspect and slope -	slope steepness, direction of slope and relationship of site to structural features e.g. watercourses etc.
avian species -	overall diversity, species composition, presence of feral species

The aim was to assess if these sites contained suitable habitat for foraging and breeding and whether they allowed for dispersal of prey and the target species into and out of the remnants. The extent of suitable habitat across the growth areas was then used to estimate the likelihood of the Kites using the area for foraging and/or breeding.

The Atlas of Living Australia (ALA) and the bird database from the Cumberland Bird Observers Club Inc. (CBOC) were searched for atlas records of the Square-tailed Kite. The records within the Atlas of Living Australia had data mainly from the Bionet Atlas of NSW Wildlife with a few records from un-named individuals contributing directly to the ALA. At the time of access the CBOC bird atlas had over 20,000 survey results for the section of the Cumberland IBRA sub-region that lies within the County of Cumberland. These 2 data sets combined would have captured most of the data on the Kite for this area.

Justification for Use of an Expert Report

The presence of suitable habitat for foraging and breeding for the Square-tailed Kite combined with the low density for this species and the difficulties with gaining sufficient access for surveys to establish the presence and habitat use by the Kite in the development area has meant that survey effort alone has not been able to establish the potential importance of the area for this Kite.

An expert in the breeding and foraging ecology of the Kite would be required to assess the importance of the habitat remnants and the likelihood of occurrence within the growth areas. The Kite is a forest and woodland specialist whose major food in its breeding season is forest and woodland birds, particularly small to medium-sized passerines and the contents of their nests, but also in recent times introduced and native pigeons and doves, and an abundant native bird (the Noisy Miner *Manorina melanocephala*), all of which are increasing in urban and near-urban areas and fragmented bushland. Therefore, an expert would also need to also be expert on the avifauna populations occurring in forest and woodland in the Cumberland IBRA Subregion. The report will address the food resources and foraging space of this raptor as well as the Kite's potential nest sites and breeding habitat within the growth areas.

Credentials of the Experts Preparing this Report

Dr. Tony Saunders

BSc University of Sydney 1976.
Dip.Ed. Sydney Teachers College 1977.
PhD University of Western Sydney 2005.

Company Director and Avian Ecologist, Merops Services Pty Ltd 1995 to present.

Relevant experience in surveys and the study of woodland and forest birds of the Cumberland plain:

- Cumberland Plain woodland bird surveys for the NSW Bird Atlas and then for the CBOC Bird Atlas 1982 to the present.
- Cumberland Plain woodland bird surveys on the UWS Hawkesbury Campus 1998 to 2005.
- Woodland bird surveys for Holroyd Council's reserves and parklands 2008 to 2011.
- Survey for threatened woodland birds in proposed urban development of the former ADI site at Penrith 2002.
- Survey for threatened woodland birds in proposed rural subdivision at Badgerys Creek 2006.
- Presented the opening presentation ' Birds of the Cumberland Plain. What was there? What have we lost?' at the ABSA Conference 2016.
- Presented 'Trends in woodland birds of the Cumberland Plain' at the RZS of NSW Conference in 2016.
- Avifauna surveys of sites for development applications and assessment of status of threatened bird species with recommendations for minimising impact of development on these species within the Cumberland Plain and eastern New South Wales. (21 years)
- Bird habitat assessment of managed landscapes and natural habitat areas and recommendations for habitat enhancement and rehabilitation for birds. (21 years)

Relevant publications relating to woodland birds of the Cumberland Plain:

- Saunders, T. (2016). Birds of the Cumberland Plain. What was there? What have we lost? Abstract from 'Birds of the Cumberland Plain: Past distributions, present studies and the outlook for their future' Australian Bird Study Association Conference - 23 January 2016. *Corella* **40**: 46.

- Saunders, T. (in prep.). Trends in woodland bird populations in the Cumberland Plain. *Australain Zoologist.*

Dr. Stephen Debus

Bachelor Arts (Biology/Behavioural. Science), Dip. Natural Resources (Wildlife), MSc. (Zoology), PhD (Zoology)

Adjunct associate lecturer/research associate, Zoology University of New England, Armidale. 2004 to present
Senior Ecologist (casual) Eco Logical Australia 2014 to present

Relevant experience in surveys and the study of the Square-tailed Kite *Lophoictinia asura* and of woodland birds:

- Birds of Prey Monitoring project: nest sites and productivity of threatened raptors on the tablelands – field survey and report (Northern Tablelands Local Land Services 2017-18)
- Regent Honeyeater, Swift Parrot, raptor and woodland bird surveys and reporting (North West Local Land Services 2015-18)

Relevant publications relating to foraging and breeding biology of the Square-tailed Kite *Lophoictinia isura*:

- Barnes, C.P., Zillmann, E.E., Rose, A.B. and Debus, S.J.S. 2001 Diet and biology of Square-tailed Kites *Lophoictinia isura* breeding in south-eastern Queensland: nest building to post-fledging. *Australian Bird Watcher* 19: 28-43.
- Bischoff, T., Lutter, H. and Debus, S 2000 Square-tailed Kites on the mid-north coast of New South Wales. *Australian Bird Watcher* 18: 233-240.
- Brown, B., Brown, F. and Debus S.J.S. 2000 Further observations on a pair of Square-tailed Kites nesting near Grafton, New South Wales. *Australian Bird Watcher* 18: 270-273.
- Debus, S.J.S. 1993. Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Square-tailed Kite, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.
- Debus, S. 2017. *Australasian Eagles and Eagle-like Birds*. CSIRO Publishing, Melbourne. [Square-tailed Kite chapter is a 25-year update of the Debus 1993 *HANZAB* Kite account.]
- Debus, S. 2012. *Birds of Prey of Australia: A Field Guide*, 2nd ed. CSIRO Publishing, Melbourne.
- Griffiths, H., Lutter, H., Rose, A.B. and Debus, S.J.S. 2002 Breeding and diet of a pair of Square-tailed Kites *Lophoictinia isura* on the mid-north coast of New South Wales. *Australian Bird Watcher* 19: 184-193.
- Lutter, H., Dinnie, R. and Debus S.J.S. 2003 Square-tailed Kites breeding in northern coastal New South Wales: post-fledging diet and behaviour. *Australian Field Ornithology* 20: 94-104.
- Lutter, H., Lutter, M., Rose, A.B. and Debus, S.J.S. 2004 Breeding biology and diet of the Square-tailed Kite on the mid-north coast of New South Wales. *Australian Field Ornithology* 21: 141-157.

2. Species Information

Species Description

Adult Square-tailed Kites are brown with a white crown and face, with dark streaked rufous nape and underparts. The tail is about half the total length and is grey-brown with a dark terminal band (Debus 2012). They can be confused with other raptors, but can be distinguished by the white cap (in adults), long and widely splayed, boldly banded primaries when soaring or gliding on upswept wings, slender bill, small feet and very short legs hidden by feathers when perched and with the long wing tips crossing below the tail tip at rest (Debus 2017). It can often be observed circling low over the tree canopy on upswept wings with spread 'fingers' (Saunders pers. obs.).

Life Cycle

Square-tailed Kites usually occur singly, in pairs or (in the post-fledging period) family groups of adult(s) and fledgling(s) (Debus 2017). The highest count in one survey within the Cumberland County was 4 (CBOC Atlas accessed 29-06-2018), and most records for the Cumberland IBRA subregion were of single birds (ALA accessed 29-06-2018). They are generally solitary during the non-breeding season (Debus 1993). They appear to be long term monogamous as breeding pairs, as they are intolerant of other adults of the same species within their breeding territory and they occupy the same nest site for many years (Debus *et al.* 1993; Bischoff *et al.* 2000). In eastern New South Wales, nest building occurs in July to October, laying in August, incubation in September to November, hatching occurs in September to October, nestlings occur from October to December and fledglings from November to December (Debus 1996; Bischoff *et al.* 2000; Brown *et al*. 2000; Griffiths *et al.* 2002; Lutter *et al.* 2003,2004; Stowe 2009). In the Cumberland County breeding has been recorded from July to February (CBOC Atlas, accessed 29-06-2018). Nestlings remain in the nest for between 55 and 60 days (Barnes *et al.* 1999, 2001; Lutter *et al.* 2003, 2004). Fledglings are dependent on the parents for about 2 months after which they generally disperse (Bischoff *et al.* 2000; Barnes *et al.* 2001; Lutter *et al.* 2003). The generational cycle is estimated to be 10 years (Garnett & Crowley 2000).

Distribution and Abundance

The Square-tailed Kite is an endemic species found over most of the Australian mainland and some larger offshore islands. It avoids the most arid, treeless central regions, where it is scarce or absent (Debus 2012). It is primarily found in open eucalypt forests, woodland and mallee where passerines are common (Garnett 1993). They are generally absent from south-eastern New South Wales during the non-breeding period (Debus 1993) and are considered to be a summer breeding migrant to the south east of New South Wales (Square-tailed Kite species profile, OEH Website, accessed 29-06-2018). Reporting rates were lower during the May to June period in the Central and South Coast regions of New South Wales (Cooper *et al.* 2014). The Kite has been recorded from August to April across the Cumberland County from the coast to the western edge of the Cumberland Plain, with a more widespread distribution in the northern half of the County (CBOC Atlas, accessed 29-06-2018). In the southern part of the Cumberland IBRA Subregion there are records from Liverpool, Macquarie Fields, Ingleburn, Appin, Wilton and Picton areas (ALA Atlas, accessed 29-06-2018, see Section 4 for more details of these atlas records). The latter area encompasses the Greater Macarthur and Wilton growth areas.

The global population of the Square-tailed Kite is estimated to be between 1000 and 10,000 birds (Ferguson-Lees and Christie 2001). Density estimates are based mainly on breeding territories. In the Bendigo area of Victoria the estimate was 25.8 pairs per 1000 km^2 of forest (Robinson *et al.* 2016). In northern coastal NSW the estimates vary from one pair per 120 km^2 to one pair per 170 km^2 (Debus 1996, Lutter *et al.* 2004).

There was a twofold increase in reporting rates in NSW over a 20-year period prior to 2006, mostly concentrated on coastal areas (Cooper *et al.* 2014). Barrett *et al.* (2007) reported a 40.8% increase in reporting rates for NSW, but this was not considered a significant change due to small sample size. Morris *et al.* (1981) reported that the Kite was scarce in coastal NSW based on records prior to the date of publication.

In the County of Cumberland there were only 2 records from more than 100 years ago (Hindwood & McGill 1958). Hoskin (1991) reported that the Kite was only a rare straggler to the County with only a few records. There has been an increase in the number of records over the last two decades and there are now breeding records for the County, from near Asquith in 2012 and 2013 and in Lane Cove National Park in 2015 (Patrick 2016). The Kite has also been recorded in the Shoalhaven area (Chafer *et al.* 1999). There were 40 records for the County in 2017 (CBOC Atlas, accessed 29-06-2018). It was seldom recorded in the Cumberland Plain prior to 1990 but has shown an increase in reporting rate from 0.5% in the 1990s to 2.5% since 2010 (Saunders in prep.). All records for the Liverpool, Campbelltown and Wollondilly Local Government Areas, which includes the growth areas, have been made since 2000 (ALA Atlas, accessed 29-06-2018). There is a recent breeding record for the Cumberland Plain (near Penrith), and recent breeding records for bushland within the Sydney suburbs (Asquith and South Turramurra) (Optland 2015; I. McAllan pers. comm.).

There have been suggestions as to why the Kite has increased in some areas. It appears to be adapting to urban bushland areas around coastal cities where it feeds on abundant native passerines and introduced bird species (Bischoff *et al.* 2000, Debus 2012). Lower competition from the Brown Goshawk *Accipiter fasciatus* (nestling predation) has been suggested as a possible explanation for the increase in breeding observed in the Bendigo area (Robinson *et al.* 2016), but reporting rates for the Brown Goshawk have increased from 2% to 7% over the last six decades in Cumberland Plain woodland sites where the Kite has also increased and so does not support this suggestion (Saunders in prep.).

Habitat Requirements

Square-tailed Kites are found mainly in coastal and sub-coastal eucalypt dominated forests and woodland, as well as treed areas in urban habitats (Debus 1993, Olsen 1995, Debus 2017), open forests and woodland (Cupper & Cupper 1981, Chafer *et al.* 1999, Barrett *et al.* 2007), passerine-rich woodlands when breeding and more open country when not breeding (Olsen *et al.* 1993) and open forests that are contiguous with very large areas of forest (Griffiths *et al.* 2002). They prefer timbered watercourses through open or cleared land and the margins between open and timbered country (Debus 1993).

When breeding, the Kite requires open forest where it can forage for nestlings in the canopy and approach the nest easily (Hollands 1984). Tall living eucalypt trees are chosen for nest sites (Debus 1993), especially where they are close to open edges (Lutter *et al.* 2004). They can tolerant human disturbance and use areas of urban bushland (Bischoff *et al.* 2000, Griffiths *et al.* 2002). Nests are mostly between 15 and 28 metres above ground in trees that range from 20 to 40 metres tall (Cupper & Cupper 1981, Bischoff *et al.* 2000, Barnes *et al.* 2001, Griffiths *et al.* 2002, Lutter *et al.* 2003, 2004, Stowe 2009 and Optland 2015). The minimum requirements for nesting based on the literature review are described in Tables 1 and 2 below.

Table 1. Minimum distances of active Square-tailed Kite nests from developments (collated from various studies cited by Debus 2017, eastern/south-eastern Australia):

Parameter	
Dwelling	60–70 m
Urban area	Within*
Industrial building	–
Sealed road	5–10 m**
Unsealed road	15 m
Track/path	0 m#

*In the carpark of a suburban facility (animal hospital) in a bushland setting
**Almost overhanging the verge of a highway
#Directly over a trail-bike track

Table 2. Minimum criteria for active Square-tailed Kite nest-site characteristics (collated from various studies cited by Marchant and Higgins 1993 and Debus 2017, eastern/south-eastern Australia):

Parameter	Measurement
Forest/woodland patch size	5 ha*
Nest-tree height	20 m
Reference tree height**	10 m
Nest-tree DBH#	30 cm
Reference tree DBH	–
Nest height	9 m

*In fragmented landscapes with much larger patches nearby
**Reference trees are other trees within the nest patch
#Diameter at breast height

There is some information on local vegetation types that are preferred by the Square-tailed Kite. One hundred and twenty one records out of the 289 records held with the CBOC Atlas (accessed 29-06-2018) contain information about the habitat type where the Kite was encountered. In order of most to least common they were:

Tall Forest	17%
Sandstone Woodland	17%
Pastureland with Scattered Trees	17%
Urban Parkland	14%
Cumberland Plain Woodland	13%
Swamp and River Woodland	9%
Heath	9%
Freshwater Wetlands	4%

The OEH Threatened Species Data Collection indicates that the Square-tailed Kite has the potential to inhabit the following plant communities within the Wilton and Greater Macarthur Growth Areas:

835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
850	Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion

The habitat requirements discussed above have been used in this report to identify important habitat areas. They have been grouped into the habitat criteria listed below. The greater the number of criteria that are met the more likely it is that the remnant will provide habitat for Square-tailed Kite.

1. The site contains tall open forest or woodland.
2. The site is near or along a timbered watercourse.
3. The site contains one or more of the following PCTs - 835, 849,850 and 1181.
4. Canopy foliage nesters, particularly honeyeaters, are common on site.
5. The site contains urban edge tolerant bird species e.g. Noisy Miner, Red Wattlebird, Lorikeets, Crested Pigeon or Spotted Dove.
6. Forest or woodland that has open edges around remnants, timbered corridors and along watercourses.
7. Forest or woodland that has tall trees (> 20m) near outer edges or emergent trees suitable for nesting.

3. Description of the Study Area's Relevance to the Square-tailed Kite

Land Use History

Much of the northern half of the Greater Macarthur growth area has been developed as residential, commercial and industrial land decades ago and any remaining habitat can only be found along watercourses and on steep slopes where these developments are not appropriate. Much of this area would have been a mix of cleared grazing land and bushland prior to this stage of development.

The southern half of the Greater Macarthur and the Wilton growth areas contain older small towns, which now have a few larger new residential developments. These occupy only a small area within the growth area. Much of the land consists of small to medium rural holdings and grazing agricultural land that was cleared for farming decades ago. Throughout this area there are many watercourses that are tributaries to either the Georges or Nepean rivers and the forests along these watercourses has largely been left intact with some clearing or thinning at the edges. Many of the remnant patches and forested watercourses have been affected by woody weed invasion since development in the area.

Landscape Context

The growth areas follow the transport corridor along the Hume Motorway that connects the area to the south-western areas of greater Sydney to the north. The area abuts intact, contiguous, forested areas to the east and to the south. These are in water catchments or national park reserves, which cover hundreds of square kilometres. The western edge abuts mostly cleared rural holdings either side of the Nepean River and then further west to the Warragamba Dam water catchment area.

Much of the region is in the western half of the Cumberland IBRA subregion, which contains most of the remaining large woodland remnants and is an important area for this reason. The woodlands of the Cumberland Plain are threatened ecological communities and have been prioritised by the Office of Environment and Heritage for habitat protection and enhancement (DECCW 2010).

Native Vegetation

The remnant native vegetation within the growth areas is mainly eucalypt forest and woodland. Forested areas on steep slopes and along watercourses have largely been left intact and often contain a structurally and species diverse understorey. Woodland areas remaining on flat or gently undulating land have a few scattered dense patches of understorey, but are mostly open woodland with a grassy understorey. Many remnants have been invaded by woody weeds and many woodland remnants are subjected to grazing pressure and are clear of any understorey. Some of the remnants have also been thinned and have only scattered paddock trees along their edges.

The following plant community types are found in these remnants within the growth areas:

PCT Codes and Names

- 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- 850 Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 877 Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion
- 1081 Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion
- 1292 Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion
- 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion

Potential Habitat

Most of the uncleared areas in the northern half of the Greater Macarthur growth area are remnant forest patches along watercourses that were unsuitable for development. They are small, often isolated and mostly surrounded by urban development with little or no open areas surrounding each remnant to act as buffers. Some have open areas within them that have mown grass and are now parkland. Only the steeper slopes along the watercourse have any shrub layer, but they also have tall eucalypts that provide suitable foraging habitat and potential nesting trees. This area has a major watercourse near the eastern edge, which is the Georges River. This river would provide access to the reserves that provide some suitable resources for the Kite.

The southern half of the Greater Macarthur and the Wilton growth areas have small areas of urban development and larger areas of open grazed pastureland and rural holdings. There are very large remnants of forest and woodland that mainly follow watercourses that are connected to either the Georges or Nepean Rivers. In the south and east sections of the growth areas many of these forest remnants are also part of contiguous habitat into water catchment reserves or national parks. The forest remnants often border open areas with scattered trees and provide good edge habitat for the Kite.

Some 40 sites, scattered over the whole length of the growth areas, were sampled for habitat quality and their ability to provide foraging and nesting resources for the Kite. Fifty potential sites were selected based on the vegetation maps of the area but access into much of the area was difficult. The habitat requirements for the Kite are described in detail in Section 2 of the report and are grouped into seven different criteria for assessing suitable habitat. Details of each site's location, their PCTs and which of the criteria were satisfied are listed below (see Table 1) and a more-detailed description of each site can be found in Appendix 1. All of the sites met at least one of the criteria and 27 of the sites meet at least 5 of the 7 criteria. The PCTs where the Kite has been observed from previous records (Bionet Atlas of NSW Wildlife, accessed 29-06-2018) include 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, 850 Grey Box - Forest Red Gum grassy woodland on shale of the Cumberland Plain, Sydney Basin Bioregion and 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion, which were recorded on many sites. Most of the larger remnants in the south Greater Macarthur and in the Wilton growth areas contain PCT 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion. Many of these sites contain emergent Grey Gums *Eucalyptus punctata,* which would provide nesting sites and this tree species would provide foraging opportunities because it is also popular with honeyeaters and other small passerines (Saunders and Burgin 2001).

These sites represent only a small portion of the forest remnants within the growth areas, yet nearly all sites satisfied many of the criteria used to assess whether suitable habitat existed on-site for the Kite. This implies that most of the remaining forest and woodland habitat in the area is potential Kite habitat, especially as the remnants are tall, have open edges and follow watercourses. Open areas that exist adjacent to the forest and woodland remnants, and especially between open woodland patches and timbered watercourses should also be accepted as potential habitat for the Kite. All forest, woodland and open areas that provide potential habitat will be shown as species polygons in Section 4 of this report. It should be noted that some of the important open areas adjacent to forest and woodland remnants overlap with the urban development footprint.

Table 3. Criteria relating to habitat resources for the Square-tailed Kite that were satisfied for each of the study sites.

Site No.	Latitude	Longitude	PCTs	Criteria Satisfied
1	-33.96801	150.90682	849	1,2,3,5,6,7
2	-33.97577	150.90994	835, 849	1,2,3,4,5,6,7
3	-33.98336	150.89717	1395	1,2,3,4,5,6,7
4	-33.99160	150.87588	835	1,2,3,5,6,7
5	-33.99667	150.87933	849	3,5,6
6	-33.00763	150.86866	835	2,3,5
7	-34.01357	150.85682	835, 1395	1,2,3,5,6,7
8	-34.01049	150.84202	849	3,6,7
9	-34.00402	150.83964	1395	3
10	-34.03953	150.84055	849	2,3,5,6
11	-34.05475	150.83743	1081, 1181	1,2,3,4,5,6,7
12	-34.05460	150.81757	850	1,3,5
13	-34.05984	150.79926	850	2,3,5,6,7
14	-34.05677	150.80422	850	2,3,
15	-34.06471	150.79735	835	1,2,3,4,5,7
16	-34.07929	150.80041	849	3,4,5
17	-34.07103	150.79253	835	1,2,3,4,5,6,7
18	-34.07175	150.78816	849	1,2,3,5,6,7
19	-34.07426	150.77886	849	1,2,3,5,6,7
20	-34.09521	150.75699	835	1,3,5,6,7
21	-34.10223	150.75169	1395	1,2,3,4,5,6,7
22	-34.09795	150.74683	849	1,3,4,5,6,7
23	-34.09972	150.7786	830	5,6
24	-34.11215	150.77988	835	1,2,3,4,5,6,7
25	-34.12015	150.79354	1395	3,5
26	-34.12996	150.78533	1395	1,5,6,7
27	-34.14001	150.79018	1395	1,3,4,5,6,7
28	-34.15692	150.78909	1395	1,3,4,5,6,7
29	-34.19165	150.78422	1395	1,2,4,5,6,7
30	-34.20653	150.76729	850	1,3,5,6,7
31	-34.20109	150.75721	1395	2,3,4,5,6
32	-34.22262	150.7522	1395	3,5
33	-34.26687	150.71363	1395	3,4,6
34	-34.24750	150.70141	1395	1,2,3,4,6,7
35	-34.23376	150.69217	1395	1,2,3,4,5,6,7
36	-34.23014	150.68057	1395	5,6,7
37	-34.21825	150.66305	849	1,2,3,4,5,6,7
38	-34.22517	150.64112	1395	1,2,3,5,6,7
39	-34.23169	150.63132	1395	1,2,3,5,6,7
40	-34.20781	150.63328	1081	1,2,4,5,6,7

Criteria:
1. Site contains tall open forest or woodland.
2. Site is near or along a timbered watercourse.
3. Site contains one or more of the following PCTs - 835, 849,850, 1181 and 1395.
4. Canopy foliage nesters, particularly honeyeaters, are common on site.
5. Site contains urban edge tolerant bird species e.g. Noisy miner, Red wattlebird, Lorikeets, Crested Pigeon or Spotted Dove.
6. Forest or woodland has open edges around remnants, timbered corridors and along watercourses.
7. Forest or woodland has tall trees near outer edges or emergent trees suitable for nesting.

4. Assessment of Specie's Presence and Suitable Habitat

Species Records for the Greater Macarthur and Wilton Growth Areas

There were 32 records for the Square-tailed Kite from the area containing the urban development area (ALA Atlas and CBOC Atlas, accessed 29-06-2018). The list of records is shown in Table 2 and the distribution of these records is shown in Figure 2.

Table 4. Records of the Square-tailed Kite *Lophoictinia isura* in and around the Greater Macarthur and Wilton Growth Areas.

Location Name	Latitude	Longitude	Date	Source
Kentlyn, NSW - Peter Meadows Creek	-34.06667	150.8513889	26-01-2003	CBOC Inc.
Leumeah, NSW, Smiths Creek Reserve	-34.0725	150.8338889	26-11-2004	CBOC Inc.
Allenby Rd, Rossmore, NSW - South Creek	-33.95306	150.7619444	05-02-2005	CBOC Inc.
Macquarie Fields	-33.99028	150.9069444	03-03-2008	CBOC Inc.
Macquarie Fields	-33.99028	150.9069444	13-05-2008	CBOC Inc.
Mannix Park, Liverpool	-33.091	150.895	28-01-2011	CBOC Inc.
Mt Annan Botanic Gardens	-34.07	150.7708333	14-02-2013	CBOC Inc.
Welling Drive, Mt Annan	-34.06278	150.7555556	16-02-2013	CBOC Inc.
Mt Annan Botanic Gardens, Mt Annan	-34.07	150.7708333	02-04-2013	CBOC Inc.
Long Point, Georges River	-34.01639	150.9022222	13-12-2016	CBOC Inc.
Appin Road	-34.122015	150.795294	23-01-2015	BioNet Atlas of NSW Wildlife
Appin Road	-34.135717	150.791111	23-01-2015	BioNet Atlas of NSW Wildlife
Wilton	-34.240399	150.698782	03-04-2016	BioNet Atlas of NSW Wildlife
Allens Creek, Wilton	-34.20266	150.694503	12-10-2017	BioNet Atlas of NSW Wildlife
Appin Road, Near Georges River	-34.160179	150.793163		BioNet Atlas of NSW Wildlife
Appin Road	-34.1235	150.798638		BioNet Atlas of NSW Wildlife
Appin Road	-34.1235	150.798638		BioNet Atlas of NSW Wildlife
Appin Road, Near Georges River	-34.160179	150.793163		BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.16	150.86	01-10-2010	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.12	150.8	01-01-2015	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.14	150.79	01-01-2015	BioNet Atlas of NSW Wildlife
CAMPBELLTOWN	-34.17	150.81	01-03-2015	BioNet Atlas of NSW Wildlife
LIVERPOOL	-34.02	150.94	01-10-2010	BioNet Atlas of NSW Wildlife
LIVERPOOL	-33.93	150.71	18-01-2012	BioNet Atlas of NSW Wildlife
LIVERPOOL	-34	150.92	16-06-2006	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.25	150.85	23-03-2009	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.08	150.5	30-01-2013	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.26	150.69	03-04-2016	BioNet Atlas of NSW Wildlife
WOLLONDILLY	-34.24	150.7	03-04-2016	OEH Atlas of NSW Wildlife
WOLLONDILLY	-33.99	150.61		Citizen Science ALA Website
WOLLONDILLY	-34.2	150.6	20-04-2010	OEH Atlas of NSW Wildlife
WOLLONDILLY	-33.9	150.6	10-01-2005	OEH Atlas of NSW Wildlife

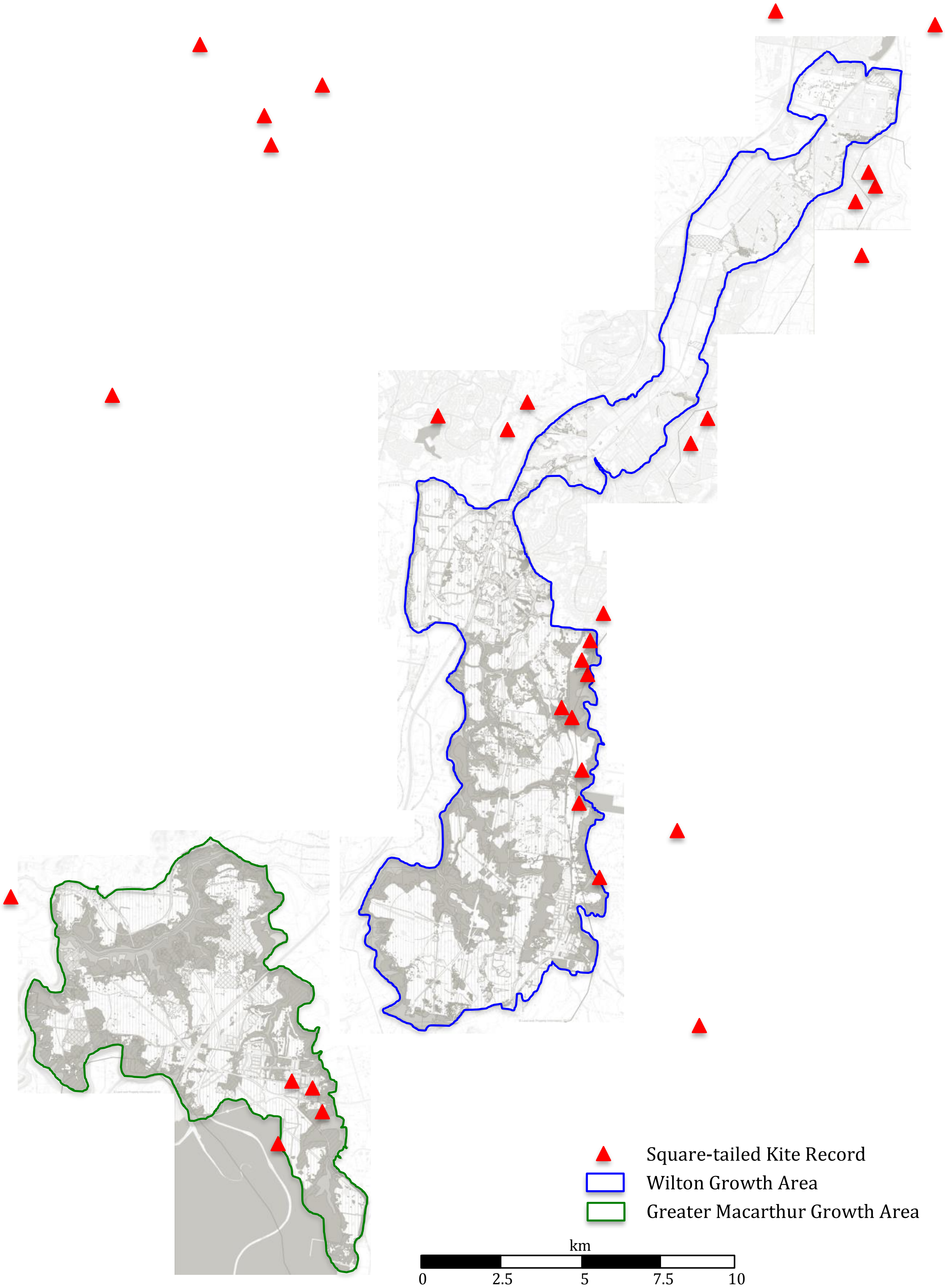


Figure 2. Distribution of records for the Square-tailed Kite *Lophoictinia isura* in and around the Greater Macarthur and Wilton Growth Areas (source ALA and CBOC Inc.).

Of these 32 records, 12 were within the southern half of the Greater Macarthur Growth Area and the Wilton Growth Area. Another 15 records are within 5 kilometres of the boundaries of the PGAs, with 11 of them just outside the northern section of the Greater Macarthur Growth Area. There were no records for July through to September with the majority of records from January through to April, being the post-breeding dispersal phase. Most of the records are associated with forest along watercourses and were made close to the edges of remnant forest. The records support that these two factors, timbered watercourses and forest edges, as being important habitat requirements for the Square-tailed Kite. These records also show that PCT 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion is an important plant community type for the Kite. We are not aware of any previous habitat assessments for the Square-tailed Kite in the study area.

Assessment of Suitable Habitat in the Growth Areas, Distribution Polygons and Justification for Determination

The areas of potential foraging habitat and potential breeding habitat for the Greater Macarthur Growth Area are shown in maps 1 to 7 in Figure 3. The areas of potential foraging habitat and potential breeding habitat for the Wilton Growth Area are shown in maps 1 to 3 in Figure 4. The existing remnant patches containing potential habitat for the Kite are shown as an overlay over the vegetation maps. These are sites where the habitat structure, plant community type and placement in the landscape, all indicate potential breeding and foraging habitat for the species (shown in red). Some habitat areas would provide potential foraging habitat but not breeding habitat (shown in orange). Some of the areas within the urban development footprint have been included because they satisfy several of the following conditions. They contain good edge habitat adjacent to an existing habitat remnant e.g. open areas with scattered trees, provide good foraging habitat, provide connectivity between existing remnants, broaden a connecting corridor or protect an edge habitat (shown in yellow). Other areas, which also satisfied any of these same conditions and that are not within the urban development footprint, are included as they are areas where habitat enhancement would improve the Kite's access to resources within the growth areas (shown in green).

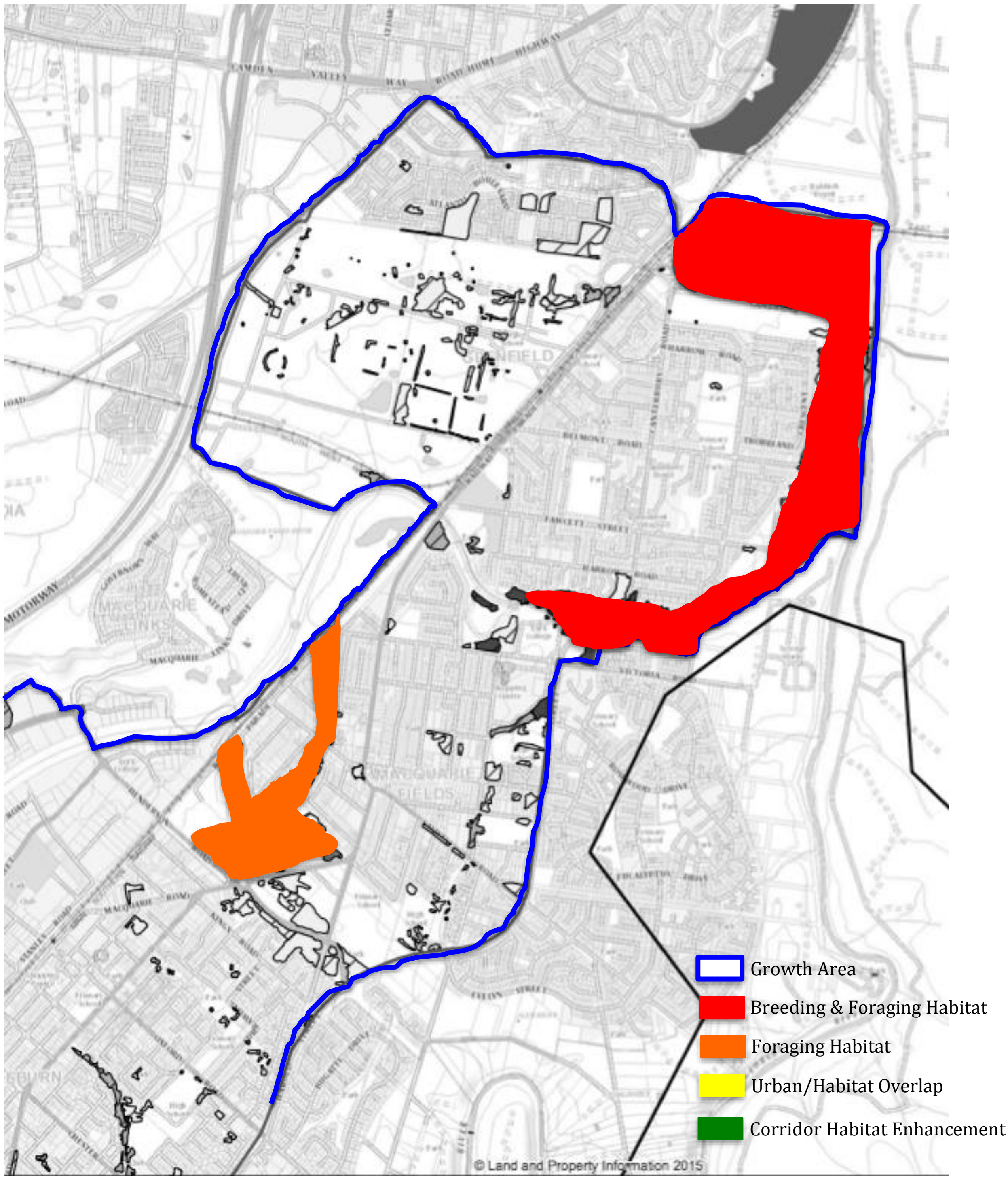


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 1). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

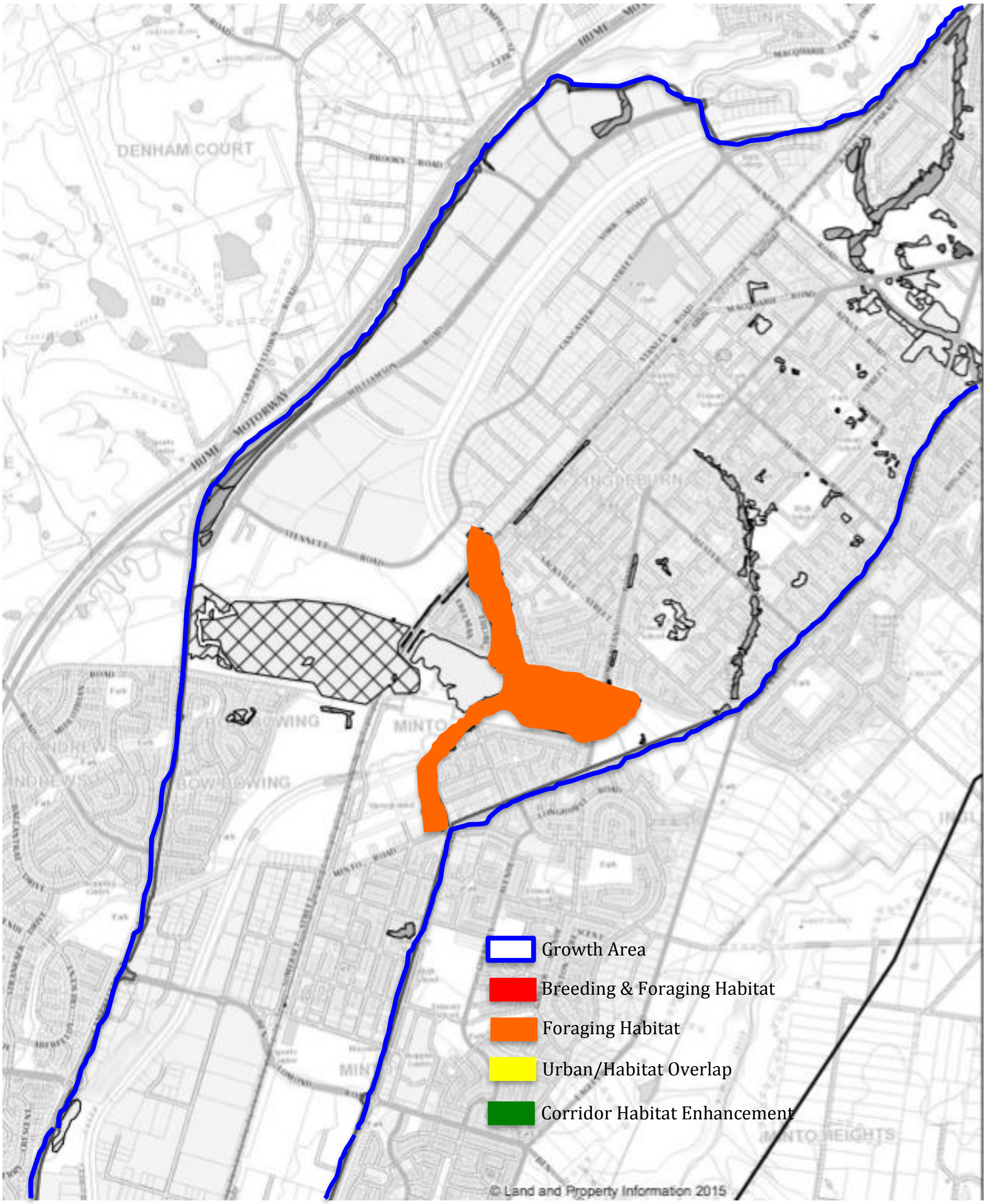


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 2). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

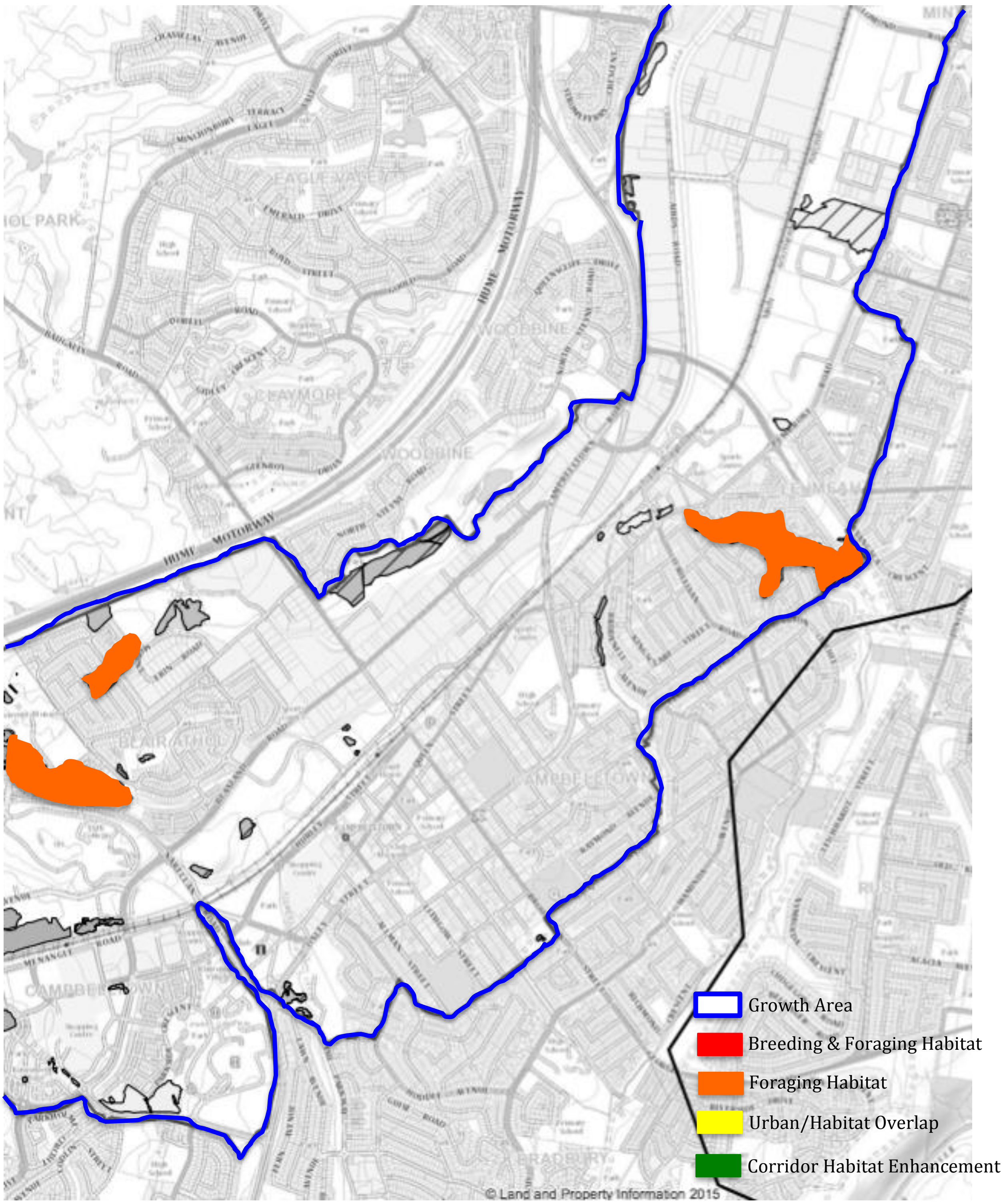


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 3). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

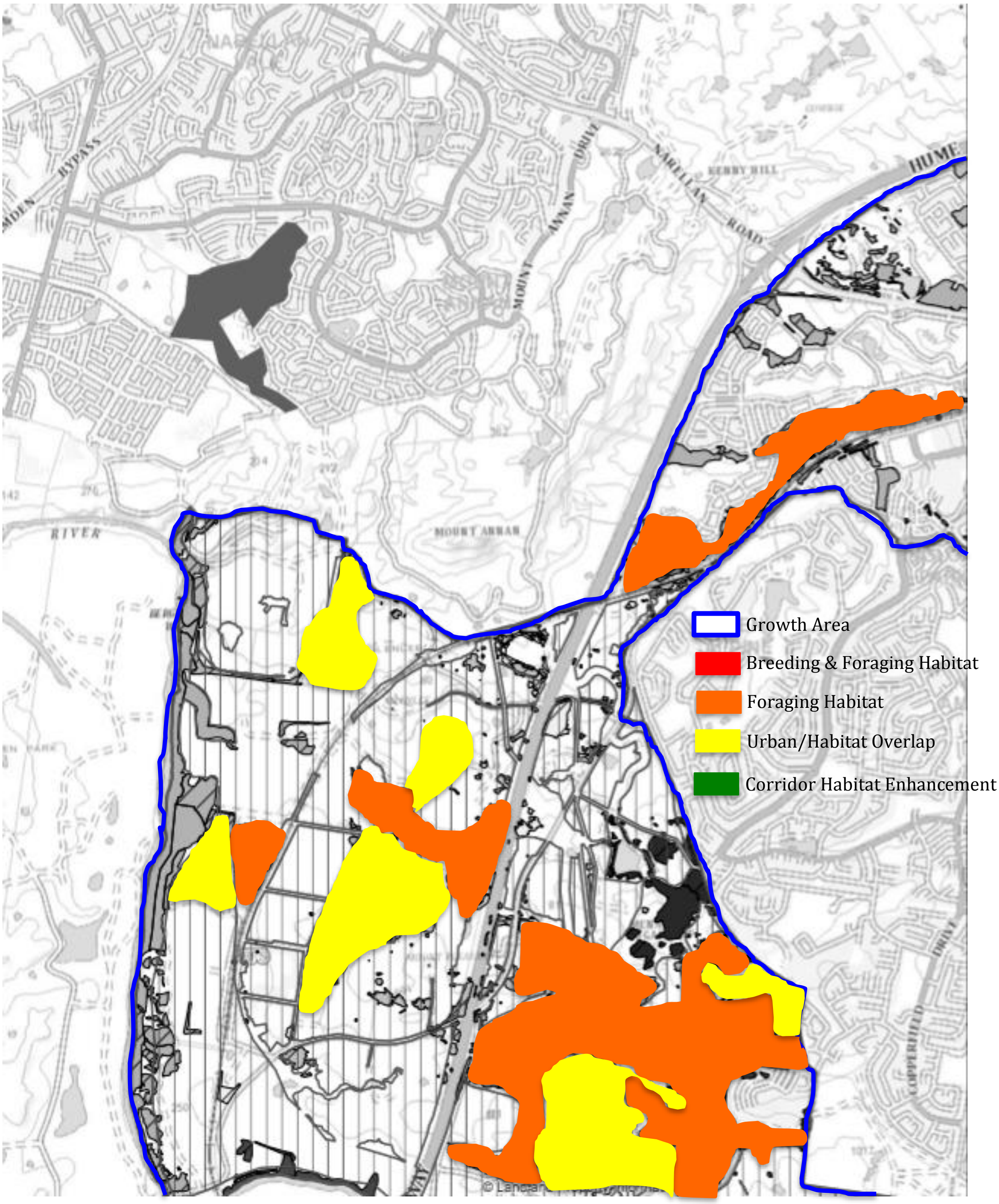


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 4). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

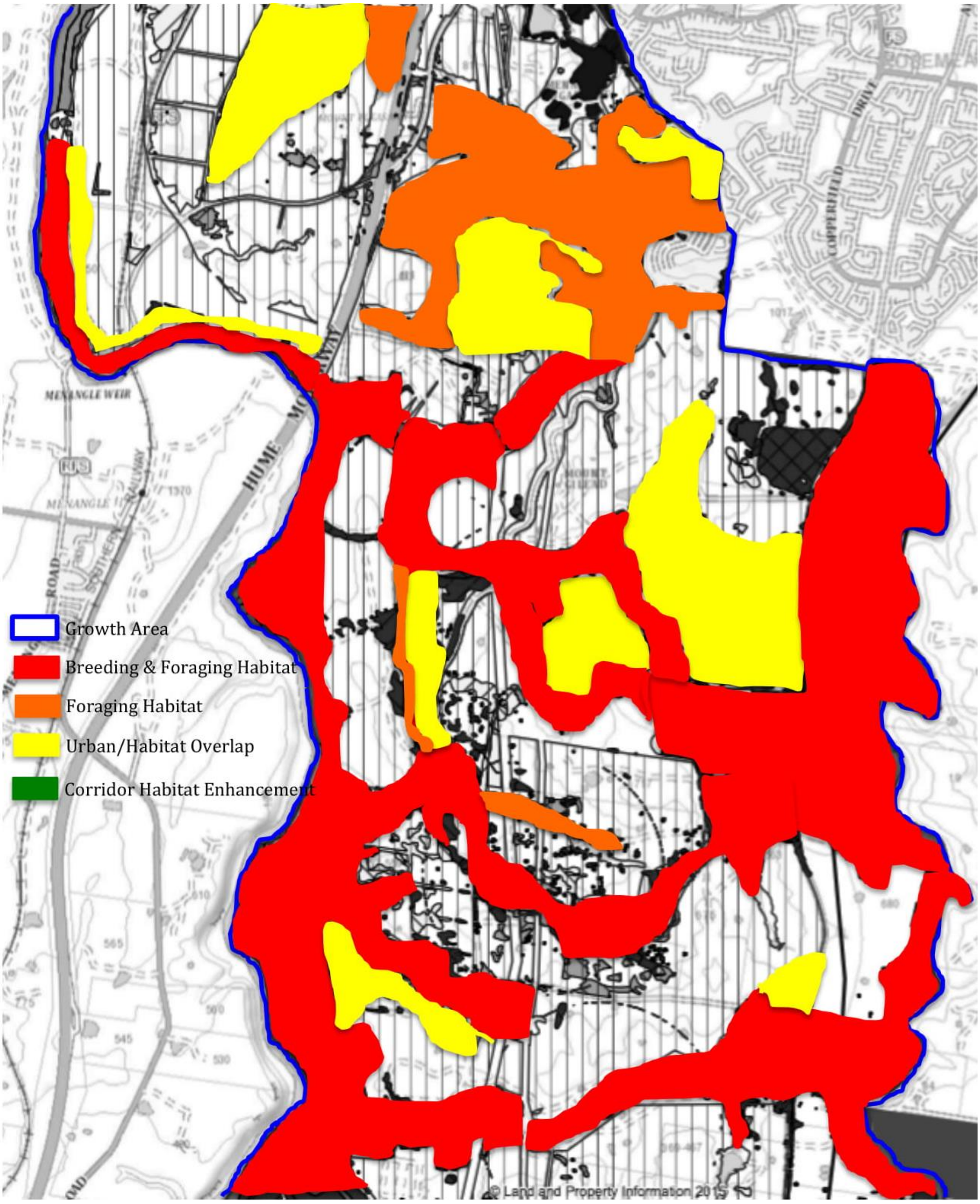


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 6). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

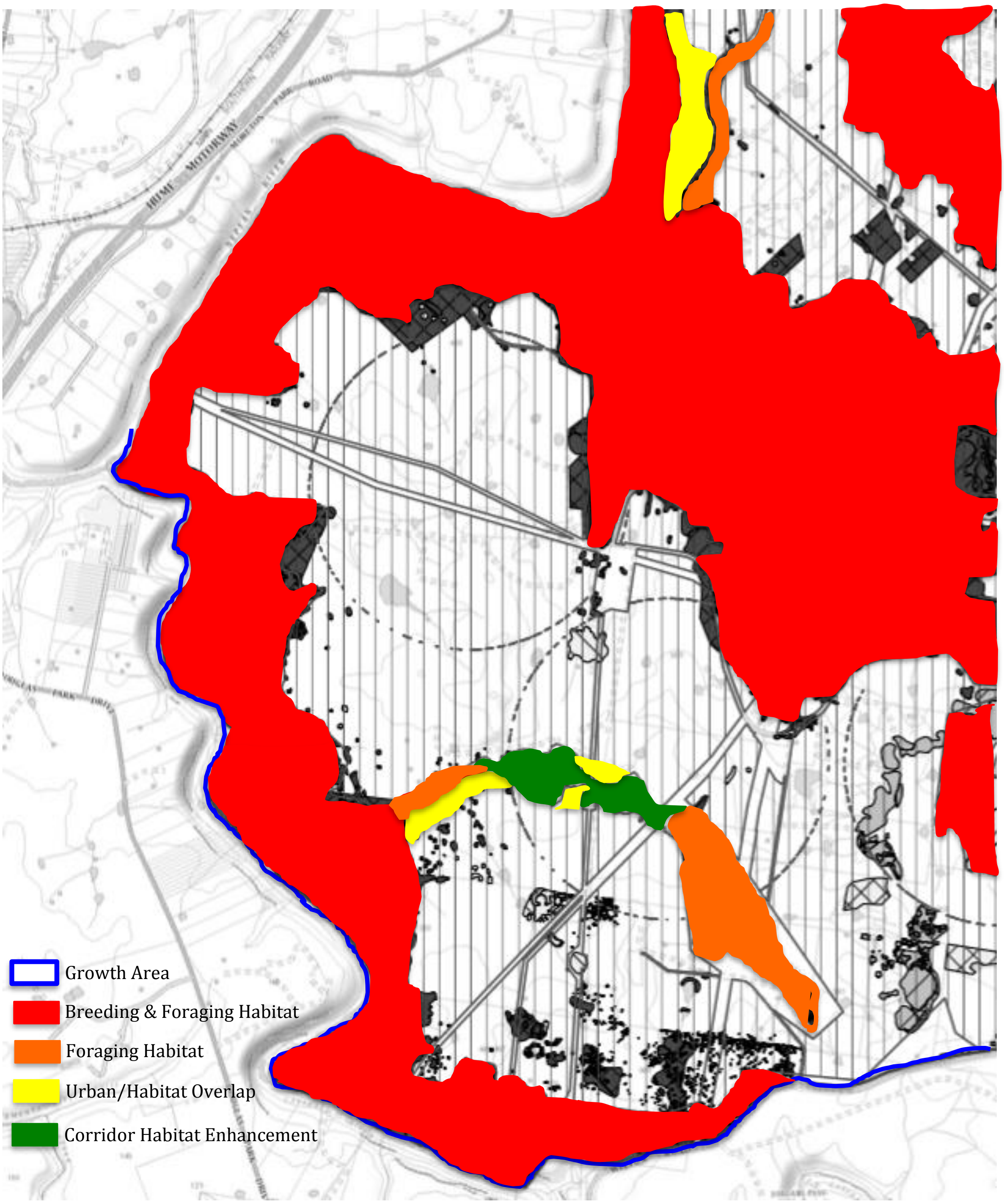


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 6). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

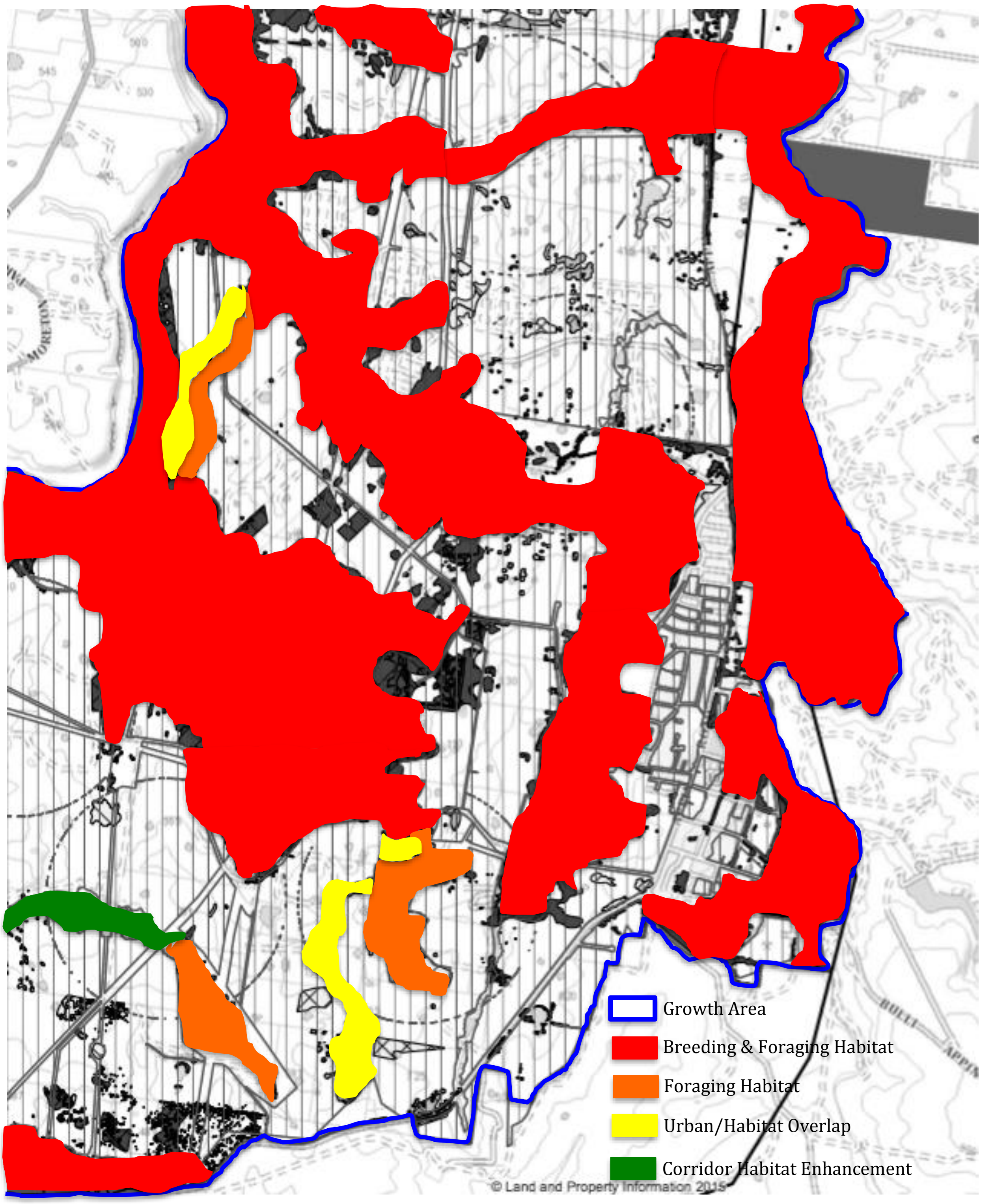


Figure 3. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 7). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

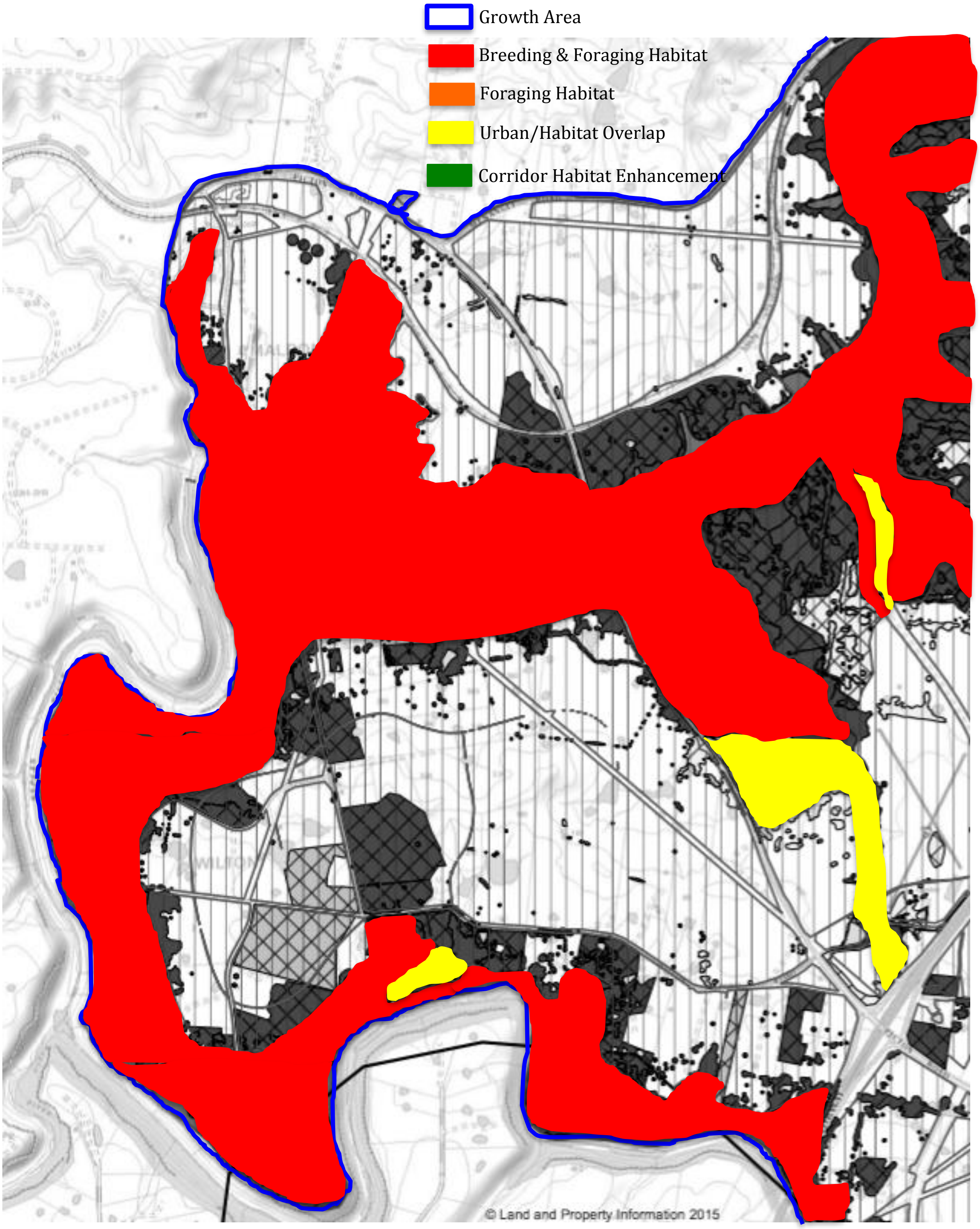


Figure 4. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Wilton growth area (Map 1). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

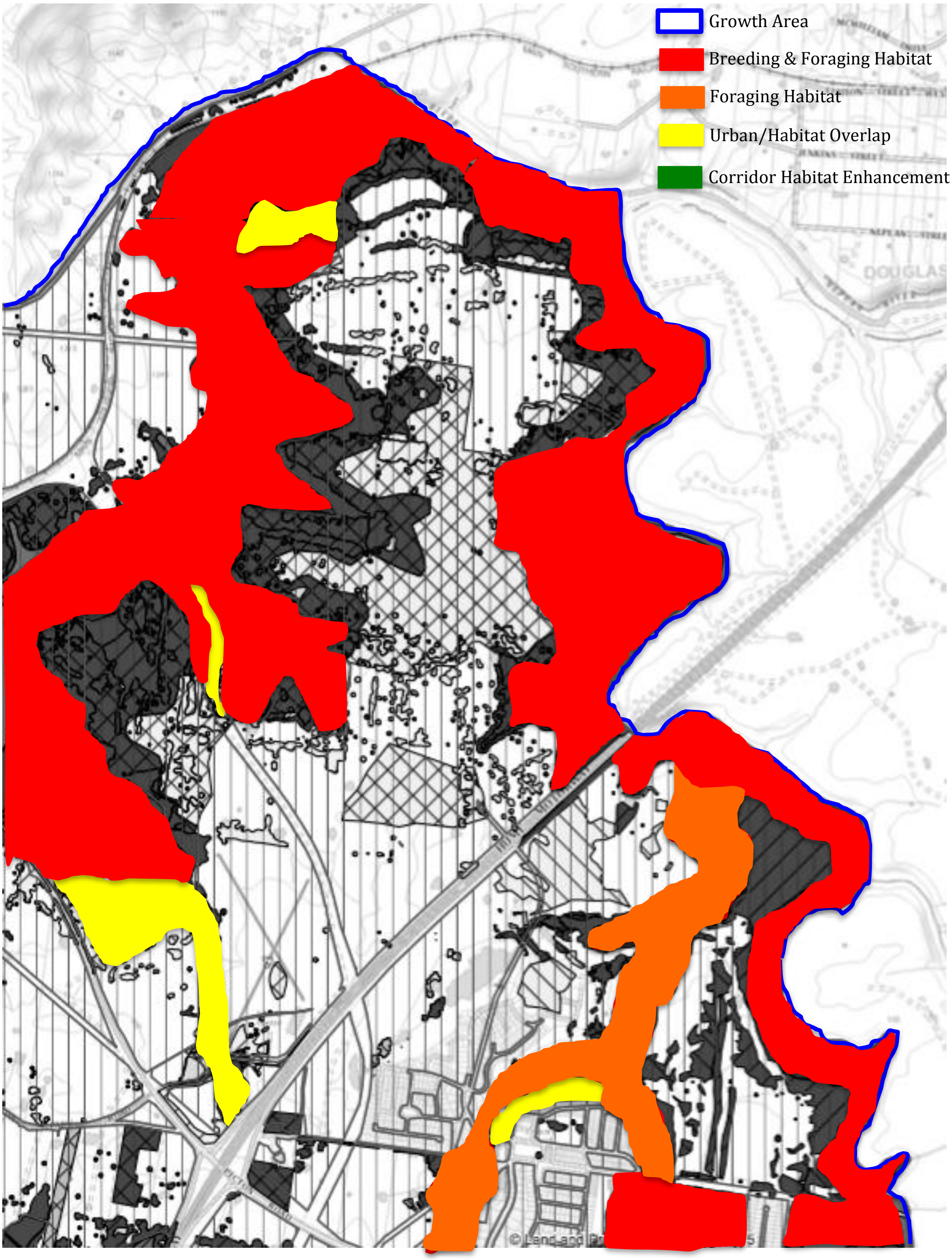


Figure 4. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Wilton growth area (Map 2). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

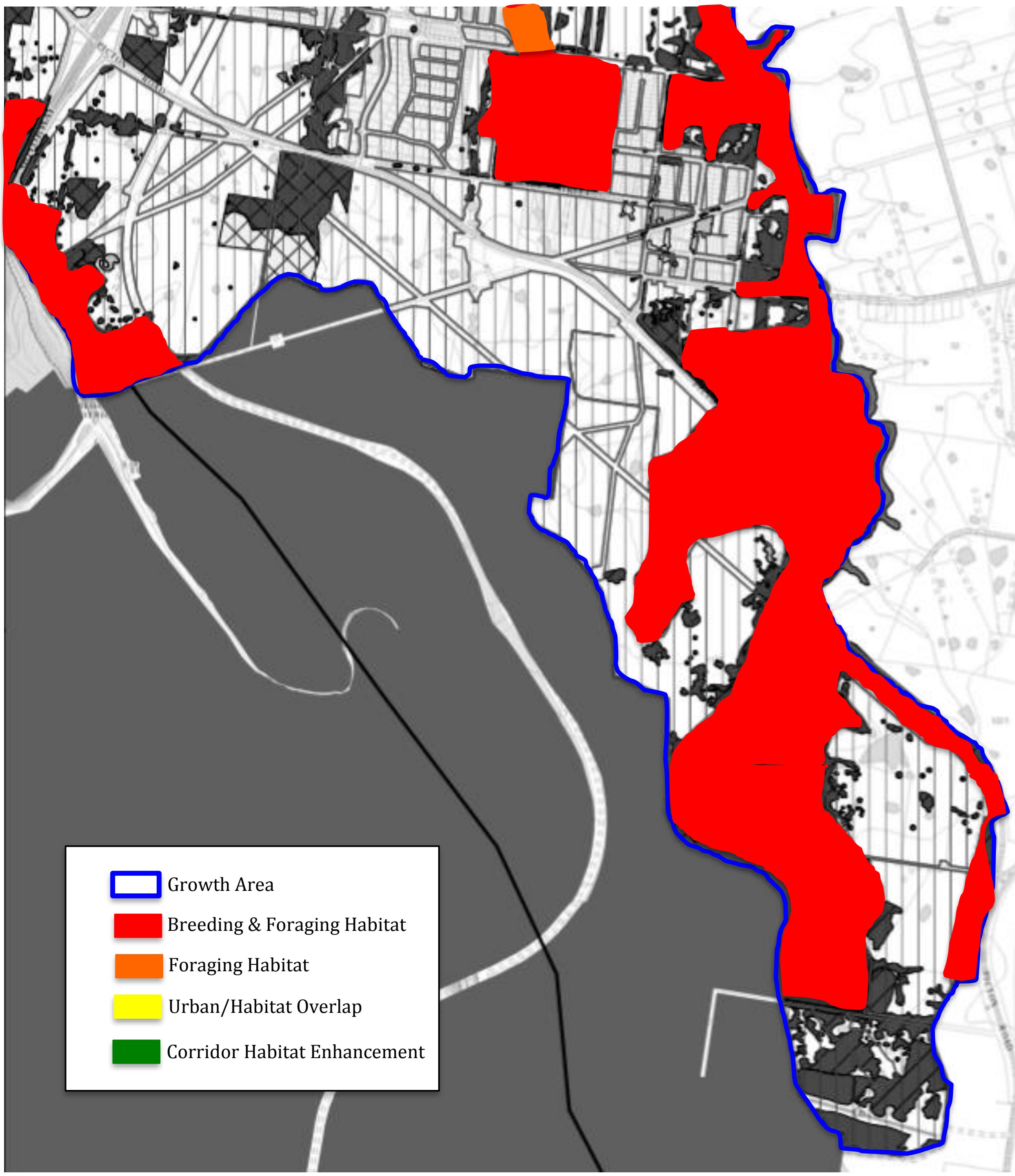


Figure 4. Potential breeding and potential foraging habitat for the Square-tailed Kite in the Greater Macarthur growth area (Map 3). Potential breeding and foraging habitat areas are shown in red, potential foraging areas are shown in orange, potential foraging areas that overlap urban development footprint shown in yellow and potential areas for habitat enhancement and improved connectivity shown in green.

Assessment of the Likelihood of Species Presence in the Growth Areas, Distribution, Population Estimate and Justification for Determination

There is a very high likelihood of Square-tailed Kites occurring within the growth areas during the breeding season. Although breeding has not been observed within the growth areas it is very likely that they will forage in the area while breeding. However, the Kite has nested in similar situations elsewhere and nesting within the growth areas would also be possible. This is supported by the occurrence of records for the Kite within and around the growth areas in October to December. The habitat remnants within the growth areas are tall open forests and woodland, are mostly along watercourses and have abundant edges. These factors provide good foraging habitat for the Kite. The Kite has also been recorded in most of the plant community types that occur within the growth areas, and again this supports a high likelihood of Square-tailed Kites occurring there.

It would appear from the distribution of records that there are likely to be 2 to 3 breeding pairs in the area that will use the site for foraging during the breeding season. Although the distance between adjacent nests in published data on nesting Kites exceeds the total length from north to south through the growth areas, there is connectivity to several larger areas of suitable habitat around the growth areas. This means that each pair's breeding territory could extend into the site from a larger area outside the growth areas. The distribution of records suggests that there may be a pair centred along the Georges River along the eastern edge of the northern half of the Greater Macarthur growth area. Another pair is likely to occur along the Appin Road area that extends into contiguous forest to the east of the southern section of the Greater Macarthur growth area. It is also possible that another pair occupies the area around the southern section of the Wilton growth area.

However, no nests have ever been recorded in the growth areas. Breeding was not observed during the surveys undertaken by Biosis or by us during our surveys. As other bird species build similar stick nests it is difficult to identify a Square-tailed Kite nest without the bird being in attendance, which would be required to confirm breeding within the growth areas. The breeding habitat areas indicated in Figures 3 and 4 are based on the minimum criteria presented in Tables 1 and 2. Although, there is much potential breeding habitat within the growth areas no breeding habitat, as defined by BAM requirements, was observed.

In summary, the evidence suggests that the Square-tailed Kite is found within the growth areas of Greater Macarthur and Wilton and that are likely to be 2 or 3 pairs occurring during the breeding season. The presence of suitable foraging habitat and potential breeding habitat within these growth areas means that protection of habitat within them may be critical to the continued presence of the Kite in the area.

5. Information Used in the Assessment

Data:

Atlas of Living Australia - occurrences of Little Eagle and Square-tailed Kite in Liverpool, Campbelltown and Wollondilly LGAs. (accessed 29-06-2018). <https://biocache.ala.org.au/occurrences/search>

Bionet Atlas of NSW Wildlife (accessed 29-06-2018).

Biosis - vegetation mapping and field survey data (supplied by the Department of Environment and Planning 21-05-2018).

Cumberland Bird Observers Club Inc. Bird Database (accessed 29-06-2018).

References:

Barnes, C.P., Zillmann, E.E., Rose, A.B. and Debus, S.J.S. 2001 Diet and biology of Square-tailed Kites *Lophoictinia isura* breeding in south-eastern Queensland: nest building to post-fledging. *Australian Bird Watcher* 19: 28-43.

Barrett, G.W., Silcocks, A.F., Cunningham, R., Oliver, D.L., Weston, M.A. and Baker, J. 2007 Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species. *Australian Zoologist* 34(1): 37-77.

Bischoff, T., Lutter, H. and Debus, S 2000 Square-tailed Kites on the mid-north coast of New South Wales. *Australian Bird Watcher* 18: 233-240.

Brown, B., Brown, F. and Debus S.J.S. 2000 Further observations on a pair of Square-tailed Kites nesting near Grafton, New South Wales. *Australian Bird Watcher* 18: 270-273.

Chafer, C.J., Brandis, C.C.P. and Wright, D. 1999 *A Handbook of Birds Found in the Illawarra, Shoalhaven and Adjacent Tablelands.* Illawarra Bird Observers Club, Wollongong.
Cooper, R.M., McAllan, I.A.W. and Curtis, B.R. 2014 *An Atlas of the Birds of NSW & the ACT. Volume 1. Emu to Plains-Wanderer.* NSW Bird Atlassers Inc., Sydney.

Cupper, J. and Cupper, L. 1981 *Hawks in Focus: A Study of Australia's Birds of Prey.* Jaclin Enterprises, Mildura.

Debus, S.J., McAllen, I.A.W. and Morris, A.K. 1993 The Square-tailed Kite Lophoictinia isura in New South Wales. *Australian Birds* 26: 104-118.

Debus, S.J.S. 1993 Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Square-tailed Kite, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.

Debus, S.J.S. 1996 Further observations on the Square-tailed Kite. *Australian Birds* 29: 44-53; 62.

Debus, S.J.S. 2012 *Birds of Prey of Australia: A Field Guide (2nd ed.).* CSIRO Publishing, Clayton South.

Debus, S.J.S. 2017 *Australasian Eagles and Eagle-like Birds.* CSIRO Publishing, Clayton South.

Ferguson-Lees, J. and Christie, D.A. 2001 *Raptors of the World* Helm, London

Garnett, S. (ed) 1993 *Threatened and Extinct Birds of Australia RAOU Report Number 82.* Royal Australasian Ornithologists Union and Australian National Parks and Wildlife Service, Moonee Ponds, Victoria.

Garnett, S. and Crowley, G. (eds) 2000 *The Action Plan for Australian Birds* Environment Australia, Canberra.

Griffiths, H., Lutter, H., Rose, A.B. and Debus, S.J.S. 2002 Breeding and diet of a pair of Square-tailed Kites *Lophoictinia isura* on the mid-north coast of New South Wales. *Australian Bird Watcher* 19: 184-193.

Hindwood, K.A. and McGill, A.R. 1958 *The Birds of Sydney (County of Cumberland) New South Wales.* Royal Zoological Society of N.S.W., Sydney.

Hollands, D. 1984 *Eagles, hawks and falcons of Australia.* Nelson, Melbourne.

Hoskin, E.S. (Hindwood, K.A. and McGill, A.R.) 2nd ed. 1991 *The Birds of Sydney, County of Cumberland, New South Wales, 1770-1989*. Surrey Beatty & Sons, Chipping Norton.

Kavanagh, R.P., Cann, B., Ellis, B. and Williams, J. 2004 Habitat selection by the Square-tailed Kite *Lophoictinia isura* on the mid-north coast of New South Wales. *Boobook* 31: 19 (abstract).

Lutter, H., Dinnie, R. and Debus S.J.S. 2003 Square-tailed Kites breeding in northern coastal New South Wales: post-fledging diet and behaviour. *Australian Field Ornithology* 20: 94-104.

Lutter, H., Lutter, M., Rose, A.B. and Debus, S.J.S. 2004 Breeding biology and diet of the Square-tailed Kite on the mid-north coast of New South Wales. *Australian Field Ornithology* 21: 141-157.

Morris, A.K., McGill, A.R. and Holmes, G. 1981 *Handlist of Birds in New South Wales*. New South Wales Ornithologists Club, Sydney.

Olsen, P., Crome, F. and Olsen, J. 1993 *National Photographic Index of Australian Wildlife Volume 8 Birds of prey and ground birds of Australia*. Angus & Robertson, Sydney.

Olsen, P.D. 1995 *Australian Birds of Prey.* University of New South Wales Press, Sydney.

Optland, W. 2015 More on the Square-tailed Kite as Australia's honey-buzzard. *Australian Field Ornithology* 32: 98-99.

Patrick, A. 2016 *Birds of Sydney.* A. Patrick, Winston Hills.

Robinson, J.L., Cooper, B.R. and Franklin, D.C. 2016 Shadows of change: Square-tailed Kites *Lophoictinia isura* nesting in the Bendigo area. *Corella* 40(3): 61-68.

Saunders, A.S.J. & Burgin, S. 2001 Selective foliage foraging by Red Wattlebirds, *Anthochaera carunculata*, and Noisy Friarbirds, *Philemon corniculatus*. *Emu* 101: 163-166.

Saunders, T. in prep. Trends in woodland bird populations on the Cumberland Plain.

Square-tailed Kite *Lophoictinia isura* Action Plan, Office of Environment & Heritage, accessed 27-06-2018. <http://www.environment.nsw.gov.au/savingourspeciesapp/project.aspx?profileid=10495>

Square-tailed Kite *Lophoictinia isura* Profile, Office of Environment & Heritage, accessed 27-06-2018. <http://www.environment.nsw.gov.au/savingourspeciesapp/profile.aspx? id=10495>

Stowe, D. 2009 Square-tailed Kite. *Wingspan* 19: 42-45.

6. Curriculum Vitae

Dr Tony Saunders

Name: Anthony Stephen John Saunders

Contact Details: 1878 Taralga Road Laggan NSW 2583 0409 399 849

Academic Qualifications:

BSc University of Sydney 1976
Dip Ed Sydney Teachers College 1977
PhD University of Western Sydney 2005

Other Qualifications:

LR Drivers Licence
Public Vehicle Driver Authority
Work Health & Safety General Construction Induction (White Card)
Chemical Use and Handling Certificate
Resuscitation Certificate
Emergency Care Certificate
Anaphylaxis Training Certificate
Drone Essentials Certificate

Fields of expertise:

Bird habitat assessment on reserves, lands in production and potential offset property.
Bird monitoring in natural, modified and managed habitats.
Assessment of likelihood of threatened woodland bird species occurrence on development sites.
Coordinating projects between government and non-government organisations.
Coordination of volunteers collecting wildlife data.
Ecotourism: guiding general interest and specialists groups in flora and fauna.
Environmental and science education at high school, TAFE, and university levels.
Habitat management for terrestrial woodland birds and other wildlife.
Presentations on ecology to public interest groups and at professional workshops.
Remote area wildlife atlassing.
Wildlife database design and management.
Land for Wildlife assessments and habitat enhancement planning.

Professional positions held:

2010 - 2018 Merops Services Pty Ltd (director, avifaunal ecologist). Environmental and landscape consultant and contractor, flora and fauna surveys, habitat enhancement plans.

2013 - 2018 Land for Wildlife Assessor for Community Environment Network

1995 - 2010 Merops Services (avifaunal ecologist). Environmental and landscape consultant and contractor.

2006 - 2018	Part-time teacher, mainly science, but also industrial arts, English and maths, Crookwell High School, Goulburn High School and Trinity Grammar School.
1997 - 2005	Part-time bird guide and ecotourism bus driver.
1993 - 2004	Part-time lecturer, supervisor and demonstrator, University of Western Sydney (biology, ecology and field survey techniques).
2001 - 2004	Atlas Facilitator, Birds Australia (organising remote atlassing, facilitating data exchange and communication between Birds Australia, state government organizations and other non-government organisations).
1997	Field Technical Officer, Birds Australia (monitoring breeding success of endangered bird species).
1996	Field Technical Officer, University of Western Sydney (reptile, bird and plant survey techniques and data analysis).
1978 - 1994	High School Science Teacher at Marsden, Heathcote, Penrith and Kingswood High Schools.

Other volunteer positions held:

2014 - 2017	Assistant to Co-ordinator of the Sydney Bird Fair.
2009 – 2018	President - Crookwell Native Flora and Fauna Club.
2013 - 2018	Secretary - Grabine/Foggs Crossing Landcare Group
2001 - 2018	Avifaunal Advisor and Education Officer for Oolong Sanctuary, Dalton.
1997 - 2010	Project Manager for Atlas of Birds of the County of Cumberland.
2010 - 2018	Technical advisor to the Cumberland Bird Observer's Club's Atlas Databasae Management Committee.
1996 - 2009	Committee Member - CBOC (Cumberland Bird Observers Club Inc.).
1998 – 2014	CBOC representative to Bird Interest Group Network (BIGnet).
1997 - 2002	Faunal Advisor for the Hawkesbury Rainforest Network.
1999 - 2002	Member of Steering Committee of Birds in Backyards for Birds Australia.
1998 - 1999	Consultant to Birds Australia Birds for Birds in Backyards Project.
1998 - 2003	Regional Organiser for Sydney and the Blue Mountains, NSW facilitator and NSW/ACT representative on the Steering Committee for the National Bird Atlas for Birds Australia.
2002	Representative on NSW NPWS Wildlife Issues Advisory Panel for Birds Australia.

Relevant experience:

Co-ordination, facilitation and organization of exhibits and presentations at field-day events and indoor venues. This has involved allocating space, providing necessary facilities and setting-up audio-visual equipment for exhibitors and presenters (18 years)

Co-ordinator of volunteers for the CBOC Inc. and the Birds Australia national birds atlas. (13 years)

Facilitated the BIGnet data exchange agreement between Birds Australia, NSW Bird Atlassers, Canberra Ornithologists Group and the Cumberland Bird Observers Club. Facilitated bird data exchanges between Birds Australia, NSW State Forests and NSW DECC. (4 years)

Presenter at seminars for Bushcare, Landcare, Greening Australia, Wires and local councils, conservation societies and garden clubs on habitat management for birds and bird survey techniques. (32 years)

Educator at public, tertiary and secondary levels in the area of bird habitat management and bird survey methodology. (23 years)

Ecotourism and bird guiding (19 years).

Undertaking avifauna surveys of sites for development applications and assessment of status of threatened bird species on sites and making recommendations for minimising impact of development on these species.

Bird habitat assessment of managed landscapes and natural habitat areas and recommendations for habitat enhancement and rehabilitation for birds. (21 years)

Design, building and management of the bird database for the birds of the County of Cumberland on behalf of CBOC Inc. (16years)

Membership and professional affiliations:

Australian Bird Study Association
Australian Bush Heritage
Birdlife Australia
Crookwell Native Flora and Fauna Society
Cumberland Bird Observers Club
Ecological Consultants Association of NSW
Grabine/Foggs Crossing Landcare Group
Greening Australia
NSW Bird Atlassers
Royal Zoological Society (Scientific member)
Wildlife Preservation Society of Queensland

Papers, Articles, Book sections and Reports:

Saunders, T. 1985. Common Bronzewings at Round Hill Nature Reserve. *CBOC Newsletter* Vol. 6 No. 6: 5

Saunders, T. 1986. Eastern Bristlebird at Ku-Ring-Gai Chase National Park. *CBOC Newsletter* Vol. 8 No. 2: 1

Saunders, T. 1990. Sooty Oystercatcher. *CBOC Newsletter* Vol. 11 No. 3 : 3

Saunders, T. 1991. Keeping Records of Bird Observations. *CBOC Newsletter* Vol. 12 No. 5: 6-7.

Saunders, T. 1997. Birdscaping Gardens *CBOC Newsletter* Vol. 18 No. 4: 6

Saunders, A.S.J. 1993. Seasonal variation in the distribution of the Noisy Friarbird *Philemon corniculatus* and the Red Wattlebird *Anthochaera carunculata* in eastern New South Wales. *Australian Bird Watcher* 15: 49-59.

Saunders, A.S.J., Ambrose, S.J. & Burgin, S. 1995. Gape width and prey selectivity in the Noisy Friarbird *Philemon corniculatus* and Red Wattlebird *Anthochaera carunculata*. *Emu* 95: 297-300.

Whelan, H. (ed.) 1997. *Australian Geographic Birdwatcher's Journal.* Australian Geographic. Chapters 'How to Watch Birds' and 'Bringing Birds into Your Garden'.

Healey, J. (ed.) 1997. *Encyclopaedia of Australian Wildlife.* Reader's Digest, Sydney. Chapters on Honeyeaters and Chats.

Saunders, A.S.J. & Burgin, S. 2001. Selective foliage foraging by Red Wattlebirds, *Anthochaera carunculata*, and Noisy Friarbirds, *Philemon corniculatus*. *Emu* 101: 163-166.

Saunders, T. 2002 *Bird Monitoring of Federal Park and White's Creek Valley Park, Annandale*. Leichhardt Council, Unpublished Report.

Saunders, T. 2002 Bird Habitat Issues and Management of Urban Bushland. *Caring For Our Bushland and Waterways: Forum Proceedings*. 2002 Wollondilly Catchment Landcare Forum.

Saunders, A.S.J., Burgin, S. & Jones, H. 2003 The importance of eucalypt nectar in the diet of large honeyeaters. *Corella* 27: 1-12.

Saunders, T. 2003 *Managing Avian Biodiversity in the Leichhardt Local Government Area.* Leichhardt Council, Unpublished Report.

Saunders, T. 2003 *Breeding Waterbird Study at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2004 *Bush Bird Status at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2005 *Bush Bird Project at Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2005 *Habitat Survey of Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2006 *Flora and Fauna Assessment of Badgerys Creek.* Unpublished Report.

Saunders, T. 2007 *Bird Habitat Management within Holroyd Local Government Area.* Holroyd City Council, Unpublished Interim Report.

Burgin, S. & Saunders, T. 2007 Parrots of the Sydney region: population changes over 100 years. Pp. 185-194 in *Pest or Guest; The Zoology of Overabundance*, edited by Lunney, D., Eby, P., Hutchings, P. & Burgin, S. Royal Zoological Society of NSW, Mosman.

Saunders, T. 2008 *Avian Biodiversity Monitoring and Bird Habitat Management within the Leichhardt LGA.* Leichhardt Council, Unpublished Report.

Saunders, T. 2009 *Bird Habitat Management within Holroyd Local Government Area.* Holroyd City Council, Unpublished Report.

Saunders, T. 2009 *Sydney Olympic Park Bush Bird Survey* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2010 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Interim Report.

Saunders, T. 2010 *Bird Monitoring at Sydney Olympic Park 1999 to 2009* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2011 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Interim Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Heathfield' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Girragirra' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Garrallan' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Garraroo' Binda*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Watervale' Boorowa*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Wookie Hills' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Orchre Arch' Cowra*, Unpublished Report.

Saunders, T. 2011 *Habitat Enhancement Plan for 'Raintree-Marra' Cowra*, Unpublished Report.

Saunders, T. 2011 *Criteria for Ranking Priorities for Habitat Enhancement for Lachlan Catchment Management Authority,* Unpublished Report.

Saunders, T. 2012 *Bird Habitat Monitoring in Holroyd LGA* Holroyd City Council, Unpublished Final Report.

Saunders, T. 2013 Birdscaping Gardens. p 16 *Our Gardens* Volume 55, The Garden Clubs of Australia.

Saunders, T. 2014 *Habitat Survey of Sydney Olympic Park.* Sydney Olympic Park Authority, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Mitchell' Binda*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Douglass' Binda*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Holmes' Peelwood*, Unpublished Report.

Saunders, T. 2015 *Habitat Assessment and Enhancement Plan for 'Ollis' Bigga*, Unpublished Report.

Saunders, T. 2015 *Habitat Assessment and Enhancement Plan for 'Flat Rocks' Bigga*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for 'Gunthori' Yass*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for Lot3 DP 789337 Taralga*, Unpublished Report.

Saunders, T. 2015 *Land for Wildlife Assessment for Lot 57 Bevendale*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 48541Abercrombie for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 48016 Abercrombie for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 823525 Binda for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2015 *Flora and Fauna Assessment of DP 753055 Binda for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for DP 1217631 Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'Callarah' Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'The Angle' Reids Flat*, Unpublished Report.

Saunders, T. 2016 *Land for Wildlife Assessment for 'Bobbins' Reids Flat*, Unpublished Report.

Saunders, T. 2016 Birds of the Cumberland Plain. What was there? What have we lost? Abstract from 'Birds of the Cumberland Plain: Past distributions, present studies and the outlook for their future.' Australian Bird Study Association Conference - 23 January 2016. *Corella* 40: 46

Saunders, T. 2016 *Bird surveys, likelihhood for threatened birds and habitat description for Syerston Mine Project, Fifield,* Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Tanjenong' Abercrombie*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bohara' Breadalbane*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Greendale' Breadalbane*, Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bunduluk' Laggan*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 48618 Windellama for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 1185604 Windellama for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Flora and Fauna Assessment of DP 823489 Cullulla for Pejar Aboriginal Land Council*, Unpublished Report.

Saunders, T. 2017 *Bird surveys, likelihhood for threatened birds and habitat description for Vickery Mine Project, Boggabri,* Unpublished Report.

Saunders, T. 2017 *Land for Wildlife Assessment for 'Bimbimbie' Bigga*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for 'Tanjenong' Abercrombie*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for DP 1162296 Crookwell*, Unpublished Report.

Saunders, T. 2017 *Habitat Assessment and Enhancement Plan for 1206394 Red Ground*, Unpublished Report.

Saunders, T. 2018 *Bird surveys, likelihhood for threatened birds and habitat description for Maxwell Mine Project, Jerrys Plains,* Unpublished Report.

Saunders, T. in prep. Trends in woodland bird populations on the Cumberland Plain.

Thesis:

Saunders, A.S.J. 2006 Comparative Foraging Ecology of the Noisy Friarbird *Philemon corniculatus* and the Red Wattlebird *Anthochaera carunculata* in central eastern New South Wales.

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Professional capacities:

Vertebrate fauna surveys. Research and survey of threatened forest and woodland birds, particularly raptors and owls. Ecology/biology/behaviour of birds, especially predatory species. Conservation and management of threatened bird species. Distribution, status and biology/ecology of NSW birds. Reviews and biological profiles of bird species. Editing ornithological papers. Peer review of ornithological documents/EISs/species impact statements. Impact assessment (avifauna). Review of conservation status of NSW fauna.

Computer skills:

Proficient in Word and Excel, limited experience with GIS and ArcView

Employment:

Eco Logical Australia 2011-18 (casual; senior ecologist: fauna survey and report)

EA Systems (now EnviroAg Australia) 2000-14 (casual; ecologist: fauna survey and assessment)

Research assistant, Zoology, UNE, casual 1984-2014 (field ornithology: bird banding, bird surveys/censusing, ecological studies)

Tutor/demonstrator, Zoology UNE (casual), 2007-13

NSW Dept Environment & Climate Change, 2008-09 (temporary) (threatened species officer: Project Officer, NSW Scientific Committee)

Research Assistant, Ecosystem Management UNE (casual), 2008-09 (bird survey)

Post-doctoral research fellow, Zoology, UNE, 2005-07 (ecology of woodland birds)

Junior research fellow, Zoology, University of New England, 1990-1993, 1998-2004 (ecology of rare forest owls in relation to habitat and forest management; ecology and management of birds)

Technical officer, University Partnerships Pty Ltd (UNE), 1995-1996 (fauna survey and report, Eastlink EIS)

Casual assistant demonstrator, Depts Zoology and Ecosystem Management, UNE, 1988-2002 (field practical classes on population ecology and behavioural ecology of birds)

Casual teacher, New England Institute of TAFE, 1987-1993 (bird biology: including laboratory and field practical classes on classification, identification and ecology)

Field technician, National Parks & Wildlife Service Armidale, 1986 (fauna inventory, vegetation sampling and analysis)

Research assistant, Department of Ecosystem Management, University of New England, casual 1986-1987 (field survey of vegetation and fauna)

Honorary position:

Adjunct associate lecturer/research associate, Zoology UNE, 2004-2017 (includes collaborative research and publication, co-supervision of Honours/Masters/PhD students)

Consultant biologist:

Whitehaven Coal 2018 (field survey, assessment and report on potential BioBank site for Regent Honeyeater)

Northern Tablelands Local land Services 2017-18 (Birds of Prey Monitoring project: nest sites and productivity of threatened raptors on the tablelands – field survey and report)

North West Local Land Services 2015-18 (Regent Honeyeater, Swift Parrot, raptor and woodland bird surveys and reporting)

28 South Environmental 2013-2018 (threatened fauna survey/assessment and report)

Fenner School of Environment and Society, Australian National, University 2016-17 (Regent Honeyeater surveys and data submission)

3E Environmental 2012-17 (flora & fauna survey and reporting)

BirdLife Australia – Northern NSW (for Bundarra-Barraba Operations Group of the Regent Honeyeater Recovery Team), 2007-17 (Regent Honeyeater/woodland bird survey and monitoring)

Southern New England Landcare 2014-16 (fauna surveys on farms, data submission, landholder workshop, report review)

James Warren & Associates 1997-2016 (fauna survey and reporting)

Conacher Environmental Group 2008, 2015 (fauna survey and report)

Ecotone Environmental Services 2012-13 (peer review of threatened fauna assessment; targeted fauna survey: federally listed birds)

NSW National Parks & Wildlife Service/Dept Environment & Conservation/DECC 1987-2013 (fauna survey, review of avifaunal component of environmental impact statements/ fauna impact statements/fauna reports, preparation of recovery plans and species profiles for threatened species)

Australian Museum, 1995, 2012 (review of fauna impact statement, avifauna; feather sampling of wild-caught birds for DNA analysis)

Cumberland Ecology 2004-2012 (fauna survey and report)

Arnhem Environmental 1996-2012 (fauna survey)

Eco Logical Australia 2010-2011 (threatened bird research, fauna database compilation)

Warkworth Mining Ltd 2008, 2011 (avifauna survey and report)

Terra Consulting/Geolyse/Orogen 2004-11 (fauna survey and assessment)

State Forests of NSW 1987-2009 (fauna survey, review of avifaunal component of environmental impact statements/fauna impact statements/fauna reports, fauna survey worskhop)

TransGrid 2009 (investigation and report: bird-related outages on 500 kV transmission lines)

Earth Services 2007-08 (fauna survey and report)

Armidale Dumaresq Council 2006-08 (fauna assessment)

Tamworth Regional Council 2007-08 (starling control/raptor assessment)

PLACE Environmental 2006-07 (fauna assessment)

ACT Planning & Land Authority 2005-06 (fauna survey and assessment)

Greenloaning Biostudies 1996-2004 (fauna survey)

Burnett Shire Council 2003 (fauna survey and assessment)

Inverell Shire Council 2003 (fauna assessment)

HWR Ecological 2003 (fauna survey)

WBM Oceanics 1999-2002 (fauna survey)

Resource Strategies 1999 (fauna survey)

Network Design & Construction Ltd, 1999 (fauna survey)

Woodward-Clyde Pty Ltd, 1994-1999 (fauna survey)

Telstra Environmental Evaluation Team 1998 (fauna survey and report)

Maunsell Pty Ltd, 1995-97 (fauna survey, review of environmental assessment)

Austeco Pty Ltd, 1990-1997 (fauna survey)

North-west Ecological Services 1997 (fauna survey)

ANCA 1995-1996 (fauna survey, Jervis Bay National Park)

SA National Parks & Wildlife Service, 1995 (fauna survey)

Grants and awards:

Search for Red Goshawk in NSW: $1,000 from the Australian Bird Environment Fund (Bird Observers Club of Aust.), 1987.

Distribution, status and habitat requirements of the Sooty Owl in northern NSW: $2,000 as a Cayley Memorial Scholarship (Gould League of NSW) 1990-93; with Associate Professors Hugh Ford & Harry Recher (UNE), $34,280 from WWF Australia and $64,835 from ANPWS (Endangered Species Program) 1990-93.

Will wildlife corridors work for sedentary birds?: with Professor Hugh Ford, $42,565 from the NSW Environmental Trust 2005, $43,359 in 2006-07.

Bird Observers Club of Australia: Distinguished Service Award, 2005 (editing the *Australian Bird Watcher*/*Australian Field Ornithology* for 21 years 1984-2005).

Royal Zoological Society of NSW Whitley Award, 2013 (*Birds of Prey of Australia: A Field Guide*, 2nd edn, best vertebrate guide in 2012)

BirdLife Australia's D.L. Serventy Medal for publication in ornithology, 2015

Voluntary work:

Editor: *Australasian Raptor Association News* 1980-1989 and *Boobook* (re-named) 2004-17 (biannual journal for bird-of-prey enthusiasts); *Australian Field Ornithology* 1984-2015 (quarterly journal)

Sub-editor: *Corella* Wedge-tailed Eagle special issue, 2007; White-bellied Sea-Eagle special issue, 2009; rare raptors special issue, 2011

Committee member: Australian Bird Study Association 1981-1988, 2005-17; Birds Australia Northern NSW Group 1996-99, 2004-12, 2015-17; Australasian Ornithological Conference 2009 organising committee 2008-09; ABSA/BirdLife Southern NSW conference organising committee 2013-14

Regent Honeyeater Recovery Team: Bundarra-Barraba Operations Group rep, 2008-18

Red Goshawk National Recovery Team 2014-18

Publications:

~130 refereed papers (selection appended), books and book contributions, theses: see appended list

Refereed publications (selected titles):

Debus, S.J.S. 1984. Biology of the Little Eagle on the Northern Tablelands of New South Wales. *Emu* 84: 87-92.

_____, Ley, A.J., Trémont, S. & Trémont, R. 1991. Breeding behaviour and diet of the Australian Hobby *Falco longipennis* in northern New South Wales. *Aust. Bird Watcher* 14: 123-137.

Debus, S.J.S. 1992. A survey of diurnal raptors in north-east New South Wales, 1987-1990. *Aust. Birds* 25: 67-77.

Debus, S.J.S. 1993a. The mainland Masked Owl *Tyto novaehollandiae*: a review. *Aust. Bird Watcher* 15: 168-191.

_____ 1993b. The status of the Red Goshawk *Erythrotriorchis radiatus* in New South Wales, in Olsen, P.D. (Ed.), *Australian Raptor Studies*, pp. 182-191. Australasian Raptor Association, RAOU, Melbourne.

Debus, S.J.S., Ley, A.J., Trémont, S.M., Trémont, R.M. & Collins, J.L. 1993. Breeding behaviour and diet of the Collared Sparrowhawk *Accipiter cirrhocephalus* in northern New South Wales. *Aust. Bird Watcher* 15: 68-91.

Debus, S.J.S., McAllan, I.A.W. & Mead, D.A. 1993a,b. Museum specimens of the Red Goshawk *Erythrotriorchis radiatus*. I. Annotated list of specimens; II. Morphology, biology and conservation status in eastern Australia. *Sunbird* 23: 5-28; 75-89.

Debus, S.J.S., McAllan, I.A.W. & Morris, A.K. 1993. The Square-tailed Kite *Lophoictinia isura* in New South Wales. *Aust. Birds* 26: 104-118.

Peake, P., Conole, L.E., Debus, S.J.S., McIntyre, A. & Bramwell, M. 1993. The Masked Owl *Tyto novaehollandiae* in Victoria. *Aust. Bird Watcher* 15: 124-136.

Ford, H.A., Davis, W.E., Debus, S., Ley, A., Recher, H. & Williams, B. 1993. Foraging and aggressive behaviour of the Regent Honeyeater *Xanthomyza phrygia* in northern New South Wales. *Emu* 93: 277-281.

Debus, S.J.S. 1994. The Sooty Owl *Tyto tenebricosa* in New South Wales. *Aust. Birds* 28 supplement: 4-19.

_____ & Chafer, C.J. 1994. The Powerful Owl *Ninox strenua* in New South Wales. *Aust. Birds* 28 supplement: 21-38.

_____ & Rose, A.B. 1994. The Masked Owl *Tyto novaehollandiae* in New South Wales. *Aust. Birds* 28 supplement: 40-64.

Debus, S.J.S. 1995. Surveys of large forest owls in northern New South Wales: methodology, calling behaviour and owl responses. *Corella* 19: 38-50.

Kavanagh, R.P., Debus, S., Tweedie, T. & Webster, R. 1995. Distribution of nocturnal forest birds and mammals in north-eastern New South Wales: relationships with environmental variables and management history. *Wildlife Research* 22: 359-377.

Debus, S.J.S. 1997a. A survey of the raptors of Jervis Bay National Park. *Aust. Birds* 30: 29-44.

_____ 1997b. The Barking Owl in New South Wales. *Aust. Birds* 30: 53-80.

_____ 1997c. Aspects of the biology of captive-bred, hack-released Masked Owls *Tyto novaehollandiae*. In Czechura, G. & Debus, S. (Eds), *Australian Raptor Studies II*, pp. 14-33. Birds Australia Monograph 3, Birds Australia, Melbourne.

_____ 1997d. Vocal behaviour of the Southern Boobook *Ninox novaeseelandiae* and other nocturnal birds. In Czechura, G. & Debus, S. (Eds), *Australian Raptor Studies II*, pp. 71-85. Birds Australia Monograph 3, Birds Australia, Melbourne.

Mathieson, M.T., Debus, S.J.S., Rose, A.B., McConnell, P.J. & Watson, K.M. 1997. Breeding diet of the Letter-winged Kite *Elanus scriptus* and Black-shouldered Kite *Elanus axillaris* during a House Mouse plague. *Sunbird* 27: 65-71.

Debus, S.J.S., Maciejewski, S.E. & McAllan, I.A.W. 1998. The Grass Owl in New South Wales. *Aust. Birds* 31: 29-45.

Brigham, R.M., Debus, S.J.S. & Geiser, F. 1998. Cavity selection for roosting, and roosting ecology of forest-dwelling Australian Owlet-nightjars (*Aegotheles cristatus*). *Aust. J. Ecol.* 23: 424-429.

Bischoff, T., Lutter, H. & Debus, S. 2000. Square-tailed Kites breeding on the mid-north coast of New South Wales. *Aust. Bird Watcher* 18: 233-240.

Brown, B., Brown, F. & Debus, S.J.S. 2000. Further observations on a pair of Square-tailed Kites nesting near Grafton, New South Wales. *Aust. Bird Watcher* 18: 270-273.

Debus, S.J.S. & Rose, A.B. 2000. Diet of Grey Falcons *Falco hypoleucos* breeding extralimitally in New South Wales. *Aust. Bird Watcher* 18: 280-281.

Harrington, G.N. & Debus, S.J.S. 2000. Dietary items of the Rufous Owl *Ninox rufa* on the Atherton Tableland, north Queensland. *Aust. Bird Watcher* 18: 251-252.

Debus, S.J.S. 2001. Surveys of the Barking Owl and Masked Owl on the North-west Slopes of New South Wales. *Corella* 25: 5-11.

Barnes, C.P., Zillmann, E.E., Rose, A.B. & Debus, S.J.S. 2001. Diet and biology of the Square-tailed Kite *Lophoictinia isura* in south-eastern Queensland: nest-building to post-fledging. *Aust. Bird Watcher* 19: 28-43.

Debus, S.J.S., Agnew, L.R. & Schulz, M. 2001. Surveys of the Grass Owl *Tyto capensis* in coastal New South Wales. *Aust. Bird Watcher* 19: 94-102.

Debus, S.J.S. 2002. Distribution, taxonomy, status and major threatening processes of owls of the Australasian Region. In Newton, I., Kavanagh, R., Olsen, J. & Taylor, I. (Eds), *Ecology and Conservation of Owls*, pp. 355-363. CSIRO, Melbourne.

Griffiths, H., Lutter, H., Rose, A.B. & Debus, S.J.S. 2002. Breeding and diet of a pair of Square-tailed Kites *Lophoictinia isura* on the mid-north coast of New South Wales. *Aust. Bird Watcher* 19: 184-193.

Debus, S.J.S. & Rose, A.B. 2003. Diet of a Barking Owl *Ninox connivens* in the channel country of south-west Queensland. *Corella* 27: 18-19.

Lutter, H., Dinnie, R. & Debus, S.J.S. 2003. Square-tailed Kites breeding in northern coastal New South Wales: post-fledging diet and behaviour. *Aust. Field Ornithology* 20: 94-104.

Debus, S.J.S., Olsen, J. & Rose, A.B. 2004. Diet of the Barn Owl *Tyto alba* near Lake Frome in arid South Australia. *Corella* 28: 40-42.

Debus, S.J.S. & Rose, A.B. 2004. Diet of the Barn Owl *Tyto alba* near Tamworth, New South Wales. *Corella* 28: 95.

Lutter, H., Lutter, M., Rose, A.B. & Debus, S.J.S. 2004. Breeding biology and diet of the Square-tailed Kite on the mid-north coast of New South Wales. *Aust. Field Ornithology* 21: 141-157.

Olsen, J., Debus, S., Rose, A.B. & Hayes, G. 2004. Breeding success, cliff characteristics, and diet of Peregrine Falcons at high altitude in the Australian Capital Territory. *Corella* 28: 33-37.

Barnes, C.P., Rose, A.B. & Debus, S.J.S. 2005. Breeding behaviour and diet of a family of Barking Owls *Ninox connivens* in south-eastern Queensland. *Aust. Field Ornithology* 22: 182-195.

Debus, S.J.S. 2005. White-bellied Sea-Eagles breeding in the Australian Capital Territory? *Canberra Bird Notes* 30: 146-147.

Debus, S.J.S., Ford, J.A. & Rose, A.B. 2005. Breeding-season diet of a pair of Barking Owls near Armidale, New South Wales. *Corella* 29: 15-16.

Debus, S.J.S. & Lollback, G. 2005. Breeding behaviour of the Restless Flycatcher near Armidale, New South Wales. *Aust. Field Ornithology* 22: 22-28.

Debus, S.J.S. & Rose, A.B. 2005. Spring diet of Pied Currawongs at Imbota Nature Reserve, Armidale, New South Wales. *Corella* 29: 19-21.

Debus, S.J.S., Hatfield, T.S., Olde, G.S. & Rose, A.B. 2005. Breeding behaviour and diet of a pair of Black Falcons *Falco subniger* in northern New South Wales. *Aust. Field Ornithology* 22: 165-181.

Courtney, J. & Debus, S.J.S. 2006a. Breeding habits and conservation status of the Musk Lorikeet *Glossopsitta concinna* and Little Lorikeet *G. pusilla* in northern New South Wales. *Aust. Field Ornithology* 23: 109-124.

_____ & _____ 2006b. Observations on the post-fledging period of the Barn Owl *Tyto alba*. *Aust. Field Ornithology* 23: 159-162.

Debus, S.J.S. 2006a. Breeding and population parameters of robins in a woodland remnant in northern New South Wales, Australia. *Emu* 106: 147-156.

_____ 2006b. Breeding biology and behaviour of the Scarlet Robin *Petroica multicolor* and Eastern Yellow Robin *Eopsaltria australis* in remnant woodland near Armidale, New South Wales. *Corella* 30: 59-65.

_____ 2006c. Breeding habitat and nest-site characteristics of Scarlet Robins and Eastern Yellow Robins near Armidale, New South Wales. *Pacific Conservation Biology* 12: 261-271.

_____ 2006d. The role of intense nest predation in the decline of Scarlet Robins and Eastern Yellow Robins in remnant woodland near Armidale, New South Wales. *Pacific Conservation Biology* 12: 279-287.

Debus, S.J.S. & Rose, A.B. 2006. Supplementary data on breeding and diet of the Northern Forest Raven *Corvus tasmanicus boreus*. *Aust. Field Ornithology* 23: 96-101.

Debus, S.J.S., Ford, H.A. & Page, D. 2006. Bird communities in remnant woodland on the New England Tablelands, New South Wales. *Pacific Conservation Biology* 12: 50-63.

Debus, S.J.S., Ford, H.A. & Trémont, S.M. 2006. Bird communities in remnant woodland on the upper North-west Slopes of New South Wales. *Aust. Zoologist* 33: 519-529.

Debus, S.J.S., Lollback, G., Oliver, D.L. & Cairns, S.C. 2006. The birds of Bulgunnia and Mulyungarie Stations in the pastoral zone of arid South Australia. *South Australian Ornithologist* 35: 27-37.

Debus, S.J.S., Olde, G.S., Marshall, N., Meyer, J. & Rose, A.B. 2006. Foraging, breeding behaviour and diet of a family of Black-shouldered Kites *Elanus axillaris* near Tamworth, New South Wales. *Aust. Field Ornithology* 23: 130-143.

Lutter, H., McGrath, M.B., McGrath, M.A. & Debus, S.J.S. 2006. Observations on nesting Brahminy Kites *Haliastur indus* in northern New South Wales. *Aust. Field Ornithology* 23: 177-183.

Debus, S.J.S. 2007a. Avifauna of remnant bushland in south-east Queensland I: Brisbane and hinterland. *Sunbird* 37(2): 14-24.

_____ 2007b. Avifauna of remnant bushland in south-east Queensland II: The Gold Coast hinterland. *Sunbird* 37(2): 25-32.

_____ 2007c. Avifauna of remnant bushland in south-east Queensland III: The Sunshine Coast and hinterland. *Sunbird* 37(2): 33-44.

_____ 2007d. Avifauna of remnant bushland on the Tweed Coast of New South Wales. *Sunbird* 37(2): 45-55.

Debus, S.J.S. & Wood, C. 2007. Growth of a nestling Masked Owl *Tyto novaehollandiae*. *Aust. Field Ornithology* 24: 49-53.

Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007a. Breeding biology and diet of the Wedge-tailed Eagle *Aquila audax* in the New England region of New South Wales. *Aust. Field Ornithology* 24: 93-120.

Debus, S.J.S., Hatfield, T.S., Ley, A.J. & Rose, A.B. 2007b. Breeding biology and diet of the Little Eagle *Hieraaetus morphnoides* in the New England region of New South Wales. *Aust. Field Ornithology* 24: 137-157.

Debus, S.J.S., Ley. A.J. & Rose, A.B. 2007. Winter diet of a Barn Owl and a Nankeen Kestrel in Diamantina National Park, western Queensland. *Sunbird* 37: 1-8.

Debus, S.J.S. 2008a. The effect of Noisy Miners on small bush birds: an unofficial cull and its outcome. *Pacific Conservation Biology* 14: 185-190.

Debus, S.J.S. 2008b. Biology and diet of the White-bellied Sea-Eagle *Haliaeetus leucogaster* breeding in northern inland New South Wales. *Aust. Field Ornithology* 25: 165-193.

Debus, S.J.S., Ley, A.J. & Rose, A.B. 2008. Further dietary items of the Eastern Barn Owl *Tyto javanica* in Diamantina National Park, Queensland. *Australian Field Ornithology* 25: 149–152.

Trost, S., Olsen, J., Rose, A.B. & Debus, S.J.S. 2008. Winter diet of Southern Boobooks *Ninox novaeseelandiae* in Canberra 1997-2005. *Corella* 32: 66-70.

Debus, S.J.S. & Ley, A.J. 2009. Aspects of the breeding cycle of the Little Eagle *Hieraaetus morphnoides*. *Australian Field Ornithology* 27: 76-99.

Cherriman, S.C., Foster, A. & Debus, S.J.S. 2009. Supplementary notes on the breeding behaviour of Wedge-tailed Eagles *Aquila audax*. *Australian Field Ornithology* 27: 142-147.

Ford, H.A., Walters, J.R., Cooper, C.B., Debus, S.J.S. & Doerr, V.A.J. 2009. Extinction debt or habitat change? – Ongoing losses of woodland birds in north-eastern New South Wales, Australia. *Biological Conservation* 142: 3182-3190.

Debus, S.J.S., Ley, A.J. & Rose, A.B. 2010. Diet of the Eastern Barn Owl *Tyto (javanica) delicatula* in Diamantina National Park, south-western Queensland, in 2008–2009. *Australian Field Ornithology* 27: 179-183.

Olsen, J., Fuentes, E., Judge, D., Rose, A.B. & Debus, S.J.S. 2010. Diets of Wedge-tailed Eagles (*Aquila audax*) and Little Eagles (*Hieraaetus morphnoides*) breeding near Canberra, Australia. *J. Raptor Research* 44: 50-61.

Debus, S.J.S. 2011. Parental time-budgets and breeding behaviour of the Little Eagle *Hieraaetus morphnoides* in northern New South Wales. *Corella* 35: 65-72.

Debus, S.J.S. & Olsen, J. 2011. Some aspects of the biology of the Black Falcon *Falco subniger*. *Corella* 35: 29-36.

Debus, S.J.S. & Tsang, L.R. 2011. Notes on Black Falcons *Falco subniger* breeding near Tamworth, New South Wales. *Australian Field Ornithology* 28: 13-26.

Barnes, C.P. & Debus, S.J.S. 2012. A snapshot in the post-fledging period of the Black Falcon. *Australian Field Ornithology* 29: 86-88.

Debus, S.J.S. 2012. Hunting behaviour of Black Falcons. *Australian Field Ornithology* 29: 83-85.

Debus, S.J.S. & Ford, H.A. 2012. Responses of Eastern Yellow Robins *Eopsaltria australis* to translocation into vegetation remnants in a fragmented landscape. *Pacific Conservation Biology* 18: 194-202.

O'Donnell, W.B. & Debus, S.J.S. 2012. Nest-sites and foraging of the White-bellied Sea-Eagle *Haliaeetus leucogaster* on the subtropical eastern Australian coast. *Australian Field Ornithology* 29: 149-159.

Debus, S.J.S. 2013. Breeding of the Hooded Robin *Melanodryas cucullata* in native and exotic woodlands near Armidale, New South Wales. *Corella* 37: 49-56.

Debus, S.J.S. & Zuccon, A.E. 2013. Observations on hunting and breeding behaviour of the Black Falcon *Falco subniger*. *Sunbird* 43: 12-26.

Debus, S.J.S., Olsen, J., Judge, D. & Butterfield, M. 2013. Numbers of breeding Little Eagles *Hieraaetus morphnoides* near Canberra in relation to atlas counts. *Corella* 37: 30-32.

Olsen, J., Debus, S.J.S. & Judge, D. 2013. Declining Little Eagles *Hieraaetus morphnoides* and increasing rabbit numbers near Canberra: is secondary poisoning by Pindone the problem? *Corella* 37: 33-35.

Olsen, J., Debus, S.J.S., Judge, D. & Rose, A.B. 2013. Diets of Wedge-tailed Eagles *Aquila audax* and Little Eagles *Hieraaetus morphnoides* breeding near Canberra, 2008–2009. *Corella* 37: 25-29.

Olsen, J., Debus, S.J.S., Rose, A.B. & Judge, D. 2013. Diets of White-bellied Sea-Eagles *Haliaeetus leucogaster* and Whistling Kites *Haliastur sphenurus* breeding near Canberra, 2003–2008. *Corella* 37: 13-18.

Trainor, C.R., Debus, S.J.S., Olsen, J., Norman, J.A. & Christidis, L. 2013. Bonelli's Eagle *Aquila fasciata renschi* in the Lesser Sundas, Wallacea: distribution, taxonomic status, likely origins and conservation status. *Forktail* 29: 100-106.

Barnes, C.P. & Debus, S.J.S. 2014. Observations on the post-fledging period of the Collared Sparrowhawk (*Accipiter cirrocephalus*). *Sunbird* 44: 12-23.

Charley, D., Lutter, H. & Debus, S.J.S. 2014. Breeding behaviour and prey of Black Falcons, *Falco subniger*, including food-caching. *South Australian Ornithologist* 40: 11-30.

Debus, S.J.S. & Searle, J.B. 2014. Surveys of the Red Goshawk and other raptors on the Weipa Plateau, Cape York Peninsula. *Sunbird* 44: 36-51.

Debus, S.J.S., Baker, G., Owner, D. & Nottidge, B. 2014. Response of White-bellied Sea-Eagles *Haliaeetus leucogaster* to encroaching human activities at nest sites. *Corella* 38: 53-62.

Baylis, T., van Gessel, F.W. & Debus, S.J.S. 2015. Some vocalisations of the Grey Falcon *Falco hypoleucos*. *Corella* 39: 73-76.

Debus, S.J.S. 2015. Assessment of band recoveries for three Australian eagle species. *Corella* 39: 67-72.

Debus, S.J.S., Baker-Gabb, D.J. & Aumann, T.A. 2015. Parental time-budgets, breeding behaviour and affinities of the Red Goshawk *Erythrotriorchis radiatus*. *Corella* 39: 87-93.

Aumann, T.A., Baker-Gabb, D.J. & Debus, S.J.S. 2016. Breeding diets of four raptor species in the Australian tropics. *Corella* 40: 13-16.

Bishop, D., Diamond, J., Hornbuckle, J. & Debus, S. 2016. New breeding, distribution and prey records for the Pygmy Eagle *Hieraeetus weiskei*. *Australian Field Ornithology* 33: 224-226.

Rourke, J. & Debus, S.J.S. 2016. The breeding cycle of a pair of Brahminy Kites *Haliastur indus* in New South Wales. *Australian Field Ornithology* 33: 151-155.

Whelan, D.J., McRitchie, B.W., Pickering, L.J. & Debus, S.J.S. 2016. Observations on a breeding pair of Black Falcons *Falco subniger* in southern Victoria. *Australian Field Ornithology* 33: 159-166.

Debus, S.J.S., Bauer, A.L. & van Gessel, F.W. 2017. Calls and vocal behaviour of the Black Falcon *Falco subniger*. *Corella* 41: 83-87.

Debus, S.J.S., Bauer, A.L. & Mitchell, G.I. 2017. Breeding biology, behaviour and foraging ecology of the Black Falcon *Falco subniger* near Tamworth, New South Wales. *Corella* 41: 71-82.

Debus, S.J.S., Martin, W.K. & Lemon, J.M. 2017. Changes in woodland bird communities as replanted woodland matures. *Pacific Conservation Biology* 23: 359-371.

Olsen, J., Judge, D., Trost, S., Rose, A.B. & Debus, S.J.S. 2018. Diets of breeding Brown Goshawks *Accipiter fasciatus* and Collared Sparrowhawks *A. cirrocephalus* near Canberra, Australia: comparisons with other regions and raptor species. *Corella* 42: 18-28.

Debus, S.J.S., McAllan, I.A.W. & Schodde, R. Submitted. *Circus assimilis* Jardine & Selby, 1828 and *Circus approximans* Peale, 1848 (Aves, Accipitriformes): conservation of usage by designation of a neotype for *Circus assimilis* Jardine & Selby, 1828. *Bulletin of Zoological Nomenclature*.

Palmer, R., Rose, A.B. & Debus, S.J.S. Submitted. Diet of the Peregrine Falcon *Falco peregrinus* in inland south-western Australia. *Australian Field Ornithology*.

Schoeb, M., Werner, R., Janetzki, H. & Debus, S.J.S. In prep. Black Falcons *Falco subniger* breeding near Mackay in coastal Queensland. *Australian Field Ornithology*.

Books:

Debus, S.J.S. 1993. Falconiformes, Accipitridae, Falconidae, Gurney's Eagle, Little Eagle, Square-tailed Kite, Osprey texts in Marchant, S. & Higgins, P.J. (Eds), *Handbook of Australian, New Zealand and Antarctic Birds, Vol. 2: Raptors to Lapwings*. Oxford University Press, Melbourne.

_____ 1994. Australasian raptor species texts in del Hoyo, J., Elliott, A. & Sargatal, J. (Eds), *Handbook of the Birds of the World* vol. 2. Lynx, Barcelona.

_____ 1996. Turnicidae, buttonquail species texts in del Hoyo, J., Elliott, A. & Sargatal, J. (eds), *Handbook of the Birds of the World* vol. 3. Lynx, Barcelona.

Czechura, G. & Debus, S. (Eds) 1997. *Australian Raptor Studies II*. Birds Australia Monograph 3, Birds Australia, Melbourne.

Debus, S. 1998. *The Birds of Prey of Australia: A Field Guide*. Oxford University Press, Melbourne.

Debus, S.J.S. (Ed.) 1999. Strigiformes, Caprimulgiformes species accounts in Higgins, P.J. (Senior Ed.), *Handbook of Australian, New Zealand and Antarctic Birds, Volume 4, Parrots to Dollarbird*, Oxford University Press, Melbourne.

Debus, S. 1999. Red Goshawk, Barking Owl species accounts in Ayers, D., Nash, S. & Baggett, K., *Threatened Species of Western New South Wales*, National Parks & Wildlife Service, Sydney (revised edition).

Olsen, P., Debus, S., Shea, C.J., Bildstein, K.L. & Ellis, S. (Eds) 2000. *Selected Australasian Falconiformes Conservation Assessment and Management Plan*. IUCN/SSC Conservation Breeding Specialist Group, Apple Valley (MN, USA).

Debus, S. 2009. *The Owls of Australia: A Field Guide to Australian Night Birds*. Envirobook, Sydney.

_____ 2009. Australasian crow/raven species texts in del Hoyo, J., Elliott, A. & Christie, D. (Eds), *Handbook of the Birds of the World* vol. 14. Lynx, Barcelona.

Curtis, L.K., Dennis, A.J., McDonald, K.R., Kyne, P.K. & Debus, S.J.S. (Eds) 2012. *Queensland's Threatened Animals* (Debus: Powerful Owl, Rufous Owl, Masked Owl species accounts). CSIRO Publishing, Melbourne.

Debus, S. 2012. *Birds of Prey of Australia: A Field Guide*, 2nd edn. CSIRO Publishing, Melbourne.

Debus, S. 2017. *Australasian Eagles and Eagle-like Birds*. CSIRO Publishing, Melbourne.

Debus, S. Submitted. Grey Falcon and Black Falcon chapters in Leonardi, G. (Ed), *Falcons of Arid Environments* (in prep.). To be published privately, Catania, Italy.

Theses:

Debus, S. 1994. Aspects of the biology, conservation and management of threatened forest owls and raptors in northern New South Wales. MSc thesis, University of New England, Armidale.

Debus, S. 2004. The impact of habitat fragmentation on woodland birds: A test of some hypotheses in New England. PhD thesis, University of New England, Armidale.

Appendix 1. Habitat descriptions for each Site in greater Macarthur and Wilton Proposed Growth Areas.

Site No.	Latitude	Longitude	PCTs	Canopy Height (m)	Canopy Spacing	DBH Range (m)	Shrub Cover	Ground Cover	Woodland Maturity	Shrub Diversity	Regeneration	Connectivity	Aspect/Slope	Avian Community
1	-33.96801	150.90682	849	15-20	Closed	0.3-0.7	Sparse tall shrubs	Sparse grass and mainly leaf litter	Mature	Poor and weedy	None evident	Good	Flat	Large passerines and parrots
2	-33.97577	150.90994	835, 849	15-20	Closed	0.4-1.3	Dense	Native grasses in open areas	Mature	Good with some weeds	Some regeneration	Very good	Along watercourse valley	Large passerines and parrots
3	-33.98336	150.89717	1395	15-20	Closed	0.2-0.5	Dense	Mainly leaf litter	Mature	Good	Some regeneration	Good	Along watercourse	Diverse, with small passerines
4	-33.99160	150.87588	835	15-20	Open and patchy	0.2-0.9	Dense along creek, absent in parkland	Mainly mown grass	Mature	Good but only along creek	None evident	Good	Along watercourse	Low diversity - dominated by N.Miner
5	-33.99667	150.87933	849	15	Open	0.3-0.7	Some dense patches	Mainly mown grass	Mature	Low	Some regeneration	Moderately good	Flat and along watercourse	Low diversity - dominated by N.Miner
6	-33.00763	150.86866	835	10-15	Scattered trees	0.3-0.7	Low	Mainly mown grass	Mature	Low	None evident	Isolated	Along watercourse	Low diversity - dominated by N.Miner
7	-34.01357	150.85682	835, 1395	15-20	Open and patchy	0.3-1.2	Dense along creek with some small patches away from creek	Mainly leaf litter and native grass in open areas	Mature	Good with some weeds	Some regeneration	Good	Along watercourse valley	Diverse, with small passerines
8	-34.01049	150.84202	849	20	Scattered trees	0.8	Mostly absent with small scattered dense patches	Native grasses in open areas	Mature	Poor and weedy	None evident	Poor	Flat area	Low diversity - dominated by N.Miner
9	-34.00402	150.83964	1395	15	Open	0.7	Dense	Mainly leaf litter	Mature	Poor mainly natives	None evident	Poor	Along a canal	Some small passerines

Appendix 1. Habitat descriptions for each Site in greater Macarthur and Wilton Proposed Growth Areas.

Site No.	Latitude	Longitude	PCTs	Canopy Height (m)	Canopy Spacing	DBH Range (m)	Shrub Cover	Ground Cover	Woodland Maturity	Shrub Diversity	Regeneration	Connectivity	Aspect/Slope	Avian Community
10	-34.03953	150.84055	849	12-15	Closed	0.2-0.8	Dense along creek, absent in parkland	Mainly mown grass	Mature	Good but only along creek with woody weeds	None evident	Poor	Along watercourse	Large passerines and parrots
11	-34.05475	150.83743	1081, 1181	20-25	Open	0.2-1.2	Dense with variable height	Mainly leaf litter	Mature	Very good	Some regeneration	Good	Along watercourse valley	Diverse with small passerines
12	-34.05460	150.81757	850	10-18	Open and patchy	0.2-0.6	Dense with variable height	Mainly leaf litter	Mature	Poor and weedy	None evident	Isolated	North facing steep slope	Large passerines and parrots
13	-34.05984	150.79926	850	10-15	Open	0.2-0.8	Some dense patches	Mainly leaf litter and native grass in open areas	Mature	Poor and weedy, but with some *Bursaria spinosa*	None evident	Isolated	Along watercourse valley	Large passerines and parrots
14	-34.05677	150.80422	850	15	Scattered trees	0.4	Some dense patches	Mainly leaf litter and native grass in open areas	Mature	Good	None evident	Isolated	Along watercourse	Large passerines and parrots
15	-34.06471	150.79735	835	15-18	Closed	0.2-0.6	Some large dense patches	Mainly leaf litter and native grass in open areas	Young	Good with some weeds	Some regeneration	Isolated	Along watercourse	Some small passerines
16	-34.07929	150.80041	849	10-15	Open and patchy	0.3-0.5	Some large dense patches	Mainly leaf litter and native grass in open areas	Mature	Poor and weedy	Some regeneration	Isolated	Along east facing slope	Large passerines and parrots
17	-34.07103	150.79253	835	12-20	Closed	0.3-0.8	Dense	Mainly leaf litter	Mature	Good with very few weeds	Some regeneration	Poor	Along watercourse	Diverse, with small passerines
18	-34.07175	150.78816	849	15-20	Open	0.3-0.8	Very dense	Mainly leaf litter	Mature	Poor and weedy	Some regeneration	Poor	Along watercourse	Large passerines and parrots
19	-34.07426	150.77886	849	15-20	Open	0.3-0.8	Very dense	Mainly leaf litter	Mature	Poor and weedy	Some regeneration	Poor	Along watercourse	Large passerines and parrots

Appendix 1. Habitat descriptions for each Site in greater Macarthur and Wilton Proposed Growth Areas.

Site No.	Latitude	Longitude	PCTs	Canopy Height (m)	Canopy Spacing	DBH Range (m)	Shrub Cover	Ground Cover	Woodland Maturity	Shrub Diversity	Regeneration	Connectivity	Aspect/Slope	Avian Community
20	-34.09521	150.75699	835	15-20	Open and patchy	0.5-0.8	Some dense patches	Mainly leaf litter and native grass in open areas	Mature	Good with some weeds	Some regeneration	Moderately good	Along watercourse	Diverse, with small passerines
21	-34.10223	150.75169	1395	15-20	Open and patchy	0.2-0.7	Mostly sparse with some small dense patches	Mainly leaf litter and native grass in open areas	Mature	Poor and weedy	None evident	Poor	Gently sloping hilltop	Low diversity - dominated by N.Miner
22	-34.09795	150.74683	849	12-20	Closed but open at patch edges	0.2-1.3	Sparse	Dense cover of native grasses	Young with some scattered mature emergent trees	None	Some regeneration	Very good	Flat area	Large passerines and parrots
23	-34.09972	150.7786	830	18-20	Open and patchy	0.3-0.6	Dense with variable height	Mainly leaf litter	Young with some scattered mature emergent trees	Poor and weedy	Some regeneration	Moderately good	Steep-sided hilltop	Low diversity - dominated by N.Miner
24	-34.11215	150.77988	835	20-25	Open and patchy	0.6-1.2	Dense with variable height	Mainly leaf litter	Mature	Poor mainly natives	None evident	Good	Along watercourse valley	Diverse, with small passerines
25	-34.12015	150.79354	1395	20-25	Scattered trees	1.0-1.3	Absent	Heavily grazed native grasses	Mature	None	None evident	Moderately good	Gently undulating	Large passerines and parrots
26	-34.12996	150.78533	1395	20-25	Small patches and scattered trees	0.6-1.3	Absent	Heavily grazed native grasses	Mature	None	None evident	Good	Gently undulating	Large passerines and parrots
27	-34.14001	150.79018	1395	15-20	Closed	0.2-0.7	Moderat e shrub cover in patches	Mainly leaf litter	Mature	Good with no obvious woody weeds	Much sapling regrowth	very good	Gently undulating	Diverse, with small passerines

Appendix 1. Habitat descriptions for each Site in greater Macarthur and Wilton Proposed Growth Areas.

Site No.	Latitude	Longitude	PCTs	Canopy Height (m)	Canopy Spacing	DBH Range (m)	Shrub Cover	Ground Cover	Woodland Maturity	Shrub Diversity	Regeneration	Connectivity	Aspect/Slope	Avian Community
28	-34.15692	150.78909	1395	15-25	Closed but open at patch edges	0.2-0.7	Dense with variable height, but patchy	Mainly leaf litter	Mature	Good with no obvious woody weeds	Some regeneration	Very good	Gently undulating	Diverse, with small passerines
29	-34.19165	150.78422	1395	15-20	Closed but open at patch edges	0.3-0.9	Dense with variable height	Mainly leaf litter	Mature	Good with very few weeds	None evident	Very good	Along watercourse	Diverse, with small passerines
30	-34.20653	150.76729	850	20-25	Open and patchy	0.8-1.3	Sparse with some scattered dense patches	Heavily grazed native grasses	Mature	Good with very few weeds	None evident	Fair	Hilltop with NW facing slope	Large passerines and parrots
31	-34.20109	150.75721	1395	15	Closed but open at patch edges	0.2-0.8	Dense with variable height	Mainly leaf litter	Mature	Good with very few weeds	Some regeneration	Very good	Gently undulating	Diverse, with small passerines
32	-34.22262	150.7522	1395	3-5	Open and patchy	0.2-0.3	Moderate shrub cover in patches	Mainly leaf litter and native grass in open areas	Young	Poor mainly natives	Some regeneration	Good	Hillside sloping to the south	Some small passerines
33	-34.26687	150.71363	1395	10-18	Closed	0.2-0.7	Sparse	Mainly leaf litter and native grass in open areas	Young with some scattered mature emergent trees	Good with very few weeds	Much sapling regrowth	Good	Flat area	Diverse, with small passerines
34	-34.24750	150.70141	1395	15-20	Closed	0.4-1.2	Dense along creek with some small patches away from creek	Mainly leaf litter	Mature	Good with very few weeds	Some regeneration	Very good	Along watercourse valley	Diverse, with small passerines

Appendix 1. Habitat descriptions for each Site in greater Macarthur and Wilton Proposed Growth Areas.

Site No.	Latitude	Longitude	PCTs	Canopy Height (m)	Canopy Spacing	DBH Range (m)	Shrub Cover	Ground Cover	Woodland Maturity	Shrub Diversity	Regeneration	Connectivity	Aspect/Slope	Avian Community
35	-34.23376	150.69217	1395	15-25	Open	0.3-0.8	Dense with variable height	Mainly leaf litter and native grass in open areas	Mature	Good with some weeds	Some regeneration	Moderately good	Flat area	Diverse, with small passerines
36	-34.23014	150.68057	1395	20	Small patches and scattered trees	0.4-1.2	Absent	Mainly mown grass	Mature	None	None evident	Good	Along watercourse	Low diversity - dominated by N.Miner
37	-34.21825	150.66305	849	10-20	Open and patchy	0.4-0.8	Absent	Heavily grazed native grasses	Mature	None	None evident	Good	Flat and along watercourse	Large passerines and parrots
38	-34.22517	150.64112	1395	10-20	Open and patchy	0.4-0.8	Absent	Heavily grazed native grasses	Mature	None	None evident	Good	Gentle slope to the south	Large passerines and parrots
39	-34.23169	150.63132	1395	10-12	Open and patchy	0.2-0.4	Dense along creek with some small patches away from creek	Heavily grazed native grasses	Young with some scattered mature emergent trees	Poor mainly natives	Mostly regeneration	Good	Gentle slope to the south	Low diversity - dominated by N.Miner
40	-34.20781	150.63328	1081	15-20	Open	0.4-0.6	Dense with variable height	Mainly leaf litter	Mature with some regeneratio n	Good with very few weeds	Some regeneration	Good	Slopes to the west	Diverse, with small passerines

Review of updates to the development footprints of the Greater Macarthur and Wilton urban growth areas in relation to strategic assessments on the Little Eagle and the Square-tailed Kite

This supplementary report has been requested by Biosis Pty Ltd in order to examine how changes in the development footprint of the growth areas may affect some of the conclusions made in the strategic assessments for the Little Eagle and the Square-tailed Kite done by Merops Services Pty Ltd in 2018.

This has involved comparisons between the maps of the development footprints from 2018 to 2020 and in particular whether there are changes to the potential breeding habitat for both bird species.

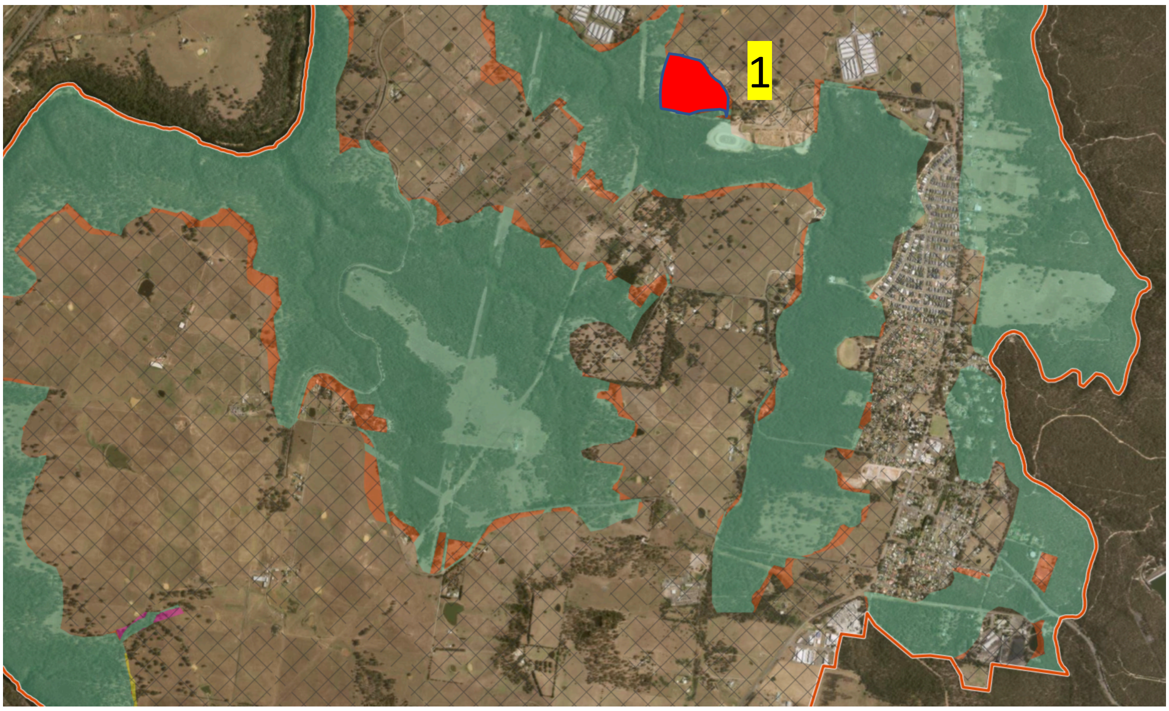
As described in the 2018 strategic assessments, there was no evidence found for breeding for either bird species within the development footprints. As a result, habitat structure, plant species composition and presence of prey species was used to assess whether potential breeding habitat areas existed for either species within the development footprint. The timing of the survey work (late May and June) was outside the breeding period for both raptor species. Although the Little Eagle is present for most of the year the Square-tailed Kite is mostly absent from south-eastern New South Wales during the non-breeding season. In addition, access to much of the area was restricted and often many of the potential areas were examined only from the edges. This was sufficient to describe habitat structure, confirm PCTs and detect potential prey species, but we were not able to check for nests that may have suggested that either species could be using the area. The habitat criteria were used as a surrogate for actual sightings of either species, detection of nests and breeding activity.

The maps created for the 2018 reports indicated potential breeding habitat and potential foraging habitat. The Square-tailed Kite will forage along forest and woodland edges and is somewhat tolerant of nearby human activity. However, the Little Eagle requires a greater buffer between urban areas and breeding habitat. Many of the areas suitable for the Little Eagle have been mapped to show foraging areas working as buffers for potential breeding areas for the Little Eagle. This species requires foraging areas to be adjacent to breeding areas and the more open areas adjacent to the woodland remnants provide these. The Little Eagle will often forage along the edges of timbered habitat and also nest close to edges of more open foraging habitat. The red polygons indicating breeding and foraging habitat represent these areas. The areas shown as orange polygons represent foraging habitat areas that are sufficiently close to potential breeding areas and the areas marked as yellow polygons indicate the same type of habitat, except that such areas overlap the development footprint. Both types of areas would also provide a buffer zone to any development.

The differences in mapping between 2018 and 2020 are considered under two headings. The first looks at potential differences in polygons from the 2018 reports and the 2018 footprint maps supplied to us in 2020. The second looks at whether changes to the development footprints between 2018 and 2020 have meant that changes to the conclusions in the 2018 reports are likely to be required.

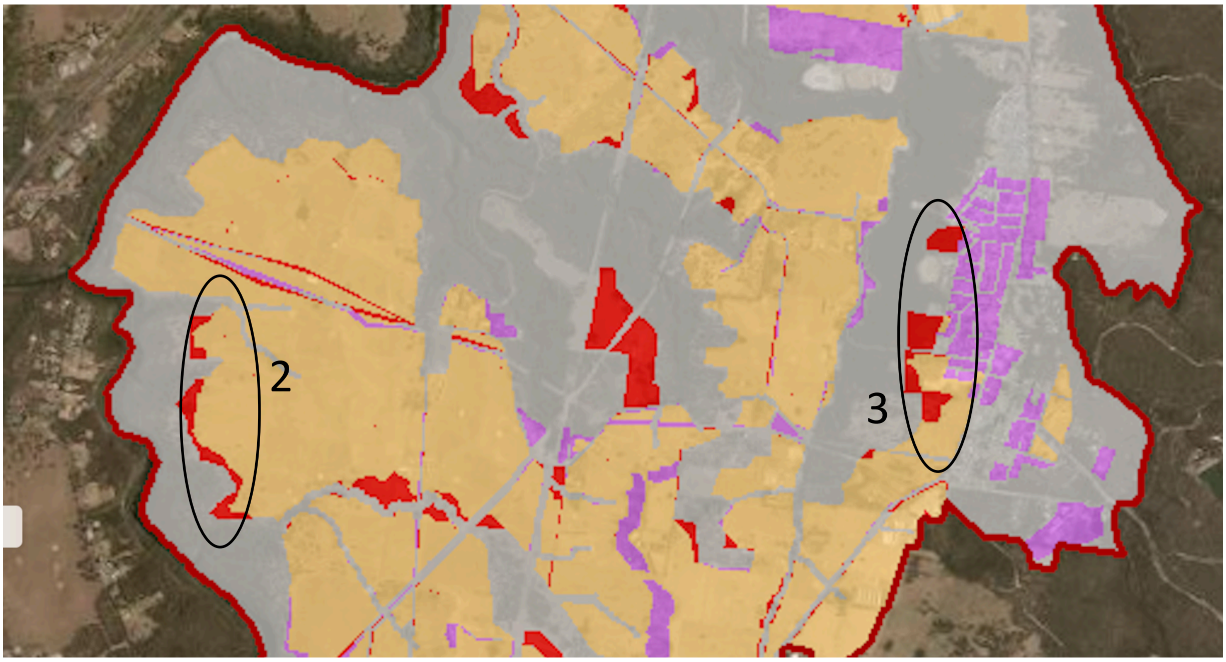
The original vegetation maps supplied to us in 2018 have large areas of PCT 1395 colour coded dark blue. Unfortunately, it was difficult to delineate between the development footprint and areas excluded from the footprint in the margins of these areas. The red polygons in the 2018 reports indicated potential breeding and foraging habitat and some edges of these polygons overlapped the development footprint. Most of these edges will need to be corrected to show foraging habitat overlapping the development footprint. Where there are exceptions to this, maps have been copied and areas of concern are labelled with a number (see sites 1, 2 and 3 on the following maps) and any concerns are discussed in the text for the area with that number.

There were three maps provided for the 2018 footprint for the Macarthur growth area. All impacted margins on the northern and middle maps will need to be changed to yellow polygons. Most of the impacted areas on the southern map will need to be changed to yellow polygons. However, it was noted that the area labelled '1' in the small section of this map inserted below was not shown as being in the original 2018 maps supplied to me. I don't think this is a problem because I also notice that the area and the adjacent area to the east have now been removed from the 2020 footprint. The two maps for the Wilton growth area can also have all impacted margin errors corrected to show yellow polygons. Hopefully this removes any problems with discrepancies between maps for the 2018 development footprints.



The change in footprint maps supplied for this report indicated areas that were not to be developed in both the 2018 and 2020 footprints, areas that were to be developed in both the 2018 and 2020 footprints, development areas that were in the 2018 footprint but which have since been removed and areas that have been added to the development footprint since the 2018 surveys.

Only the changes in footprint are considered here. We have no problems with the areas that have been removed from the development footprint unless there are substantial changes in land-use practices somewhere in the future. At present we see that these changes reduce some of the pressures on local populations of both raptor species. From the maps it appears that most extensions to the development footprint are in areas that have been mostly already cleared of woodland. They are mostly pastureland with some areas where substantial tree thinning has occurred. We can see no problems with these extensions for either raptor species. There are only two areas that may be of concern and these are in the southern section of the Macarthur growth area (see sites 2 and 3 in the section of map shown below). In area 2 the development footprint has been extended into the open woodland buffer zone adjacent to potential breeding habitat and is likely to impact on potential breeding. In area 3 the changes in the development footprint further fragment PCT 1395 habitat which is part of a north-south trending tongue of habitat area. The edge effect of urban development in this area is likely to reduce the area of habitat available to either species, particularly the Little Eagle.



It is suggested that the development footprint within area 2 be moved back to the 2018 position to protect the buffer area and provide more foraging area adjacent to the potential breeding area. Without this suggested change, area 2 should be labelled with yellow polygons as under this development footprint the urban area will overlap foraging habitat. It is difficult to tell from the maps what the habitat quality is like in areas where the development footprint has been extended in area 3 and it may be necessary to examine the site to further assess possible impacts.

In summary, most of the red areas that are margins to potential breeding habitat can be removed as this was due to not being able to see where the development footprint extended into PCT 1395, and the new development footprint appears to be fine except for areas 2 and 3 as described above.

Expert report – *Melaleuca deanei*

Expert report for *Melaleuca deanei* (Deane's Paperbark), Dr Steven Douglas, February 2019

Expert Report For

Melaleuca Deanei

(Deane's Paperbark)

Strategic Assessment for the
Cumberland Plain Conservation Plan

Greater Macarthur, Greater Penrith to Eastern Creek,
Wilton, and Western Sydney Aerotropolis Growth Areas

Prepared for NSW Department of Planning & Environment, February 2019

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1. Introduction

1.1 Purpose of the Expert Report

An Expert Report may be prepared under s.6.5 of the Biodiversity Assessment Method (BAM) in place of undertaking a threatened species survey of sufficient extent, intensity and duration as would otherwise be necessary to comply with the BAM. Use of an Expert Report may be beneficial where it is highly unlikely that a species may occur within a study area; where survey cannot meet BAM specifications; and/or the reliability of detecting the species is low. In respect of *Melaleuca deanei*, insufficient survey extent; constraints on the effectiveness of survey; and unreliability of detection due to aspects of the species' ecology are the primary reasons for preparing an Expert Report.

The purpose of this Report is to provide an assessment of the current status and conservation requirements of *Melaleuca deanei* within the four priority growth areas of Greater Macarthur (GMGA); Wilton (WGA); Greater Penrith to Eastern Creek (GPECGA); and Western Sydney Aerotropolis (WSAGA)to determine whether:

a) The species is unlikely to be present and would thus require no further assessment; or
b) The species is known or likely to be present, and the Expert Report must provide estimates of potential habitat within growth areas and development footprints as part of the biocertification process.

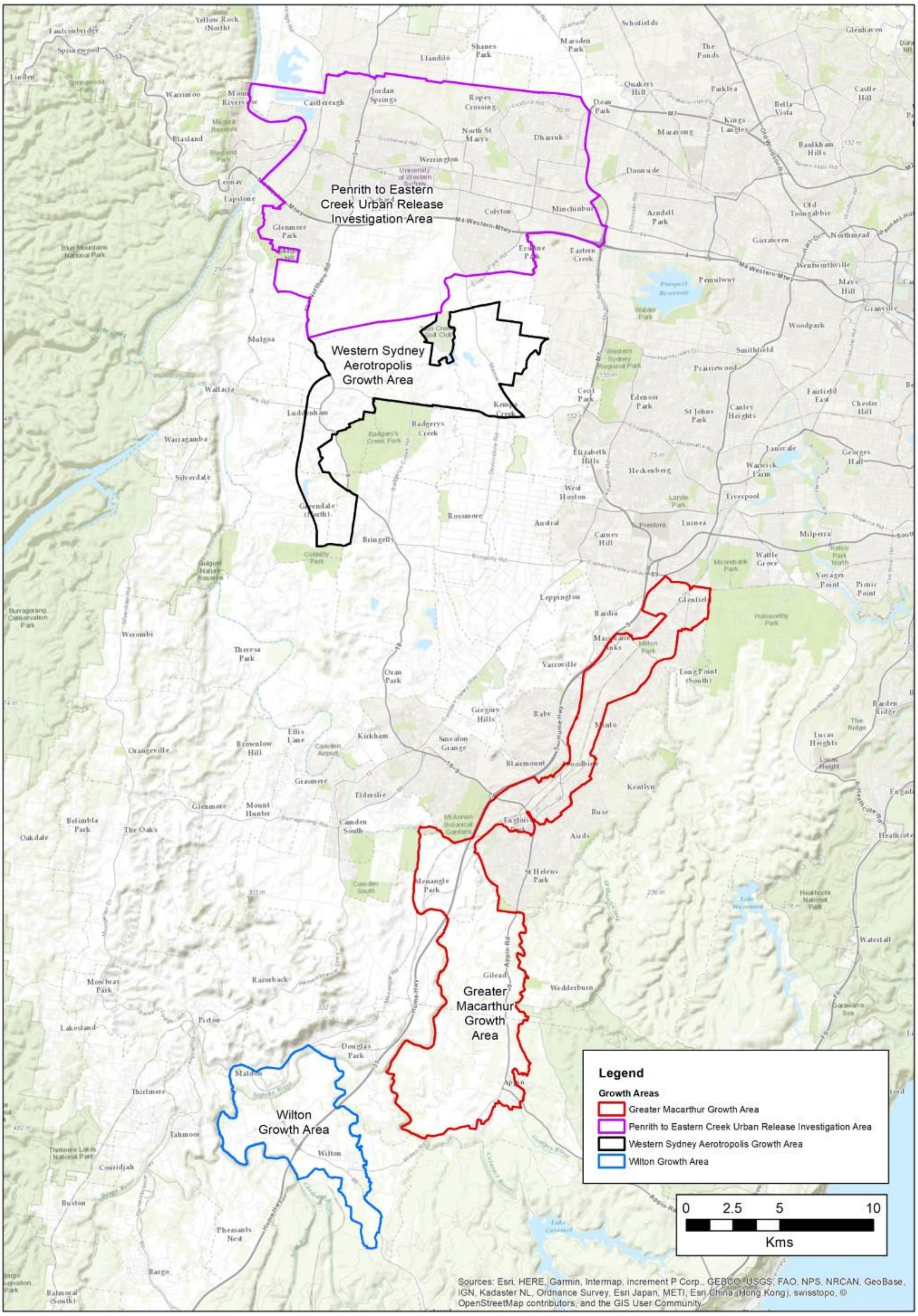
1.2 Project context

The NSW Government is identifying areas for future urban land use and associated infrastructure in western Sydney. The four priority growth areas are all located in the Cumberland Subregion under the Interim Biogeographic Regionalisation for Australia (IBRA) (SEWPaC, 2012).

As part of the planning for these areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify land use outcomes. A strategic assessment of this Plan is underway, and this Expert Report will assist in determining the extent and quantum of impacts of the proposed urban growth on *Melaleuca deanei*.

Melaleuca deanei © Martin Bremner

1.3 Study area



Map 1. Growth Areas subject to this Expert Report

Greater Penrith & Eastern Creek Growth Area (GPECGA)

A large portion of this Growth Area is already urbanised, with several areas of industrial land use. Significant rural and peri-urban areas remain in the central north, the centre, and the southwest. Large areas of remnant vegetation are present in the far north (former Australian Defence Industries site, now in part Wianamatta Regional Park), and the Orchard Hills Defence facility. Mining of alluvium for sand and soil continues in the far northwest of the area in the Penrith Lakes locality.

The area has been extensively cleared because of its relatively arable terrain, based mainly on shale and alluvium. Some of the remaining vegetation is associated with the much less arable to infertile Castlereagh Woodlands and its older, leached and mineralised alluvium and shale-derived soils. Strips of remnant vegetation are present along some of the larger watercourses such as Eastern and South Creeks. Significant parts of the study area are or were flood-prone, and this has influenced the retention of vegetation in some affected areas.

Western Sydney Aerotropolis Growth Area (WSAGA)

This Growth Area adjoins the Greater Penrith to Eastern Creek area, extending south to the locality of Greendale, west of Bringelly. It is currently largely rural, with villages at Luddenham and Kemps Creek. Most rural areas are pastoral, but there are significant areas of more intensive rural use, including poultry and egg production, a large dairy and associated fodder cropping, and some market gardens and enclosed fruit and vegetable production. Quarrying occurs at the localities of Badgerys Creek and Kemps Creek.

This Growth Area is extensively cleared but retains native vegetation in areas where rural uses were constrained by steeper terrain, flooding along streams, or unsuitable soils.

Greater Macarthur Growth Area (GMGA)

The GMGA occurs in southwestern Sydney on predominantly shale soils that have been heavily cleared for agriculture and urban or industrial use. The northernmost section has long-established urban and commercial / industrial land use, while the southern section is largely rural (pastoral, minor cropping), with some villages and primarily subsurface mining (e.g. coal and coal seam gas). It extends from urban Glenfield in the north, to the rural village of Appin in the south.

In the southernmost section, geological uplift and erosion have exposed infertile sandstone terrain along gullies and valleys. Much of that terrain remains naturally vegetated because it is unsuited to agriculture, however it occupies only a small percentage of the total area of this heavily-cleared region. Between the infertile sandstone valleys and the relatively arable shale plateau and hills is a geological and ecological transition zone. Whilst much of the vegetation of the shale terrain has been cleared, a greater area of vegetation remains on the transition zone, primarily in the south. Both the shale and transition zones support Critically Endangered ecological communities that are potential habitat for some threatened plant and animal species.

Wilton Growth Area (WGA)

The Wilton Growth Area is the most southerly of the four Western Sydney Growth Areas dealt with in this Report. It extends from the village of Douglas Park in the north, to the village of Wilton in the south. It is primarily rural (pastoral) area with some more intensive agriculture, significant but mostly underground mining (primarily coal), and some long-established villages. The Hume Motorway dissects this Growth Area.

The pattern of clearing and vegetation retention is broadly similar to that of Greater Macarthur, with the majority of remnant vegetation associated with infertile but biodiverse sandstone gullies and the Nepean River gorge, and with associated transition into the heavily cleared shale landscapes.

1.4 Justification for the use of an Expert Report

An Expert Report for *Melaleuca deanei* is required as part of the threatened biota assessment for the Cumberland Plain Conservation Plan because:

1) Survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH, 2016) for field traverses due to limitations on land access, particularly in the GMGA;
2) Survey quality was constrained by drought conditions. Whilst this species is perennial, under sufficiently severe drought and associated total grazing pressure (livestock, if relevant; native species; feral species), it can be suppressed such that it only remains apparent (but likely undetectable) as rootstock and as seed bank;
3) Survey effectiveness was further constrained by parts of the study area having been long-unburnt. This can create an unnaturally dense shrub layer that limits access.

Surveys associated with biocertification of the study areas and earlier projects in those areas have been insufficient to reliably determine the presence and extent of the species. An Expert Report is required to provide an assessment of the likely presence, location, and significance of occurrences of the species in those areas.

1.5 Credentials of expert

I have worked as an ecologist since the mid-1990s, primarily in the Greater Sydney region, but also in the ACT, Central Coast, southern NSW (coast, tablelands and slopes), throughout Victoria and into eastern South Australia. I have primarily been self-employed, with a mix of government, private, and corporate clients, and have also worked as a subconsultant to larger firms, including two university-based consultancies. I have also worked directly for the NSW NPWS, and more recently for OEH (Native Vegetation Information Science). A summary of my credentials as required under the BAM is provided below as Table 1. I was approved by OEH as a species expert for *Melaleuca deanei* under s.6.5 of the BAM in November 2018.

Table 1. Credentials of Dr Steven Douglas as Expert in relation to *Melaleuca deanei*

BAM section	BAM requirement	Details
s.6.5.2.8 (g)	Name of expert	Dr Steven Douglas
s.6.5.2.3 (a)	Expert's qualifications	Bachelor of Science (Plant Ecology, Land Management, Resource & Environmental Management), Macquarie University, 1993. Master of Environmental Planning, Graduate School of Environment, Macquarie University, 1996. Doctor of Philosophy, Australian National University, 2008. Graduate Certificate of Information Literacy, ANU, 2006. BAM Accredited Ecologist, 2018.
s.6.5.2.3 (b)	History of experience in ecological research and survey method for the relevant entity	Partial review of BioNet and incorporated NSW Herbarium database records of *Melaleuca deanei* in the Cumberland Subregion and immediately adjoining areas (DPE, 2018). Discovery and documentation of new populations of *Melaleuca deanei* in The Hills Shire (former Maroota State Forest, 1994 and 2001). Contributor to National Recovery Plan for *Melaleuca deanei* (2010). Preparation of species management profile for Hornsby and later Gosford LGA Threatened Biota Management Plans (1999, 2001). Surveys, documentation and recommendations for threatened species including *Melaleuca deanei* as part of the Landcom ESD report (Total Environment Centre, 1999). Successfully nominated species for listing as Vulnerable under Threatened Species Conservation Act 1995 (1998-99). Numerous historic surveys in northwest and western Sydney including Hills Shire, Hornsby Shire, Blue Mountains City and Hawkesbury LGAs (1994-2000). Most records lodged are from Berowra Valley NP. Most surveys were opportunistic or if targeted, specified impact areas to be searched, e.g. road verges.
s.6.5.2.3 (c)	Resumé detailing projects pertaining to the survey of the relevant entity	See Appendix 1. Relevant surveys and works listed above.
s. 6.5.2.3 (d)	Employer's name and period of employment (if relevant)	Self-employed ecological consultant, 1996 to present (continuous other than for periods of study). Employed by OEH as contracted staff from November 2015 to July 2018 (Wingecarribee Shire vegetation map, South Coast Regional vegetation map, Review of mapping issues for TECs).
s.6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant entity	Profiles prepared for this species in threatened biota management plans for Hornsby and Gosford Councils. Successful nomination to NSW Scientific Committee required preparing of a review of the species' conservation status. Consulted by DECCW on this and other threatened flora species of the region as part of a data review for the purposes of the BioBanking Tool (2006). Approved by OEH as a species expert for *Melaleuca deanei* under s.6.5 of the BAM in November 2018.

2. Species information

2.1 Description

Melaleuca deanei is a shrub to 3 metres high with fibrous-flaky bark. Leaves are alternate, narrow-elliptic to lance-shaped and 12-25 mm long and up to 6 mm wide. The smooth leaves are not paired. The leaves are moderately dark green in colour and twisted so the edges turn towards the stem, while the leaf tip ends in a sharp point. The mature plant is hairless, however new shoots are covered in white hairs. Flowers are creamy-yellow and arranged in a typical ‘bottlebrush’ spike, up to 6 cm long. Within each flower, groups of stamens (17-28) are fused together at the base. Fruit is barrel-shaped, 3-7 mm in diameter, and the opening to the fruit is 3 mm in diameter (DECCW, 2010; OEH, 2017).

Melaleuca deanei (Maroota) © S. Douglas

2.2 Ecology

“The longevity of individuals is reported to be greater than 100 years (Benson & McDougall 1998). As a clonal species, *M. deanei* has the ability to re-sprout from a swollen rootstock (lignotuber) to produce coppiced growth, and it can also sucker from its rootstock (Felton 1993).

The exact age at which *M. deanei* starts to produce flowers and seed is unknown. Some observers estimate this age as 3-4 years (Wrigley pers. comm. cited in Maryott-Brown & Wilks 1993), while others claim that it may take as long as 10 years (Ross Doig, Australian Plant Society, pers. comm.). *Melaleuca* seedlings, in general, take between 7 and 20 years to start flowering (Holiday 1999, cited in Virtue 1991).

It is not known how *M. deanei* is pollinated, though insects are the most likely group of pollinators (Turnbull & Doran 1997 cited in Virtue 1991). Self-fertilisation of *M. deanei* should also not be ruled out (Virtue 1991). Clonal plants, such as *M. deanei*, are known to produce flowers and seed infrequently and at irregular periods of time (Benson & McDougall 1998). Flowering has been observed in spring (Fairley & Moore 1989; Wrigley & Fagg, 1993) and summer (Beadle *et al.*, 1983; Maryott-Brown & Wilks 1993; [Hewitt *et al.*, 2014a, b]).

Infrequent flowering was evident when some populations did not flower for more than 4-5 years (Benson & McDougall 1998), for 15 years (R. Payne pers. comm., cited in Benson & McDougall 1998), or for many years (Doig & Thumm, pers. obs.). In contrast, one population in Royal National Park has flowered annually for a number of years (Felton 1993). In the populations surveyed for the present Recovery Plan, only approximately half (20 of 43 surveyed) showed evidence of flowering (including the presence of fruit). Low levels of flowering are apparently common in many other *Melaleuca* species (Travers Morgan 1990; Virtue 1991). Felton (1993) suggests that in *M. deanei*, this may be a result of the following two factors: first, this species can re-sprout and hence often invests energy in vegetative reproduction rather than flower and seed production. Second, a specific stimulus (or set of stimuli) may need to trigger flowering in the species, e.g. fire or high/prolonged rainfall. However, Felton also observed that time since last fire did not influence flowering of *M. deanei*, nor did other variables, such as plant height.

Seed production is described as poor and infrequent by several authors (Virtue 1991; Travers Morgan 1990). For example, only 5 of 28 populations surveyed were carrying seed capsules (Felton 1993).

The only variable of importance in Felton's study was the size of *M. deanei* populations, as low density stands appeared less likely to flower than high density stands. The important role of population size is supported by Virtue (1991) who observed that seed set appeared to be greater in large populations. It is also supported by the data in the Recovery Plan: all populations with more than 100 ramets produced seed, and populations with less than 10 ramets were most likely to contain no seed. The relationship between population size and fruit or seed production may be explained by crossbreeding. Virtue (1991) suggests a requirement for crossbreeding in the species, that is, for breeding between different individuals" (DECCW, 2010).

Recent research on *M. deanei* (Hewitt *et al*., 2014b) confirmed that this species "had a low incidence of flowering within the small populations, significantly fewer fruiting plants per population and significantly lower numbers of viable seeds per square metre, most likely compounding its limited recruitment. Flowering, when it occurred in *M. deanei*, was from mid to late October through to late November–early December with increased flowering in response to fire and along road edges" "Results suggest that seed production within smaller populations of *M. deanei* is poor because of a low frequency of flowering and a low proportion of flowering plants per population, rather than plant-level pollination, fruit- or seed-set barriers" (Hewitt *et al*., 2014a).

Seed dispersal and seed bank dynamics

"Seed in *M. deanei* is produced in barrel shaped woody capsules that contain 500-600 seeds (Felton 1993). It is held in the canopy of the plant for several years (possibly up to 15 years) until dehydration allows the capsules to open (Benson & McDougall 1998). Seed release is triggered by fire, occasionally also by drought or frost (Virtue 1991; Felton 1993).

Melaleuca deanei seed is wind dispersed. Light winds are sufficient to empty most capsules of *M. quinquenervia*, which has similar sized seed (Virtue 1991). It is unknown whether *M. deanei* possesses a persistent soil seedbank. Its seeds remain viable for at least nine weeks following release from the capsules, but their viability after this period is unknown (Felton 1993). Felton suggests that the species does not require a persistent soil seedbank as the requirements for germination are provided by fire, which also triggers the release of the seed from its capsule.

Under laboratory conditions, seeds germinated readily and had high levels of viability (Virtue 1991; Felton 1993). Germination seems to be greatest in seeds that are sourced from large populations (Virtue 1991). However, in the wild, no seedlings have been observed during the field work associated with the preparation of this recovery plan, or in previous studies (Travers Morgan 1990; Virtue 1991; Felton 1993). Doig (pers. comm.) notes that despite setting lots of potentially viable seed, germination in the wild is poor and many seedlings do not survive. Seedling establishment is most likely also dependent on prolonged moisture availability (Virtue 1991). It appears that overall, this species relies predominantly on clonal reproduction and produces seed infrequently" (DECCW, 2010). These findings were validated by Hewitt *et al.* (2014a, b).

Disturbance ecology

"*Melaleuca deanei* frequently produces coppiced growth and suckers from its roots, particularly after fire or the disturbance and death of a major stem (Travers Morgan 1990). The species has also been observed to regenerate from epicormic buds that are protected from fire by thick, papery bark (Felton 1993).

It has been suggested that fire is required to provide the right conditions for germination and seedling growth and that seedlings very rarely establish at any time other than after fire (Felton 1993). It has also been suggested that fire may be required to stimulate flowering of *M. deanei* (L. McDougall pers. comm. cited in Benson & McDougall 1998), however Felton (1993) states that some populations flower annually regardless of time since the last fire.

Melaleuca deanei has been observed growing most commonly and vigorously in sites exposed to direct sunlight, or in places where light penetration has been increased by disturbance, such as the edge of fire trails (Travers Morgan 1990; S. Douglas, pers. comm.). The species' preference for light may explain its habitat preference for open ridgetop vegetation (Felton 1993). Shaded plants seem to have fewer and shorter new stems and leaves, and a shorter internodal distance (Travers Morgan 1990).

It is therefore likely that fire, and possibly other physical disturbances that increase light levels without impacting upon the soil, play a role in providing for the recruitment and long-term persistence of the species" (DECCW, 2010).

"The size of the minimum viable population is unknown, however, some of the small sites such as those in Pennant Hills Park (now part of Lane Cove National Park) are unlikely to survive in the long-term due to (apparent) inbreeding depression" (ESP Ecological Surveys & Planning, 1999). This view has been partially substantiated by Hewitt *et al*. (2014a, b; 2019). Without supportive intervention, it seems likely that these particularly small populations will be increasingly restricted to vegetative growth. This may undermine their long-term viability because it does not permit recombination of DNA as might allow adaptation to changing circumstances.

2.3 Distribution and abundance

Melaleuca deanei is endemic to the Sydney Basin Bioregion. The currently accepted distribution of the species extends from Colo Heights and St. Albans in the northwest and west; to Faulconbridge in the lower Blue Mountains in the west; to Brisbane Water National Park in the northeast, through several peri-coastal areas of the lower Hornsby Plateau in metropolitan Sydney, southward through Royal National Park and numerous locations on the Woronora Plateau and the Upper Nepean catchment; an unconfirmed record from Hill Top in the Southern Highlands; then a significant gap before reaching the southern limit in Colymea State Conservation Area west of Nowra; and to Tallowa Dam in the southwest (*sensu* DECC, 2010, augmented by review of BioNet records).

The species' distribution can be divided into a northern and a southern range. "The northern range extends north from Ryde LGA, including the Blue Mountains (48 populations), whereas the southern range extends south from Sutherland LGA (46 populations). The two ranges are separated by a distance of approximately 28 km. This is partly a consequence of unsuitable habitat for the species occurring on the Cumberland Plain in Western Sydney but is also the result of the loss of habitat in northern, southern, and inner western Sydney to urban development" (DECCW, 2010). The southernmost occurrence is ~ 68 km south of the nearest record to the north on the Woronora Plateau. Additionally, the southernmost records are on older, Permian geology rather than Triassic geologies typical of all of the other records.

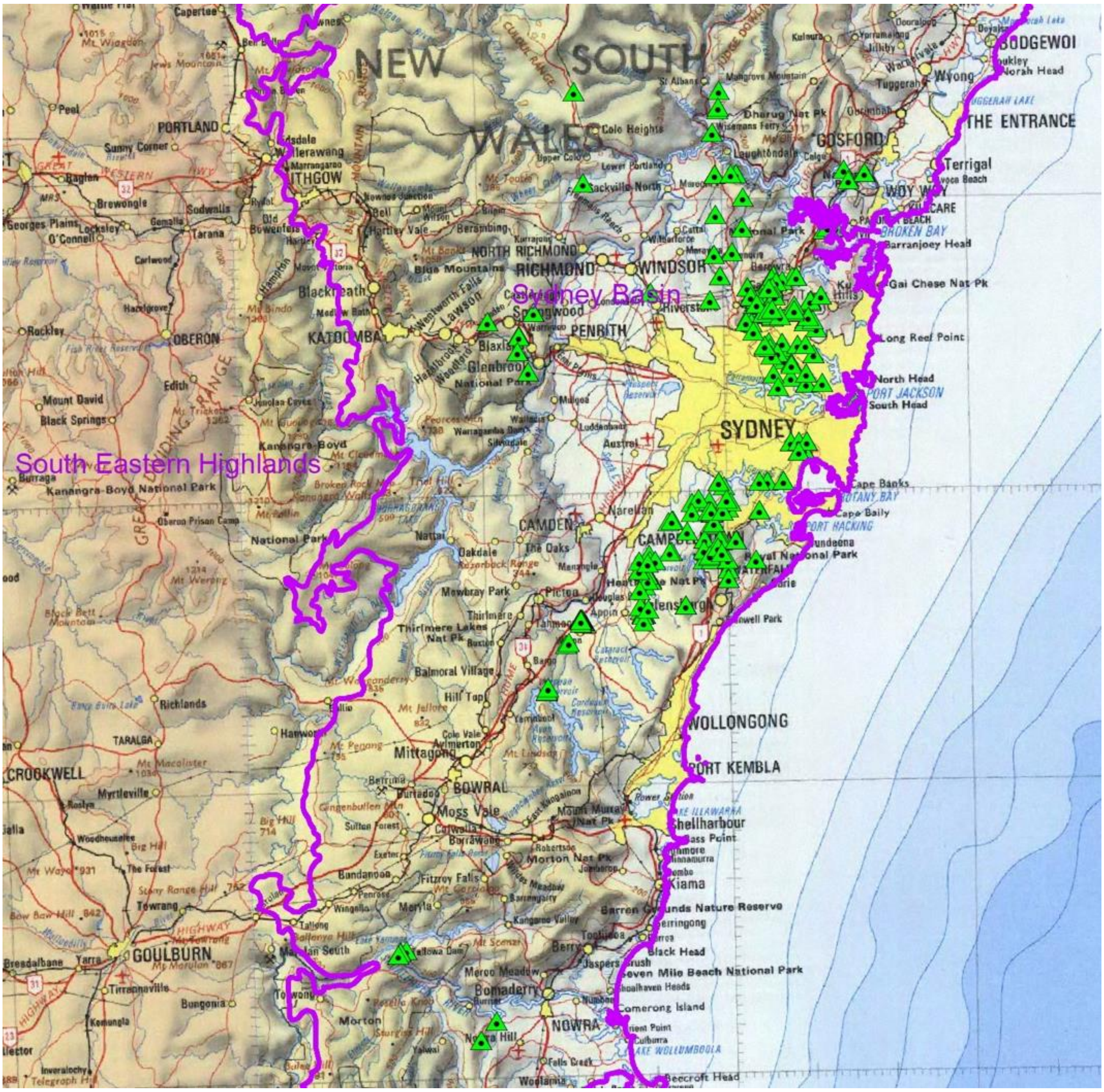
“It is likely that our understanding of the distribution of *M. deanei* is incomplete” (DECCW, 2010). It is feasible that populations are yet to be documented between the Upper Nepean record and the Shoalhaven hinterland records, however, similar to the situation in metropolitan Sydney, these populations will still be separated by the substantial area of unsuitable and largely cleared habitat of the Wingecarribee Plateau between Morton National Park, Meryla State Forest (now largely a Flora Reserve) and Budderoo National Park in the south, and Macquarie Pass National Park and Upper Nepean State Conservation Area to the north. The prospective record at Hill Top may indicate that the species could occur in Nattai National Park, which may provide a link to the Lower Blue Mountains populations.

Several of the early collections of *M. deanei* were made from now-suburban areas where the species is considered locally extinct. These include Kogarah (1884), Arncliffe (1897), Tempe (1898), Oatley (1899), Cooks River (1901), and Earlwood (1912) (Fairley, 2004; DECCW, 2010). “In the last ten years, sites have also been lost to residential development and road construction in Hornsby Heights (J. Slaven, Hornsby Council, pers. comm.), Bangor, and Menai (I. Drinnan, Sutherland Council, pers. comm.)” (DECCW, 2010).

“The available habitat for *M. deanei* has been severely reduced and fragmented by urban development, quarrying, and associated disturbances. This is primarily a consequence of the species’ distributional range being centred upon the Sydney region, and its apparent preference for ridge-top locations and sites with lateritic soils… Ongoing urban consolidation and expansion continues to threaten a number of populations. For example, undetected, though probably small, populations may be present in the rural-residential areas of Baulkham Hills (now The Hills) and Hornsby LGAs where the threat of clearing is substantial (S. Douglas, pers. comm.)” (DECCW, 2010). Hewitt et al. (2014b) also notes, “The species’ naturally restricted distribution has been markedly reduced by urban development in the Sydney area, and many sites where it was previously recorded (Australia’s Virtual Herbarium 2013) were visited and found to have been lost in the years since the records were made” (DECCW, 2010).

In the species’ Recovery Plan, “*M. deanei* records within 500 metres of each other have been defined as belonging to the same population, as dispersal of the species is unlikely to exceed this distance (Felton 1993). Populations may consist of a number of sites, as sites have been determined on the basis of tenure… It is difficult to count individual plants within populations, because *M. deanei* is a clonal species. This means that an individual (or genet) may occur as a number of stem clumps (or ramets), which may appear as different plants (Myerscough 1998)... Research by Felton (1993) suggests that for every 10-15 *M. deanei* ramets counted, two to three individuals may be present, while the NSW Scientific Committee (1999) notes that for this species ‘ramet counts may overestimate population size by two or three times’. This difficulty with identifying genetically distinct plants needs to be considered when discussing the size of populations based on ramet counts. It also explains why no attempt has been made to determine the size of 28% of all populations. Generally, it is likely that the number of genetically distinct plants is lower than the number of ramets counted… At least 52% of the populations contain less than 50 ramets, and thus most likely even less (*sic*) individual plants. Only four populations contain more than 500 ramets. Of these four, only one occurs in the northern part of the species’ range, the other three are in the southern part” (DECCW, 2010).

The latest research in this field is bey Hewitt *et al*. (2019) who undertook genetic analysis of selected *M. deanei* populations and determined that “Multiple stems were found to comprise single genets up to ~10m diameter on the ground, and (that) molecular evidence points to an outcrossing breeding system. Genetic diversity was positively correlated with population size, and significant genetic differentiation was shown between northern and southern regions using clustering analyses.” Of particular importance is that they also found that estimates of population size given in DECCW (2010) are likely to be a least 6 times higher than what is now supported by molecular analysis.



Map 2. BioNet records (26/11/18) for whole of species' range

The above map was generated from BioNet data and gives a generally accurate indication of the species' known range, but not the extent of potential habitat. Large areas of NPWS estate and Water NSW catchment lands have not been subject to the same level of survey effort as areas where pressure for land clearing is high or where activities such as mining have funded surveys. The map shows an absence of records of the species between the lower Blue Mountains and the Southern Highlands, despite there being extensive areas of potential habitat present. Similarly, there are very few records north from the Blue Mountains villages through to those north of Colo Heights and near St. Albans. Again, that area contains significant areas of potential habitat.

2.3.1 Reservation status

As of 2010, more than 50% of all 'sites' of the species were known to occur in NPWS reserves (DECCW, 2010). "Holsworthy Military Reserve, contains 17 % of the known *M. deanei* population, including large populations that extend along the ridgelines in the central and western section of the area" (DECCW, 2010). That area is largely naturally vegetated but is subject to clearing and detrimental disturbance for military purposes and is not conservation estate. Two large populations occur on land managed by Water NSW for potable water catchment protection within the Nepean and Avon Dam catchments. Since the 2010 Recovery Plan, these populations have received additional protection through the gazettal of the large Upper Nepean State Conservation Area. Whilst this reserve permits subsurface mining and some surface infrastructure for mining and water management purposes, the two populations are close to dams, and unlikely to be threatened by mining activities. Additionally, gazettal of Dharawal National Park in place of and beyond the scope of most of the former Dharawal State Conservation Area has protected numerous occurrences of the species. The now much smaller portion that remains a State Conservation Area does not contain records of this species, based on BioNet data.

Berowra Valley Regional Park, which according to DECCW (2010) was known to contain 17% of the sites of *M. deanei* at that time, has since been gazetted as a National Park, increasing the emphasis on conservation in this area, and affording the species some additional protection, subject to resourcing.

The north-western populations on the fringes of metropolitan Sydney, primarily in The Hills Shire, remain unreserved in terms of NPWS estate. These extend from Kenthurst through Middle Dural, Glenorie, the former Maroota State Forest, to north-nor-west of the locality of Maroota. Most are on Crown land or former Crown land where there are conflicts between grants or claims under the NSW Aboriginal Land Rights Act and competing claims under the Commonwealth Native Title Act. These areas are not known to be actively managed for conservation but may be increasingly protected through biodiversity stewardship agreements / biobanking.

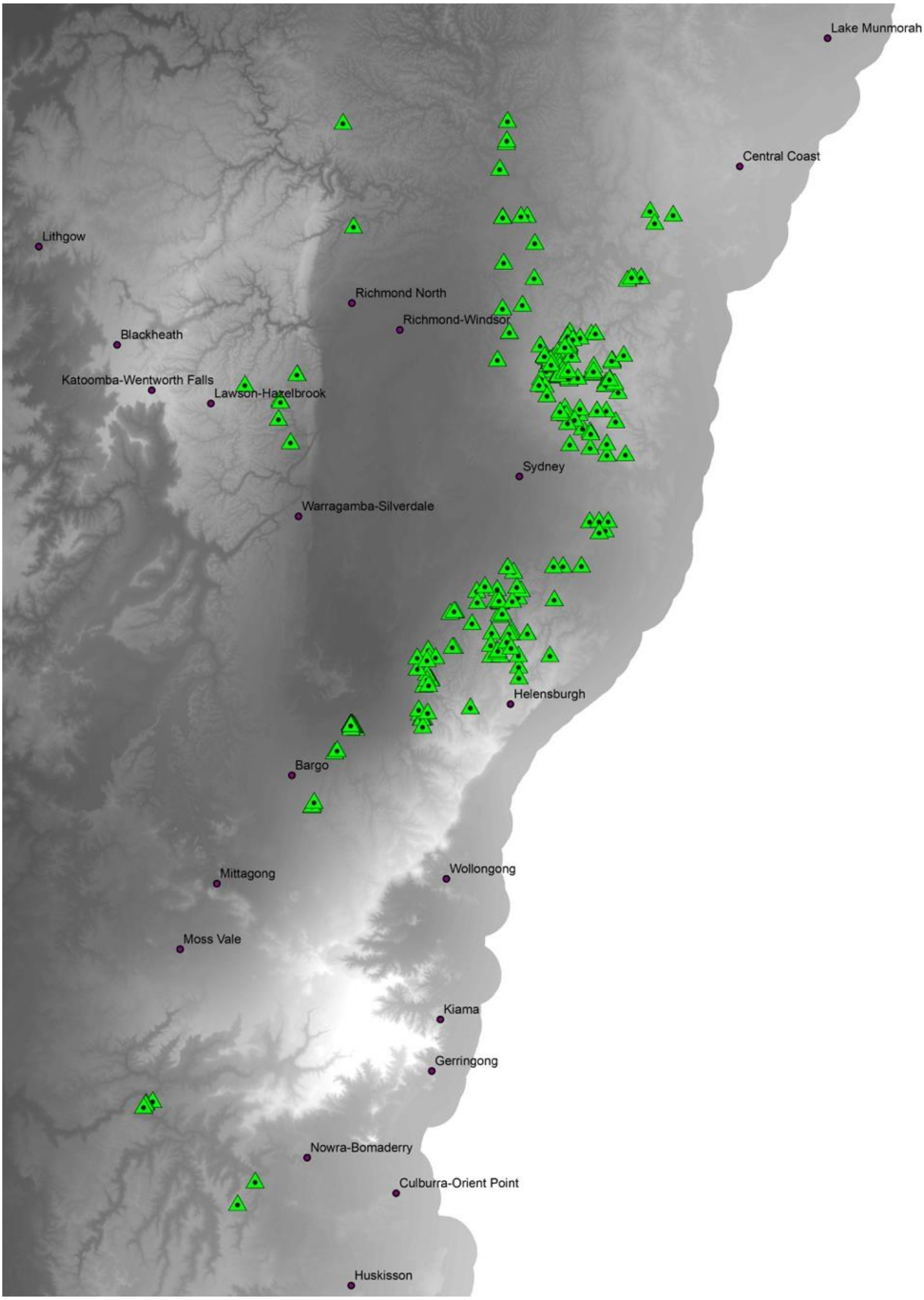
The outer northernmost populations are within Parr State Conservation Area and Yengo National Park. A 1933 record 'near Hawkesbury Punt' (ferry) plots in unsuitable habitat can could be in Dharug National Park north of the River, in Wisemans Ferry Historic Site south of the River, or on unreserved freehold nearby.

2.4 Habitat

2.4.1 Geology, soil, climate

"*Melaleuca deanei* mostly occupies broad flat ridgetops, dry ridges and slopes (Benson & McDougall 1998). In southern Sydney, the species is most often found on flat broad ridge tops more than 100 metres wide (Travers Morgan 1990). The altitudinal range of *M. deanei* is between 20 and 410 metres above sea level, and annual rainfall in the species' distribution ranges from 1,000 to 1,400 mm (Benson & McDougall 1998)" (DECCW, 2010). However, more recent distribution and rainfall data obtained from OEH indicates that the species' minimum average annual rainfall tolerance is considerably lower: ~830 mm (Wilton), with several occurrences in areas with 900 -950 mm in western and north-western Sydney and environs. Notably, the species has a very narrow range of annual average temperature tolerance based on current BioNet distribution data: ~14 to ~16 C.

"*Melaleuca deanei* is strongly associated with sandy loam soils that are low in nutrients, sometimes with ironstone present (Benson & McDougall 1998). In a study of ten populations in southern Sydney, Travers Morgan (1990) found that the species most frequently occurred on deep and well-developed lateritic soils, i.e. soils where an indurated iron-rich layer usually overlies a mottled clay and a pallid clay (Murphy 1993)." (DECCW, 2010).



Map 3. *M. deanei* locations shown over average annual rainfall (lightest shading shows highest rainfall)

Analysis of BioNet records and mapped Soil Landscapes indicates that the species is strongly associated with the Lucas Heights Soil Landscape, especially south of metropolitan Sydney. The northern Sydney records are mainly associated with Hawkesbury and Lucas Heights Soil Landscapes, with some occurring on Gymea and Lambert Soil Landscapes. Most of these are associated with the upper Hawkesbury Group, principally Hawkesbury Sandstone, though the Lucas Heights Soil Landscape is associated with the Mittagong Formation. This is a transitional bed between the Wianamatta Group (mostly shale) and the Hawkesbury Group (mostly sandstone) (*sensu* Martyn, 2018) and is very strongly associated with several threatened plant species, and at least one threatened ecological community.

A very small number of records occur on the Glenorie and Blacktown Soil Landscapes, which are derived from Wianamatta Shale. When reviewed, most of these records were very vaguely located, with very low spatial Accuracy scores. The exception is recent, spatially accurate records near Wilton, which plot on the Blacktown Soil Landscape. The apparent explanation in this case is that the Soil Landscape mapping is very coarse on the Wollongong 1:100,000 sheet, and that the Lucas Heights Soil Landscape is under-mapped. This is supported by recent vegetation mapping. In this area, the map shows the Blacktown landscape directly adjoining the Hawkesbury landscape – a situation that effectively does not occur in Nature, as there is almost always some transition between the purely shale terrain and the purely sandstone terrain.

2.4.2 Associated vegetation communities and NSW TECs

"M. deanei occurs in a wide range of vegetation communities but is most often found in Coastal Sandstone Ridgetop Woodland (Tindall *et al.* 2004). Several authors state that there seems to be no obvious association between *M. deanei* and any particular components of the ridgetop flora (Specht 1981; Travers Morgan 1990; Felton 1993; Benson & McDougall 1998)" (DECCW, 2010).

The OEH Threatened Biodiversity Data Collection lists the following Keith Vegetation Classes as being associated with *M. deanei*:

- Coastal Valley Grassy Woodlands;
- South East Dry Sclerophyll Forests;
- Sydney Coastal Dry Sclerophyll Forests;
- Sydney Coastal Heaths;
- Sydney Hinterland Dry Sclerophyll Forests; and
- Sydney Montane Dry Sclerophyll Forests.

The Threatened Biodiversity Data Collection indicates that *M. deanei* is potentially associated with 20 Plant Community Types (PCTs) across its range. Two of these are also associated with State and/or Commonwealth-listed Threatened Ecological Communities (TECs). Within the Growth Areas, relevant communities and NSW-listed TECs, excluding apparent errors, are shown in Table 4. The associated PCTs are treated by OEH as *potential* habitat, and the species may not actually occur in all of those communities.

Associations between a species and Vegetation Classes and PCTs in the Threatened Biodiversity Data Collection represent *potential* habitat, not actual habit. Given the limitations of vegetation mapping and that in most cases, survey effort for threatened species is incomplete across their range, such an approach is understandable.

The listed association between *M. deanei* and Coastal Valley Grassy Woodland is a consequence of the association with PCT 1395. Ordinarily, *M. deanei* would not be considered to be associated with this Vegetation Class as the vast majority of occurrences are in heathy/shrubby habitats. However, PCT 1395 is legitimately associated with this species, even though such occurrences are atypical across the species' range.

An assessment of the association between *M. deanei* and PCTs was undertaken to better understand the potential habitat for this species in terms of plant communities. The information is used to generate 'species polygons' (maps of potential habitat) as required under the BAM. Whilst DPE required habitat associations to be graded i.e. strong to weak association with particular PCTs, only ungraded PCT association data was used to generate the 'species polygons'. The assessment is constrained by limitations of BioNet data and available vegetation maps. The assessment of the species' relationship with PCTs in and near the Cumberland Subregion used publicly available OEH vegetation maps and did not use the updated vegetation maps produced by Biosis within the Growth Areas. There are now known to be significant differences between Biosis' updated and finer-scale map and OEHs earlier maps. These have a bearing on the results presented in Table 2. However, the effect on the modelling of habitat for *M. deanei* is likely to be far smaller for *M. deanei* than for species that are strongly associated with the Cumberland Subregion.

Some of the records of the species are not spatially associated with a PCT. This may be because:

- the record occurs in a site now cleared of native vegetation or too degraded to be captured by mapping;
- because the record is too spatially uncertain, so has been assigned generic co-ordinates, usually in a named town or suburb, and such settled areas often lack native vegetation; and/or
- the record plots just outside an area of mapped vegetation because it is on a road verge, and even most GPS records are only accurate to 5m, meaning it could plot on the road, not on the verge.

To overcome this latter problem, those records were assigned a 10m buffer so that they would associate with the nearest mapped vegetation polygon up to 10m from the plotted location.

A further consideration is that survey effort for the species is not evenly distributed across the area subject to analysis. Some sites of potential habitat have had very little or no effort, often due to tenure constraints, yet others have had every apparent plant recorded (mostly in reserves or as part of ecological impact assessments). This creates very substantial biases in the data, which can create misleading weightings of association between the species and particular PCTs. Furthermore, most records do not include population data, such that a record might be for one plant or many. In short, this analysis is best used only for presence/absence i.e. whether the species has been recorded at a point that is mapped as a particular PCT, or not. Analysis beyond that is very constrained by deficiencies and biases in the datasets, especially in BioNet data.

The analysis of association with PCT in Table 2 below deals only with records in the Cumberland Subregion plus a 10 km buffer. Records that associate with a PCT when a 10 m buffer is used are included in the counts of sightings below and are not shown separately. Two analyses were undertaken: All records in the target area without regard to spatial Accuracy score; and only records in that area with Accuracy score of 100 m or better. The latter analysis is considered more reliable, but both sets of figures are provided. Sightings with Accuracy <=100 m are shown in square brackets **[ ]** and in bold text. Where available, the combined count of individuals associated with the records is provided in parentheses { }. Those counts relate only to records with Accuracy <=100 m. Where a record doesn't contain population data, it is assumed to relate to a single plant.

Only PCTs mapped in the Growth Areas are dealt with in the table below. For PCTs outside the Growth Areas but within the 10 km buffer, 1777 (63 **[49]** {1641}) and 1787 (24 **[11]** {14}) are significantly associated with *M. deanei*. Those PCTs are more typical of the species' habitat across its range.

Because there are very few records of *M. deanei* from the Cumberland Subregion, a 10 km buffer (which mostly comprises incompatible geology and soils for this species) has been used to broaden the dataset. Even with this buffer, the analysis in Table 2 is unrepresentative of the species' association with PCTs across its range, as the species primarily occurs outside the Cumberland Subregion. Additionally, the recent records of the species from the Bingara Gorge housing development skew the analysis in favour of PCT 1395 because it is over-mapped by OEH where this population occurs. The more recent and accurate map by Biosis designated as 1181 much of what OEH maps at that site as 1395. The boundary between these communities is unlikely to be as clear as either map indicates, and it is likely that unmapped, transitional areas related to PCT 1081 are present.

A pattern of PCT 849 on shale, 1395 on the high-shale part of the transition, 1081 on the low-shale part of the transition, then 1181 on the predominantly sandstone terrain is evident just to the north of the Bingara Gorge site but 1081 is not mapped at this latter location. It is likely that 1081 is a more strongly associated PCT for this species than is 1181, despite what the basic analysis of association suggests. It is also very likely that the apparently Very High association with 1395 is primarily an artefact of the dataset and is unrepresentative. All such biases are dealt with in the column, Adjusted relative significance.

In my Expert Report for *Persoonia nutans*, I compensated for the fact that vegetation mapping of the Growth Areas is arguably affected by the fact that two different OEH PCT maps cover this area, and they don't seem to be as aligned as they might be in terms of PCT allocations – at least not where they adjoin in some cases. For *P. nutans*, two PCTs that are clearly very similar to PCT 1081 but that do not occur in the Growth Areas were treated as 1081 for the purpose of analysing the association of that species with PCTs. Were a similar approach taken in relation to *M. deanei*, the number of sightings and the population sizes associated with PCT 1081 would significantly increase because most of the records of this species in the 10 km buffer come from PCTs that are similar to or at least closest to 1081. That PCT is present in parts of the Wilton and Greater Macarthur Growth Areas but absent further east.

It is important to note that the ranking of relative significance of PCTs for this species does not infer that the species will occur where any of these PCTs are present in the two relevant Growth Areas. It only indicates the relative probability of occurrence and of associated population size in the context of this limited analysis.

TABLE 2. Species records relative to mapped PCTs and their relative significance for the species in the Growth Areas

PCT	PCT Name	Associated TECs (NSW BC Act)	% Cleared (VCD)	Sightings & Population	Relative association	Adjusted relative association#
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Not a TEC but some areas may be within Shale Sandstone Transition Forest (CE)	40	20 **[13]** {561}	Moderate	High
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney	Not a TEC	20	23 **[16]** {587}	Moderate	Moderate
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (CE)	80	41 **[40]** {1192}	Very High	Moderate

Figures for the % Cleared column were obtained from the OEH BioNet Vegetation Classification Database (VCD).

2.4.1 Description of PCTs associated with *Melaleuca deanei* in each Growth Area

PCT 1081

This community is a form of 'shale/sandstone transition forest' that was previously within the scope of the now circumscribed Shale/Sandstone Transition Forest TEC. It has been independently assessed as a prospective threatened community, that whilst significantly reserved, is suffering on-going losses around Sydney, largely due to urban and peri-urban land use. It is a very significant habitat for *M. deanei* and several other threatened plant species.

This PCT is absent from GPECGA and WSAGA due to the lack of suitable geology. It is a present but as a very minor component of the GMGA (one site and three polygons) and as a moderate component of the WGA. It is likely to have been naturally uncommon to rare in those areas and has probably not been heavily cleared there. It is not readily mapped with high reliability because of the broad ecotone with PCT 1395. Consequently, a precautionary approach is particularly necessary when dealing with areas mapped as PCT 1081, as some may be better classified as 1395 and therefore a Critically Endangered Ecological Community. It is also highly likely that 1081 is present but unmapped in areas that show 1395 immediately adjoining 1181, as the transition zone between the associated geologies is rarely as simple as most maps indicate.

No areas mapped as PCT 1081 are within the proposed urban footprint in either of the two relevant Growth Areas.

PCT 1181

This community is mapped within the WGA and GMGA, but is largely outside the proposed areas of urbanisation, being associated with sandstone soils in gullies, valleys and slopes. It is associated with often-protected habitat along watercourses, and with relatively high bushfire risk and with steep, often rocky terrain.

This PCT is highly associated with *M. deanei* habitat within the study area but this is probably amplified by limitations of the vegetation mapping, which tend to simplify the shale/sandstone transition and over-map PCTs 1395 and 1181 by under-mapping PCT 1081. This PCT is not present in the GPECGA or the WSAGA due to the absence of associated geology.

PCT 1395

This community is the principal PCT of the Shale Sandstone Transition Forest TEC and has a significant though atypical association with *M. deanei* in and beyond the study area. This community occurs on flat to gently sloping terrain, usually bordering cleared or highly modified rural land. This PCT is absent from the GPECGA and the WSAGA due to the lack of associated geology.

Most mapped occurrences are excluded from the proposed urban footprint in the two relevant Growth Areas. However, even where proposed urbanisation does not involve clearing, habitat can be increasingly threatened by urban encroachment in the form of bushfire hazard reduction works, recreational pressures, urban pollution e.g. nutrient-laden runoff, increased weed invasion from inappropriate landscaping/gardening, and increased predation of fauna by domestic pets.

2.4.2 Associated Commonwealth TECs

As of November 2018, there was not an Approved Conservation Advice for this species. The Commonwealth Department of Environment & Energy appears to defer to the Recovery Plan (DECCW, 2010) in this regard.

GIS analysis indicates that *M. deanei* is associated with the nationally listed Shale Sandstone Transition Forest (this is essentially the same entity as the NSW TEC of the same name, though it permits greater inclusion of PCT 1081 / DSFp146 of Tozer *et al*., 2010).

2.4.3 Habitat condition

Degraded and significantly modified areas of the above-described PCTs can still be habitat for this species due to its ability to persist as woody rootstock and in the soil seed bank. Such modified sites may have reduced or no canopy and/or midstorey, and/or reduced understorey and some weed invasion. The species could persist in highly modified sites such as slashed bushfire Asset Protection Zones, and road and trail verges. Some forms of disturbance, even relatively severe forms that would be considered clearing of vegetation, could be beneficial to this species, within limits. This situation is recognised for numerous threatened plant species in and beyond the Sydney Basin Bioregion. It is believed to be related to the fact that modern fire regimes are likely to be significantly different to those prior to 1788. *M. deanei* is known to be disadvantaged by prolonged absence of fire because reproduction is promoted by, though not dependent on plants and habitat being burnt. Conversely, too frequent fire would be detrimental because seedlings would not have sufficient time to develop post-fire recovery functions such as a lignotuber and epicormic buds, so would likely be killed.

The condition of potential habitat for this species is not, in itself, a reliable indicator of the species' presence, and accordingly, **all condition states except derived grassland are considered in determining suitable habitat** i.e. intact, thinned, scattered, and derived shrubland.

3. Description of the study area

3.1 Landscape context and land use history

All of the Growth Areas have been significantly cleared for earlier activities, primarily timber production associated with opening areas for agriculture and pastoralism, minor areas of surface resource mining, and to varying degrees, for urban and commercial/industrial use. They are proposed to accommodate phased increases in urban land use, primarily within existing cleared or highly modified lands. Increased urban use is planned as a response to population growth.

3.1.1. Greater Macarthur Growth Area (GMGA)

The GMGA extends from Glenfield in the north to Appin in the south. It is largely within the Campbelltown LGA with the southernmost section within the Wollondilly LGA. The northern half comprises an urban renewal corridor centred on the Sydney to Main Southern railway line. It encompasses the existing industrial and residential suburbs of Glenfield, Macquarie Fields, Minto, Leumeah and Campbelltown. The GMGA is associated with extensively cleared, gently undulating shale terrain typical of the Cumberland Plain, and contrasts the sandstone gorges of the Woronora Plateaus across the Georges River to the east. The northern portion of the GMGA is already substantially urbanised, with remnant vegetation largely restricted to creek-lines or small patches associated with designated open space. Vegetated creek-lines include Bunbury Curran Creek, Bow Bowing Creek, Leumeah Creek, Fishers Ghost Creek and Spring Creek.

The more extensive southern half of the GMGA, south of Rosemeadow, comprises proposed urban land releases at Menangle Park, Mount Gilead and Appin. Menangle Park and Mount Gilead are subject to separate planning processes, so are not within the scope of this biocertification. In the north-west, Mount Sugarloaf (213 m AHD) forms the southern end of a hilly ridge on the Luddenham Soil Landscape above the Menangle floodplain that extends north to Denham Court, then to Cecil Hills and Prospect Hill. Some native vegetation persists, although it is often invaded by African Olive. The floodplain is dissected by Menangle Creek and its tributaries, including Nepean Creek, Woodhouse Creek and Leafs Gully.

The southern GMGA is primarily semi-rural and agricultural land, with creek corridors and some larger patches of remnant vegetation located between the Nepean and Georges Rivers. Geologically, the area comprises gently undulating hills on Wianamatta Shale intergrading via a shale sandstone transitional zone (can include the Mittagong Formation) with steeper and infertile terrain on Hawkesbury Sandstone along the rivers. Transitional and sandstone geologies are sometimes exposed along the smaller creek lines.

3.1.2. Wilton Growth Area (WGA)

The WGA is a relatively smaller area that occurs to the south of the GMGA, extending from the vicinity of Douglas Park in the north, Maldon in the north-west, and beyond Wilton in the southeast. The boundaries closely follow the Nepean River in the north and west, a tributary Allens Creek in the east, and the Cordeaux River in the south. Away from the Nepean River and gullies, a higher, gently undulating zone has been largely cleared for agriculture. The Woronora Plateau forms the southern boundary and includes the northernmost section of the large Upper Nepean State Conservation Area, with unreserved but closed areas of the Water NSW Special Area (Sydney water supply catchment) extending to the east and southeast. The Hume Highway dissects the WGA roughly north to south, and Picton Road traverses it roughly northwest to southeast.

The WGA includes both shale, shale sandstone transition and sandstone environments. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The flatter shale terrain has soils of the Blacktown Soil Landscape, which is derived from Ashfield Shale (a member of the Wianamatta Group), and typically supported the now Critically Endangered Cumberland Plain Woodlands. Much of this area is cleared or modified for agriculture and hobby farms. It comprises native/exotic grassland with smaller areas of Derived Native Grasslands in relatively better condition. Areas above the gullies feature soils of the Lucas Heights Soil Landscape derived from the Mittagong Formation (a transitional bed between the Wianamatta and Hawkesbury Groups). These support variable shale sandstone transition woodlands and forest, some of which are also Critically Endangered. In the steeper gullies, the Hawkesbury Soil Landscape dominates, and supports Hawkesbury Sandstone Gully Forest types with Ridgetop Woodlands on some of the upper slopes.

3.1.3. Penrith to Eastern Creek Growth Area (GPECGA)

The GPECGA is a relatively large area that extends from Rooty Hill, Minchinbury and Hassell Grove in the east, across the Cumberland Plain to the Hawkesbury-Nepean River in the northwest, then south through Jamisontown, Glenmore Park, to the intersection between The Northern Road and the Warragamba Water Supply Pipelines in the far south-west. The predominant geology is Wianamatta Shale on flat to gently undulating terrain that has been extensively cleared for agriculture, and later for housing and industrial use, with some remnant vegetation on current and former Defence holdings. The shale soils support(ed) Cumberland Plain Woodlands. Overlying the extensive shale deposits are small areas of weathered Paleogene-Neogene alluvium e.g. Shalvey and Willmot, that are much more common to the north. These support(ed) the Castlereagh Forests & Woodlands complex of vegetation types, which is strongly associated with several threatened plant species. More common are broadly linear deposits of Quaternary alluvium along watercourses such as South Creek and Eastern Creek, and on the flood terraces of the Hawkesbury-Nepean River. Other lithologies occur but are very rare and of very small extent.

Very little of the GPECGA is reserved in NPWS estate. Wianamatta Regional Park (which emphasises recreational uses) encloses small areas of former Defence land in the far north. Adjacent to the southwestern boundary is the small Mulgoa Nature Reserve (emphasises biodiversity values). Two Biobanking sites adjacent to the Nature Reserve have increased the area under conservation.

3.1.4. Western Sydney Aerotropolis Growth Area (WSAGA)

The WSAGA abuts the GPECGA’s southernmost border near the locality of Sovereign (east of Mulgoa), then extends south past Greendale, northeast to the locality of Badgerys Creek, east to Kemps Creek, and northward to the vicinity of Mount Vernon, excluding Twin Creeks Golf Course and associated settlement.

The lithology and soils are broadly similar to that of the GPECGA, being effectively just an extension of that area to the south to incorporate the developing Badgerys Creek Airport and environs. The area is even more severely cleared of native vegetation, except along some streams and on rare occurrences of steeper terrain. It contains no NPWS reserves, with the nearest being the small Kemps Creek Nature Reserve, outside the Area to the southeast. Gulguer Nature Reserve and Bents Basin State Conservation Area occur to the southwest of Greendale.

3.2 Geology and remnant vegetation

All of the Growth Areas are within the Cumberland Subregion. The dominant lithology across all of the Growth Areas is Wianamatta Shale (Ashfield and Bringelly Shales), with much smaller areas of Paleogene-Neogene alluvium occurring largely outside these boundaries, and much larger areas of Quaternary alluvium associated with floodplains of the many watercourses (*sensu* Martyn, 2018).

The terrain varies from almost flat through to steeply hilly areas associated with minor volcanism and more often, in association with shale ranges. In the far south, the more elevated shale landscapes have been eroded down to the underlying Hawkesbury Sandstone in a series of gullies and gorges. A transition zone between the shale and the sandstone is discernible in some areas.

On the dominant shale geology, the associated Critically Endangered Cumberland Plain Woodlands are still present in all of the four Growth Areas but have been disproportionately cleared for rural and later urban and allied uses. Much of what remains of this ecological community occurs as paddock trees and areas of remnant native ground-layer vegetation in pastoral and other contexts, with the exception of some substantial, though fragmented and isolated remnants. Remnant vegetation in these relatively fertile and arable landscapes is often in poor condition. In the most heavily cleared areas, it can be restricted to strips along watercourses. Some forms are dominated by *Casuarina* species. Weeds are common and sometimes severe in the moister situations. Weeds often extend into higher and drier terrain, especially in the form of African Olive and African Love Grass, both of which can occur on a landscape scale.

Small areas of the biodiverse Castlereagh Forests and Woodlands persist in all but the Wilton Growth Area on often-laterised Paleogene-Neogene alluvium. These variable woodlands and open forests support a particularly high number of threatened plant species, and because their soils are less suitable for agriculture and grazing, are better conserved than the Cumberland Plain Woodlands. Nonetheless, they are all listed as threatened ecological communities.

In the two southern Growth Areas, vegetation of the shale sandstone transition zone is relatively common and tends to remain in less arable areas adjoining the largely cleared former Cumberland Plain Woodlands. It is often found fringing the largely uncleared sandstone-based terrain, and ranges from highly intact to significantly modified and degraded, largely due to grazing and weed invasion. The associated Shale Sandstone Transition Forest is recognised as Critically Endangered due to extensive clearing across its substantial range, and because of the severity of other threats. Very little is present in formal conservation areas.

In the two southern Growth Areas, diverse, sandstone-based vegetation persists in association with most of the many incised watercourses. This vegetation is broadly the same as what occurs in extensive conservation estate around urban Sydney, but some communities adjoining current or former Shale Sandstone Transition Forest are not well-conserved and are threatened by further clearing and degradation.

3.2.1 Plant Community Types

The following section lists the Plant Community Types mapped in each Growth Area with brief notes about their distribution in those Areas. The list is not restricted to PCTs associated with *M. deanei*.

3.2.1.1 Greater Macarthur Growth Area (GMGA)

The predominant ecological communities in the GMGA are or were Cumberland Plain Woodland (CPW), Shale Sandstone Transition Forest (SSTF) and River-flat Eucalypt Forest (RFEF), all of which are Threatened Ecological Communities. All have been extensively cleared and degraded, primarily by agriculture and weed invasion, but also by urban and allied uses. There are no NPWS reserves in this Growth Area. However, the very small Leacock, Edmondson and William Howe Regional Parks occur just outside the border and are managed primarily for recreation rather than conservation. Dharawal State Conservation Area and National Park border the southern portion of the Growth Area to the east.

A summary of the mapped ecological communities is found in Table 3. The maps are based on OEH products that have been updated by Biosis for DPE.

Table 3. Summary of all ecological communities within the Greater Macarthur Growth Area

PCT	PCT Name	Distribution & notes
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Small patch at Menangle Sugarloaf on SE slopes.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Along creek lines in shale areas in northern and central parts of GMGA.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Small patches on shale soils throughout GMGA but mostly in northern and central parts.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches on shale soils throughout GMGA, more common in southern parts on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	4 polygons, Macquarie Fields, most of which have long been historically mown (Milton Park Softball Complex). They are now subject to regeneration.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	One small occurrence mapped around the margins of bushland associated with Smiths Creek at Leumeah.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Nepean River north from Menangle Bridge.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Narrow zone along Nepean & Georges Rivers and tributary gullies and a small zone along Smiths Creek at Leumeah.
1292	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Restricted to parts of the riparian zones of the more incised and larger watercourses. Very restricted extent in this Area.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Relatively small remnants extend from Glenfield into the far south where it is extensive on transitional soils mostly south from Rosemeadow. Can intergrade with 849 and 1081.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Only mapped to a very minor extent as highly linear remnants between Glenfield and Macquarie Fields (along the railway) and at Ingleburn (adjoining roads).

3.2.1.2 Wilton Growth Area (WGA)

The predominant ecological communities in the WGA are or were Cumberland Plain Woodland (CPW) and Shale Sandstone Transition Forest (SSTF) both of which are Threatened Ecological Communities. Sandstone-based communities occur in and surrounding the more incised watercourses. There are no NPWS reserves in this Growth Area, though Upper Nepean State Conservation Area occurs immediately to the south. There is a Biobanking site on the northern side of the river near Douglas Park (within the WGA), and three more such properties to the immediate north (including St Marys Towers) and those associated with coal mines (Steenbeeke, pers. comm.).

Table 4. Summary of all ecological communities within the Wilton Growth Area

PCT	PCT Name	Distribution & notes
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	On shale soils of higher, gently undulating terrain of northern and central areas. Small patches with scattered trees (farming properties) adjoining more extensive exotic and native grasslands.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	One patch in a derived grassland (treeless) condition in the west, and a much larger portion in the far north.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Limited to a few patches in the north between 1395 on plateau edges and 1181 in sandstone gullies.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Common on slopes and plateau edges above and around incised sandstone-based watercourses that surround most of the Area.
1292	Water Gum – Coachwood riparian scrub along sandstone streams	Restricted to a very narrow riparian strip along the Nepean River.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	The most extensive community on shale sandstone transition soils between 849/850 and sandstone communities along gullies. Variable floristics.

3.2.1.3 Greater Penrith to Eastern Creek Growth Area (GPECGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Shale Gravel Transition Forest and Castlereagh Forests & Woodlands. River-flat Eucalypt Forest was previously much more extensive along the Hawkesbury-Nepean River and adjoining primary floodplain, and it remains to varying degrees along many watercourses such as Eastern Creek, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. There is one NPWS reserve in this Growth Area: Wianamatta Regional Park, however it is already significantly fragmented and may be required to potentially accommodate a large transport corridor. The small Mulgoa Nature Reserve and associated Biobanking sites occur near the south-western border of this Growth Area. Yarramundi SCA occurs on the western boundary but across the Nepean River, and Wianamatta NR occurs near the NW corner.

Table 5. Summary of all ecological communities within the GPECGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Scattered as small remnants and one larger remnant in the central portion, but with greater extent in the central north, mainly in the western ungazetted portion of Wianamatta Regional Park.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	A few very small remnants present south of the M4, with larger remnants within and near the gazetted and ungazetted portions of Wianamatta Regional Park.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northwest, with some small remnants in the southwest, often associated with watercourses.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Present to a very minor extent on the southwestern edge adjoining Mulgoa Nature Reserve
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains through the south and central areas.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Common in and near Orchard Hills in the south, and former ADI lands in the central north, with some areas in the ungazetted portion of Wianamatta Regional Park. Other scattered remnants, particularly in the east.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches in the south west, primarily in pastoral settings and on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Restricted to one linear polygon in the eastern portion of Wianamatta Regional Park.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Hawkesbury-Nepean River, primarily near Penrith Lakes.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Present as mostly-linear remnants along South Creek and Eastern Creek and tributaries, with some scattered occurrences, including along the M4.

3.2.1.4 Western Sydney Aerotropolis Growth Area (WSAGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Castlereagh Forests & Woodlands near the localities of Kemps and Badgerys Creeks, and potentially in the vicinity of the water pipeline crossing of Luddenham Road. Riverflat Eucalypt Forest remains to varying degrees along most watercourses, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. Swamp Oak Forest occurs mainly along South Creek and some tributaries. There are currently no NPWS reserves in this Growth Area. The small Kemps Creek Nature Reserve occurs just outside the south-eastern corner and Gulguer Nature Reserve and Bents Basin State Conservation Area are near the south-western corner.

Table 6. Summary of all ecological communities within the WSAGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Restricted to the Kemps and Badgerys Creek area as three patches of remnants.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	As above: two patches with smaller remnants nearby and on slightly higher ground than 724.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northeast, with one remnant in the centre.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains but very little remains, and most occurrences are linear.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	The most common PCT in this Area, with remnants throughout on the dominant shale terrain.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Only very small patches in the far south.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain and Hunter valley	Present as mainly very linear remnants along most watercourses but largely absent from the southernmost portion.

4. Assessment of species' presence and suitable habitat

4.1 Existing records and surveys

The principal source of threatened flora records in NSW is the OEH BioNet database, which includes most records held by the NSW Herbarium (specimen-based), as well as sightings, including those associated with vegetation sampling for the purposes of mapping. Other databases, such as Atlas of Living Australia, largely mirror BioNet data within NSW, but are not used in this Report due to their having lower data quality control, and because they do not allow even a registered user to access data that may not have been generalised to obscure the exact location of a record. Very few flora records that are in ALA but not in BioNet are original – most are simply replicate records based on specimens held in other herbaria.

The preliminary assessment of threatened species records undertaken for the preparation of this Expert Report reiterated the merit of reviewing BioNet data and resolving a range of errors, rather than simply using data 'as held'. *Melaleuca deanei* records within BioNet were reviewed, and numerous corrections were made, though the majority of these relate to the assigned spatial accuracy scores and to clarifying or correcting location placements and descriptions. Not all records were able to be checked in that stage, and a second review for records in or near the Growth Areas was conducted to further improve data quality. The reviews eliminated a range of errors and allowed many records that were otherwise too spatially vague, to be refined such that they were suitable for habitat modelling and for general reference. Not all records were reviewed, and inaccuracies remain in the dataset, but records within the Cumberland Subregion are now far more accurate in terms of their identification of the species, their location, and their spatial accuracy score.

BioNet data should only be treated as indicative, not least because there has not been comprehensive survey of all of the Growth Areas or environs, and surveys have been variously constrained. The absence of records from an area does not necessarily mean the species is absent, as it may not have been surveyed there, or survey conditions and methods may have been inadequate.

Field survey undertaken by consultancy firms engaged by DPE (Biosis and Ecoplanning) did not add any records of *M. deanei*.

The preliminary assessment of threatened species records undertaken for the preparation of this and three other Expert Reports reiterated the merit of reviewing BioNet data and resolving a range of errors, rather than simply using data 'as held'.

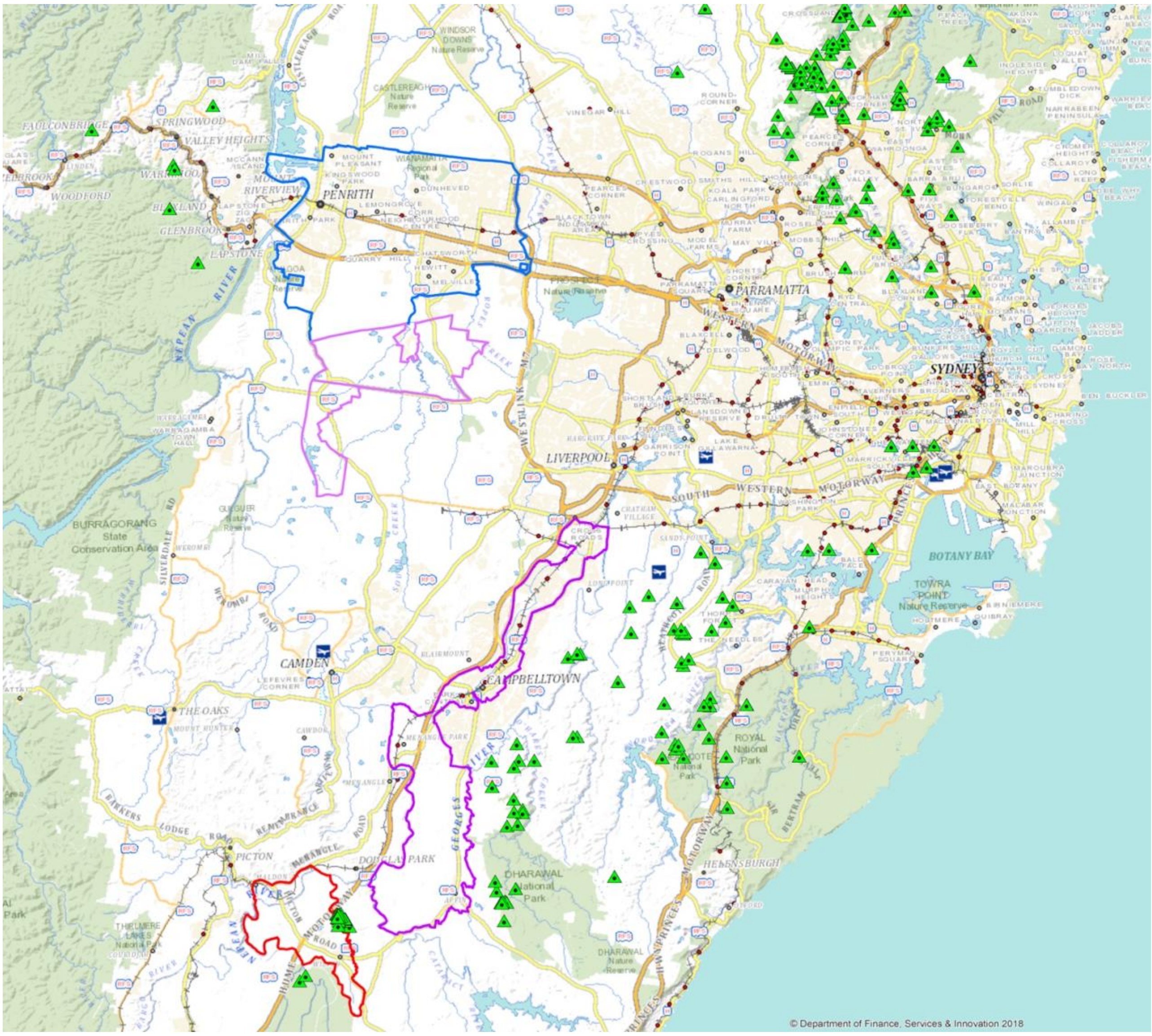
The preparation of this Report entailed detecting and notifying OEH about the correction of several records of *M. deanei* that were errors of some form. One record from the Cumberland Plain near Vineyard was determined to be a data entry error (wrong species). Another record plotted in the GMGA from an experienced botanist had a 1 km spatial accuracy and sparse notes: "north of Appin" and "in swampy area". The plotted location of the record was highly arbitrary and in a cleared paddock in the southern half of Appin village on unsuitable geology. The observer of the record was contacted about the inconsistency and was able to supply information confirming its proper location. BioNet staff have since moved this record. There is no longer a record of this species from the GMGA.

4.1.1 Existing records by Growth Area

There are no BioNet records of *M. deanei* from either the GPECGA or the WSAGA. There is no suitable habitat for this species in those areas.

There are no records of *M. deanei* in the GMGA, but there are numerous valid records to the east on the Woronora Plateau. Equivalent habitat extends into the GMGA and is identified in this Report.

M. deanei is known from numerous spatially accurate records of a population within and just outside the WGA. Other threatened flora species are present in the same area e.g. *Epacris purpurascens* var. *purpurascens*, *Acacia bynoeana*, *Persoonia bargoensis*, *Grevillea parviflora* ssp. *parviflora*. The records are dated 2015 and are from flora assessments for the Bingara Gorge housing project, which is outside the scope of the WGA.



Map 4. BioNet records (as of 26/11/18) relative to Growth Areas

Each point on Map 3 may not designate a collection or observation at that location, as most very old records lacked any co-ordinates, or only supplied coarse co-ordinates, and may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

4.1.2 Prior surveys within each Growth Area

There is no central or local registry of surveys and survey effort for threatened biota, and a large proportion of survey reports are not made public or only made public when lodged with a planning consent authority. This makes it extremely difficult, if not impossible to compile a list of surveys, methods and findings across the study area.

The OEH Authorised Officer for *M. deanei* was contacted in this regard. She provided information in the form of two 2014 publications by Alison Hewitt *et al*. (Western Sydney University) and mentioned a site in Sutherland Council area (outside the Growth Areas) that may have been subject to rehabilitation. She also mentioned a report that was seen to be of potential relevance (c.f. Cumberland Ecology, 2011).

The aforementioned surveys associated with the Bingara Gorge housing project have been considered in the preparation of this report.

4.2 Summary of survey work undertaken for the biocertification assessment

4.2.1 Vegetation mapping

Vegetation mapping of the Cumberland Subregion was completed in stages by OEH in 2013 and 2016. These two vegetation layers have been used as the base to compile an updated vegetation community layer for each of the Growth Areas. This updated work has been completed by Biosis under contract to DPE. The mapping update includes checking plant community types and confirming the accuracy of boundaries to account for clearing or regrowth that may have occurred since the original mapping was completed. Field verification of the mapping was undertaken by Biosis and Ecoplanning, both of whom undertook vegetation surveys where access was permitted.

Vegetation in the Growth Areas was mapped and assessed based on five vegetation condition classes:

- Intact;
- Non-offsettable Grassland;
- Offsettable Grassland;
- Scattered Trees;
- Thinned.

4.2.2 Field survey effort

The information in section 4.2.2 has been provided by DPE but has been edited here to only deal with threatened flora where feasible. Further details are provided separately by DPE:

An initial 726 letters were sent to landholders within the Wilton and Greater Macarthur Growth Areas in late 2017 with a second letter following in March 2018. To increase the response rate, Biosis commenced targeted door-knocking in May 2018. From this, just under 20% of landholders within these Growth Areas allowed access to their property. However, this included access to large parcels of land owned by major developers, which allowed a reasonable amount of access, particularly for the Wilton Growth Area.

Floristic plot data collected:

- Wilton (86 plots across 6 PCTs)
- Greater Macarthur (82 plots across 9 PCTs)

Approximately 150 of the plots required to meet BAM requirements were obtained by supplementing Biometric plots from various recent assessments. This involved locating the previous plots and collecting additional data on stem classes, number of large trees, and litter cover to meet BAM requirements. The ecologists had no trouble locating the original survey sites and found that the additional data was quick and easy to collect (approximately 30 minutes per site).

The remaining plots in Wilton and Greater Macarthur, and all of the plots in Western Sydney Aerotropolis and Greater Penrith to Eastern Creek consisted of new plots surveyed for this project. All plots were sampled according to the methods prescribed by the BAM Manual (OEH 2017). This includes collecting information on species cover and abundance from 20 x 20 m or equivalent configuration plots within each vegetation zone.

A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Growth Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council.

Floristic plot data collected:

- Western Sydney Aerotropolis (53 plots across 6 PCTs)
- Greater Penrith to Eastern Creek (26 plots across 7 PCTs)

Targeted survey for threatened species

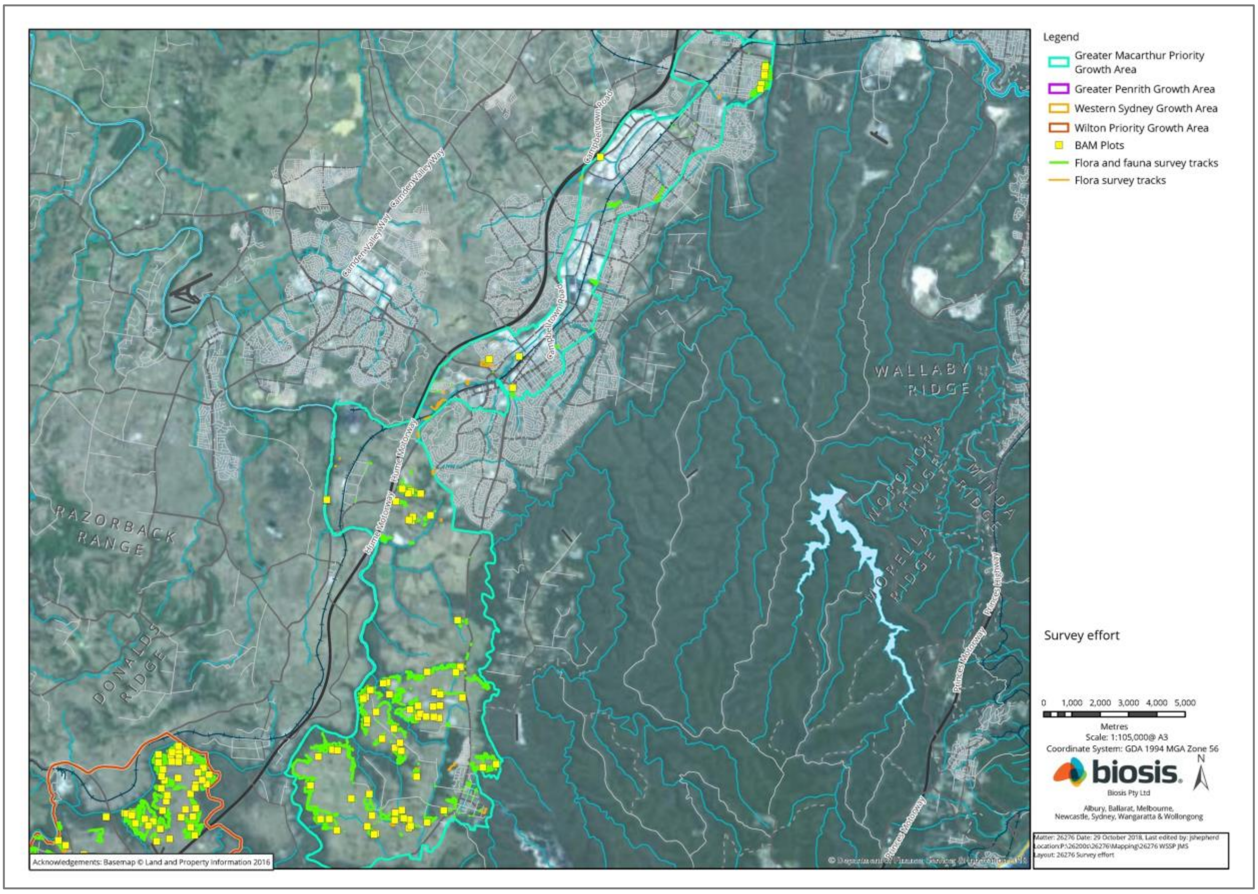
Targeted survey for threatened plant species has been conducted on lands where access has been granted. Vegetation transects and random meanders for threatened flora was conducted by Ecoplanning and Biosis in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey has included effort through each PCT and vegetation zone and has extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m).

Likely habitat for most threatened flora species comprised areas of lower disturbance. This includes areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora.

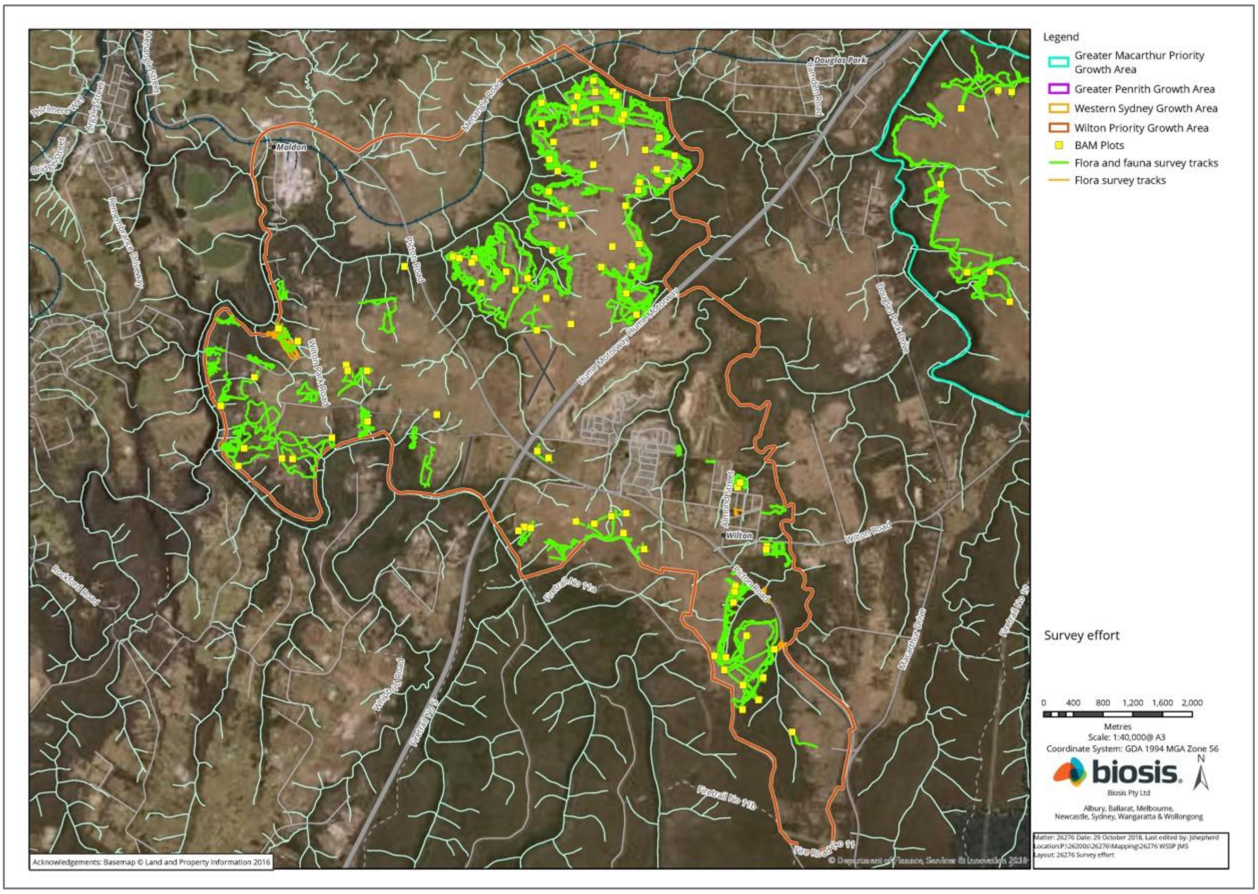
Table 9. Survey effort for threatened plant species *and* fauna habitat by PCT

PCT No.	Area of PCT in Growth Area (ha)	Area of PCT in urban zone (ha)	Field survey area (ha)	Percent of PCT surveyed within Growth Area (%)	Percent of PCT surveyed relative to urban zone (%)
724	191.3	57.0	12.1	6.3%	21.2%
725	167.4	51.4	6.9	4.1%	13.4%
781	68.9	5.6	0.9	1.4%	16.8%
830	21.6	0.8	1.7	7.8%	206.5%
835	1175.8	287.3	30.5	2.6%	10.6%
849	3078.3	637.6	125.0	4.1%	19.6%
850	522.9	294.3	36.1	6.9%	12.3%
883	7.4	0.0	0.5	6.8%	
1081	74.2	0.0	0.2	0.3%	
1105	138.6	0.0	0.0	0.0%	
1181	780.7	0.2	39.6	5.1%	19794.4%
1292	39.8	0.0	0.3	0.7%	
1395	3326.6	486.9	483.4	14.5%	99.3%
1800	232.6	20.2	7.3	3.1%	36.2%
TOTAL	**9826.1**	**1841.3**	**744.5**	**7.6%**	**40.4%**

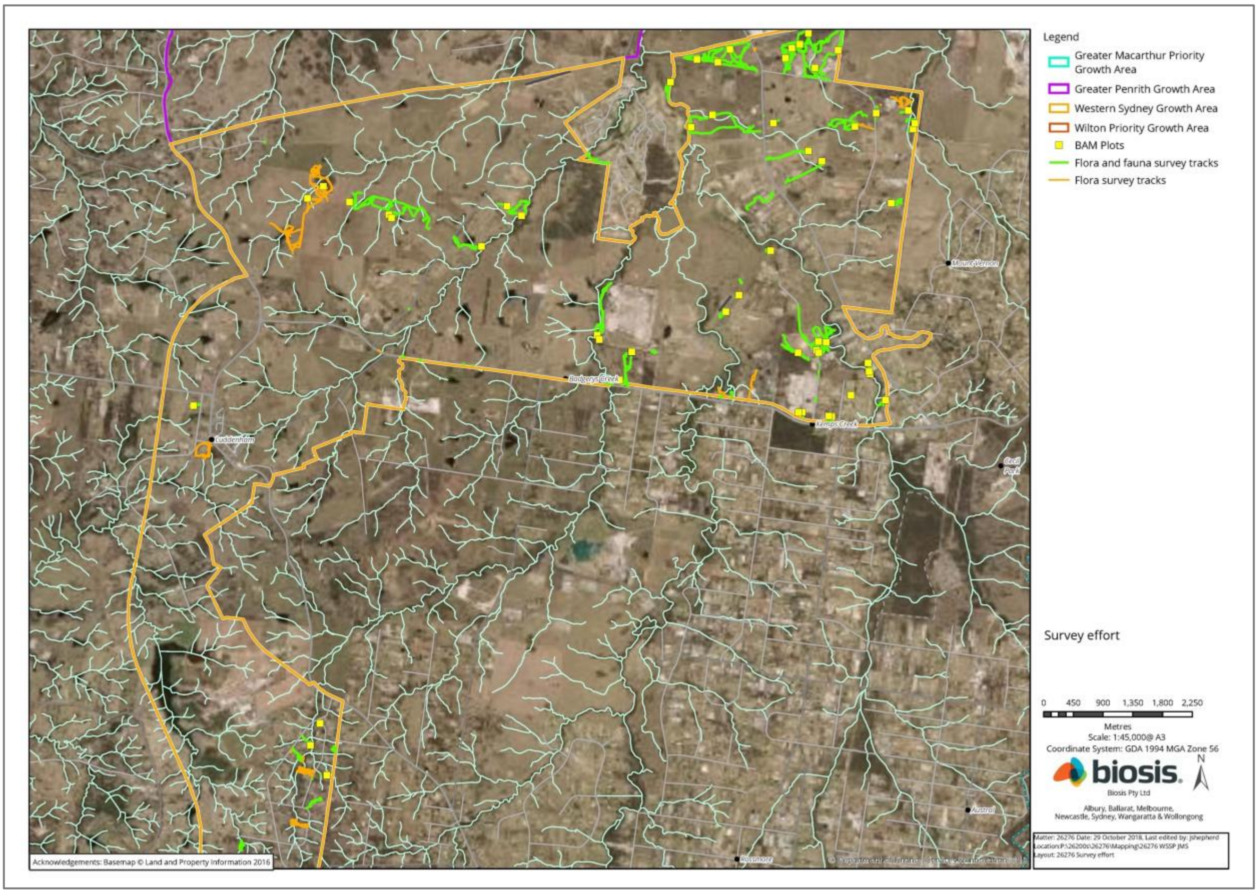
Field survey effort was not confined to the urban zone. Surveys occurred into nearby vegetation zoned for conservation. The urban zone has been revised over time and some areas where survey had already occurred were later removed. For these reasons, comparison of the survey area to the urban zone is indicative only. Survey effort has been calculated using a 20-metre buffer either side of GPS survey tracks. For the purposes of this analysis, the urban zone includes land zoned for future urban development plus transport corridors within the growth areas. It does not include any transport corridors outside the growth areas.



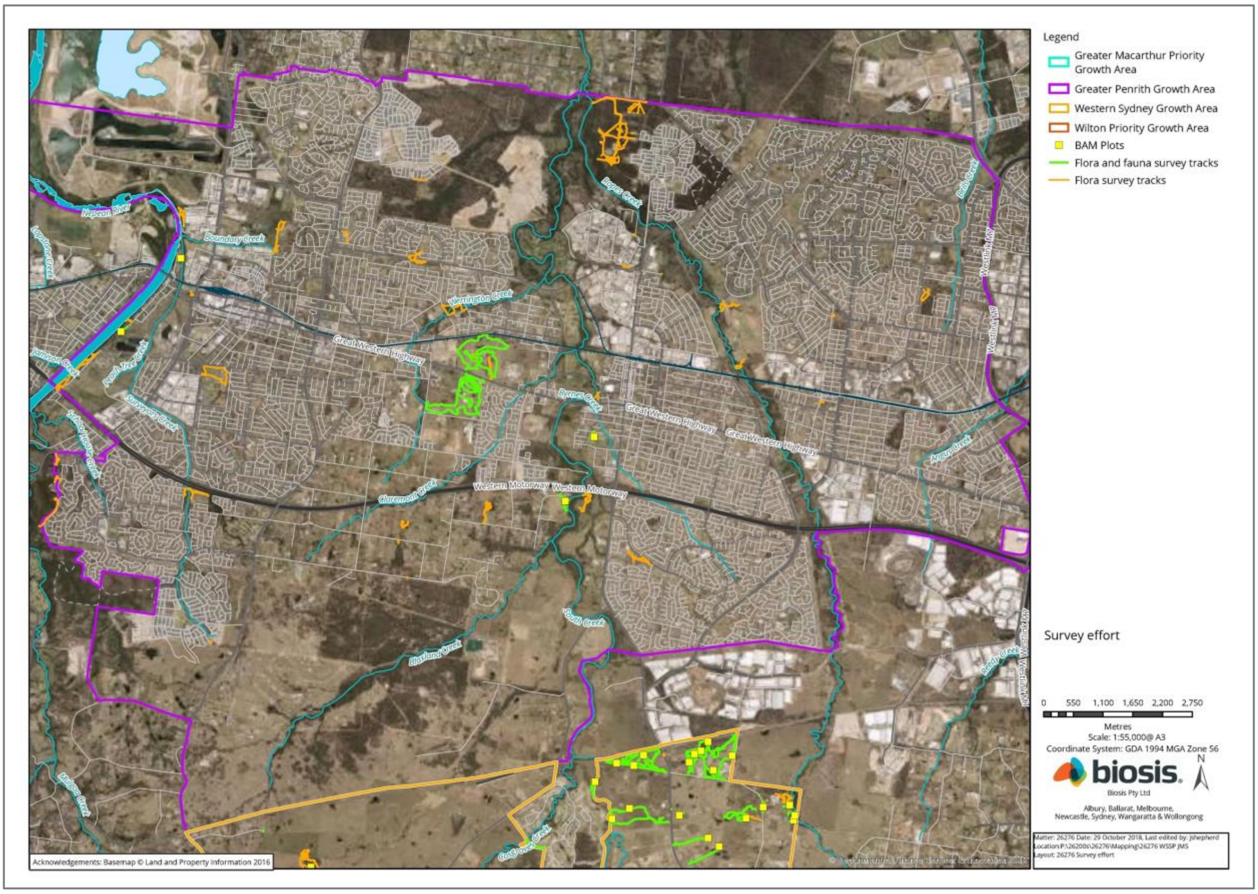
Map 5. GMGA survey effort (Biosis & Ecoplanning)



Map 6. WGA survey effort (Biosis and Ecoplanning)



Map 7. WSAGA ('Western Sydney') survey effort (Biosis and Ecoplanning)



Map 8. GPECGA survey effort (Biosis and Ecoplanning)

4.2.3 Survey constraints –timing / site conditions

As noted earlier, severe drought affected all of the study areas for some or all of the survey period. The Wilton and Greater Macarthur GAs were only surveyed during drought, whereas the Penrith & Eastern Creek and the Aerotropolis GAs were surveyed both during intense drought and the subsequently slightly wetter conditions that followed in the Spring of 2018. Whilst wetter, drought remained present, and fellow Expert, Robert Miller, reported that vegetation was evidently drought-affected across all of the Growth Areas into November.

Drought, combined with increased intensity and extent of total grazing pressure, meant that affected surveys may have under-recorded the target species compared to normal conditions. Whilst drought alone is unlikely to cause *M. deanei* to die back to rootstock or die and only remain as seedbank, when combined with increased herbivory due to drought, this is a far more likely outcome. The extent to which herbivory of any kind affects this species is unknown. It is unlikely to be palatable to livestock because of the high volatile oil content, and that it is not likely to be nutritious, but native browsers may consume it e.g. Swamp / Black Wallaby or Brushtail Possum under harsh conditions.

Irrespective of drought, surveys for this species are constrained by consideration of fire ecology, in that this species can be suppressed and potentially rendered apparently extinct at a site if the area has not been burnt for many years and shrub growth is thick. Prolonged absence of fire is a constraint in some of the surveyed areas. Conversely, the species could be undetectable or not readily distinguished and identified in areas burnt very recently.

4.2.4 Survey constraint – surveys undertaken by generalists / non-experts

M. deanei is not a cryptic species and it is not easily missed when suitable conditions are present. However, it is more likely to be present but not recorded when surveyed by personnel not very familiar with the species, and more so in situations such as restricted visibility and access due to dense scrub cover as a result of prolonged absence of fire and/or regrowth after earlier clearing or intense grazing etc. Those situations are more likely in some of the areas surveyed i.e. between grazed lands and ungrazed bushland.

4.3 Surveys completed specifically for this Report

I did not undertake any surveys for this species in either of the two Growth Areas in which it is either known or likely to occur. Reasons for this include:

- Consultants who detected the Bingara Gorge population had earlier surveyed some of the nearby equivalent habitats, but did not detect this species or the other associated threatened plant species present at that site (G. Steenbeeke, pers. comm.);
- Surveys by other consultants on behalf of DPE traversed some additional areas of potential habitat, and also did not detect the species;
- There were constraints in terms of ready access to properties other than those that DPE’s consultants had already surveyed or were scheduled to survey, and some sites of potential habitat were inaccessible due to the land owner not providing permission to enter;
- Relatively little time was available given the timeframes that had been specified for the provision of the four Expert Reports that I was commissioned to complete;
- *M. deanei* is naturally rare and patchily distributed, and the species appears to be at its low rainfall limit of distribution in the WGA and GMGA. Most of the more westerly populations are at higher elevations with greater orographic rainfall and/or less rain-shadow than the WGA and GMGA (both of these Areas experience rain-shadow from the Woronora Plateau to the east, and the Greater Blue Mountains to the west);

Having regard to the above, there seemed to be relatively little merit in my undertaking additional surveys, especially given that my work in this Expert Report is intended to cover gaps in survey effort, so would necessarily take a precautionary approach when dealing with the prediction of potential habitat. This decision has been further supported by the fact that the majority of potential habitat for this species has been excluded from the proposed urban footprint.

4.4 Assessment of species' presence

The following section deals with known occurrences of the species in the context of the four Growth Areas.

4.4.1 Greater Macarthur Growth Area

Most of the northern half of the GMGA is not likely to support the species based on the extent of land clearing and/or the scarcity of suitable habitat parameters such as plant communities and soil types. Were the species found in the highly urbanised northern GMGA, it is likely that unless on public land able to be managed for conservation, any such occurrence may not be viable in the long-term terms because of threats including fragmentation / isolation of habitat, and ability to maintain ecological processes.

In contrast, the southern half of the GMGA contains significant areas of potential habitat. This habitat mainly occurs around the upper slopes and ridges associated with gullies and valleys of incised watercourses, and some other remnants that appear to have escaped clearing and grazing due to their relative infertility or other constraints. Some potential habitat is present within and on some edges of the biocertification area (urban footprint). However, potential habitat within the proposed urban footprint is likely to be of lower condition and less viable due to historic and current land uses.

4.2.2 Wilton Growth Area

The species is known to be present in this Growth Area, and nearby to the south, with both populations being substantial in extent and the number of apparent individuals. The only occurrences in the Growth Area are on a site outside the proposed urban footprint, within the separately approved Bingara Gorge housing project. A significant area of similar habitat occurs largely outside but occasionally on the margins of or adjoining the proposed urban footprint. However, surveys of some nearby sites supporting apparently suitable habitat by the same personnel who found the documented population did not detect any further occurrences. This may be a result of the areas having different disturbance histories, particularly in terms of fire. This situation does not preclude the species being present in those sites, as it may be restricted to the seed bank or to rootstock, or in areas with thick scrub cover.

The species is unlikely to occur within the majority of the proposed urban footprint as it is not suitable habitat or has been too heavily modified. Potential habitat within the proposed urban footprint is likely to be of lower condition and less viable due to historic and current land uses.

4.2.3 Greater Penrith & Eastern Creek Growth Area

The species is not known to be present in this Growth Area, nor immediately nearby. This Area does not contain suitable habitat for this species.

4.2.4 Western Sydney Aerotropolis Growth Area

The species is not known to be present in this Growth Area, nor nearby. This Area does not contain suitable habitat for this species.

4.5 Assessment of suitable habitat for *Melaleuca deanei*

4.5.1 Description and relative significance of potential habitat

The species' ecology and distribution are now sufficiently known to be confident in predicting the Plant Community Types, associated Threatened Ecological Communities and landscapes in which it is likely to occur, both in general, and within the Growth Areas. DECCW (2010) indicates that there is not a clear association between the species and particular habitat. However, this may refer to the fact that the species is not specific to a *single* habitat. At that time, vegetation maps were not as developed as they are now over much of the species' range, which likely constrained DECCW's ability to perceive and describe habitat associations.

Potential habitat for *M. deanei* has been determined based on the species' known affinity with particular geology, soils, and vegetation communities, with some regard to habitat condition. Additionally, the species is not associated with watercourses, so graded riparian exclusion buffers have been applied in the creation of the required 'species polygons' that map potential habitat. All vegetation condition classes are included except Derived Native Grassland.

As per the findings presented earlier, combined with expert knowledge, the following vegetation communities are regarded as potential habitat for *M. deanei* across the **two southern Growth Areas** in which it is either known or considered likely to occur:

Table 8.

PCT	PCT Name	Relative significance
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	High to potentially Very High when compensating for limitations of datasets
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney	Moderate to Low when compensating for limitations of datasets
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion	Very High to High when compensating for limitations of datasets

Again, it is important to note that the relative significance of these PCTs for this species should only be seen in the context of the Greater Macarthur and Wilton Growth Areas. Across the species' range, the relative strength of association for these PCTs will likely drop, not least because other PCTs, particularly more coastal heathy woodlands, are strongly associated with this species.

Greater Macarthur Growth Area

The vegetation mapping provided for use in the project indicates that there are **1645.0 ha** of potential habitat for this species in this Growth Area based only on the extent of relevant PCTs. However, significant portions of some components are of lesser habitat significance due to persistent disturbance, particularly intensive pastoralism (sewing of introduced pasture species, addition of fertiliser, commercial stocking rates), and are less likely to retain this species in any form. This is particularly the case for PCT 1395, which is the most likely to be directly degraded by rural land uses. PCT 1181 is more likely to be compromised by rural and urban run-off and associated weed invasion but only along riparian zones in which *M. deanei* does not occur.

Table 9. Potential habitat in the GMGA

PCT	Distribution	Relative habitat value of local occurrences
1081	Very rare in this GA – just one site and three polygons above a drainage line in an established urban area.	Moderate to high depending on condition (mapped as Intact but likely to suffer from urban pressures, particularly weeds and altered fire regime). Site has very high edge to area ratio, further reducing general habitat value.
1181	Common within sandstone gullies and gorges, mainly on or near WGA boundaries, primarily in the southern portion. Only one small example in the northern portion (urban bushland).	Low to moderate depending on sandstone influence – high sandstone and no shale influence is of lower habitat value. Not suitable habitat close to watercourses. Areas degraded by adjoining rural and urban land uses are likely to be of less habitat value.
1395	Common in the far south from around Menangle Park through Gilead to Appin area; between cleared shale landscapes and sandstone gullies	High to moderate depending on shale content: high shale content is of lower habitat value. Unlikely habitat when near other than low order watercourses

Wilton Growth Area

There is a substantial area of potential habitat in the WGA, with several recent records within one population mapped as part of the Bingara Gorge housing project. Similar habitat extends along the upper slopes of many remnant vegetation areas associated with larger watercourses. The updated vegetation map indicates that there are **1162.2 ha** of potential habitat for this species in this Growth Area.

Table 10. Potential habitat in the WGA

PCT	Distribution	Relative habitat value of local occurrences
1081	Uncommon and restricted to three substantial patches above sandstone gorges, mainly on or near edges of WGA.	High to moderate even when considering that the nearby records are not mapped in this PCT (likely due to limitations of that mapping).
1181	Common within sandstone gullies and gorges, mainly on or near WGA boundaries.	Low to moderate depending on sandstone influence – high sandstone and no shale influence is of lower habitat value. Not suitable habitat close to watercourses.
1395	Common in the far south from around Menangle Park through Gilead to Appin area; between cleared shale landscapes and the upper margins of sandstone gullies	High to moderate depending on shale content and site condition: high shale content is of lower habitat value. Unlikely habitat when near anything other than low order watercourses

4.5.2 Species habitat polygons

Species habitat polygons generated by this report relate to the extent of potential habitat that is proposed to be cleared for urbanisation or related purposes, such as transport corridors. The polygons were generated to inform biodiversity offset assessments. The data presented in this section does not deal with species habitat outside proposed urban zones as those areas are treated as conservation zones or are excluded from urban and associated transport zones for a range of reasons.

The habitat polygons include all relevant condition classes of relevant PCTs as identified in this Report. In this case, all condition classes are included except Derived Native Grassland. However, that class was apparently accidentally included in the calculations, but the effect of this is trivial.

Species habitat polygons have been generated based on DPE's project-specific PCT maps and the application of graded riparian buffers. The riparian buffer distances used to generate the polygons increase with the Strahler stream order as shown below. The buffer is applied either side of the mapped stream centreline. The distances have been determined based on observations of spatially accurate records of the species in relation to relevant stream orders. Riparian exclusion buffers are used for this species as *M. deanei* is primarily associated with ridge tops, plateau margins, spurs, and upper slopes with relatively exposed aspects. It is not associated with lower slopes or sheltered aspects, and not with riparian habitats. Note that these riparian buffer distances are a different concept and serve a different purpose to those applied by DPE for the purposes of protecting streamside vegetation and watercourses in its planning within the Growth Areas.

Spatially reliable records of this species do not occur near streams, but can occur closer than would otherwise be expected, simply because of steep terrain. This factor is partly why a simplistic linear GIS-based assessment has not been used to determine the optimal buffer distances. The distances used here err in accordance with the precautionary principle. Many spatially reliable records occur considerably more than 20 m from first order streams. A simple linear relationship between stream order and buffer distance was not evident because higher order streams in elevated areas tend to be deeply incised such that ridgetop habitat can be relatively close to the stream but over very steep, sometimes vertical terrain. The distance can be relatively short, but the altitude difference can be dramatic.

Table 11.

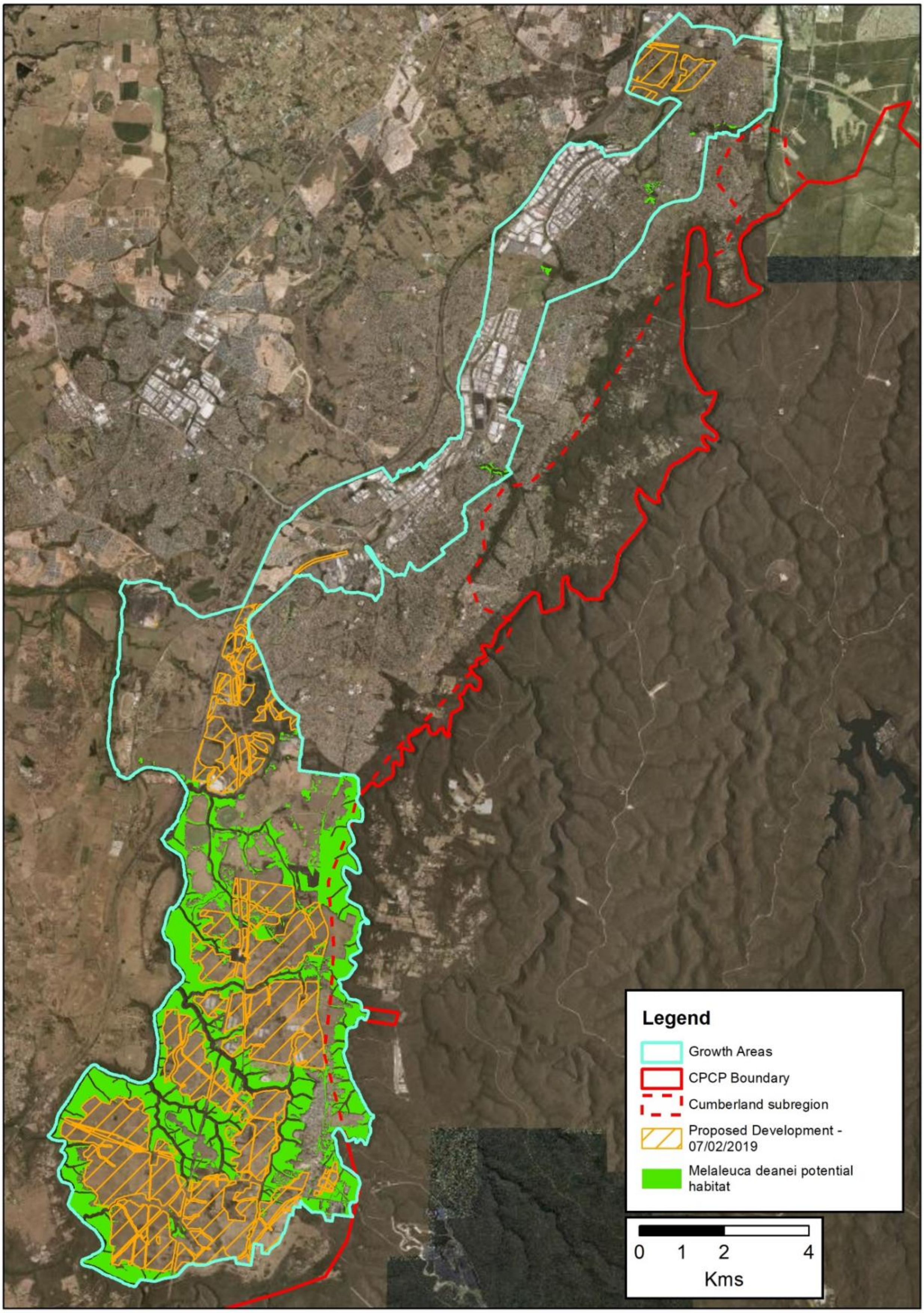
Stream order	Buffer distance (m)
1	20
2	30
3	40
4	60
5	70
6	80
7	90

Species polygons in the form of GIS shape files were provided to the Biodiversity and Sustainability Branch of DPE in November 2018. A summary of the analysis of these shape files is presented in Table 12. These figures are based on precautionarily modelled *potential* habitat, and do not necessarily equate with *actual* habitat, nor do they provide any information of potential population sizes or population viability. It is unlikely that a large percentage of the potential habitat identified in this Report would actually support *M. deanei* because this species is naturally rare and patchily distributed, even though it can be locally abundant in favourable conditions.

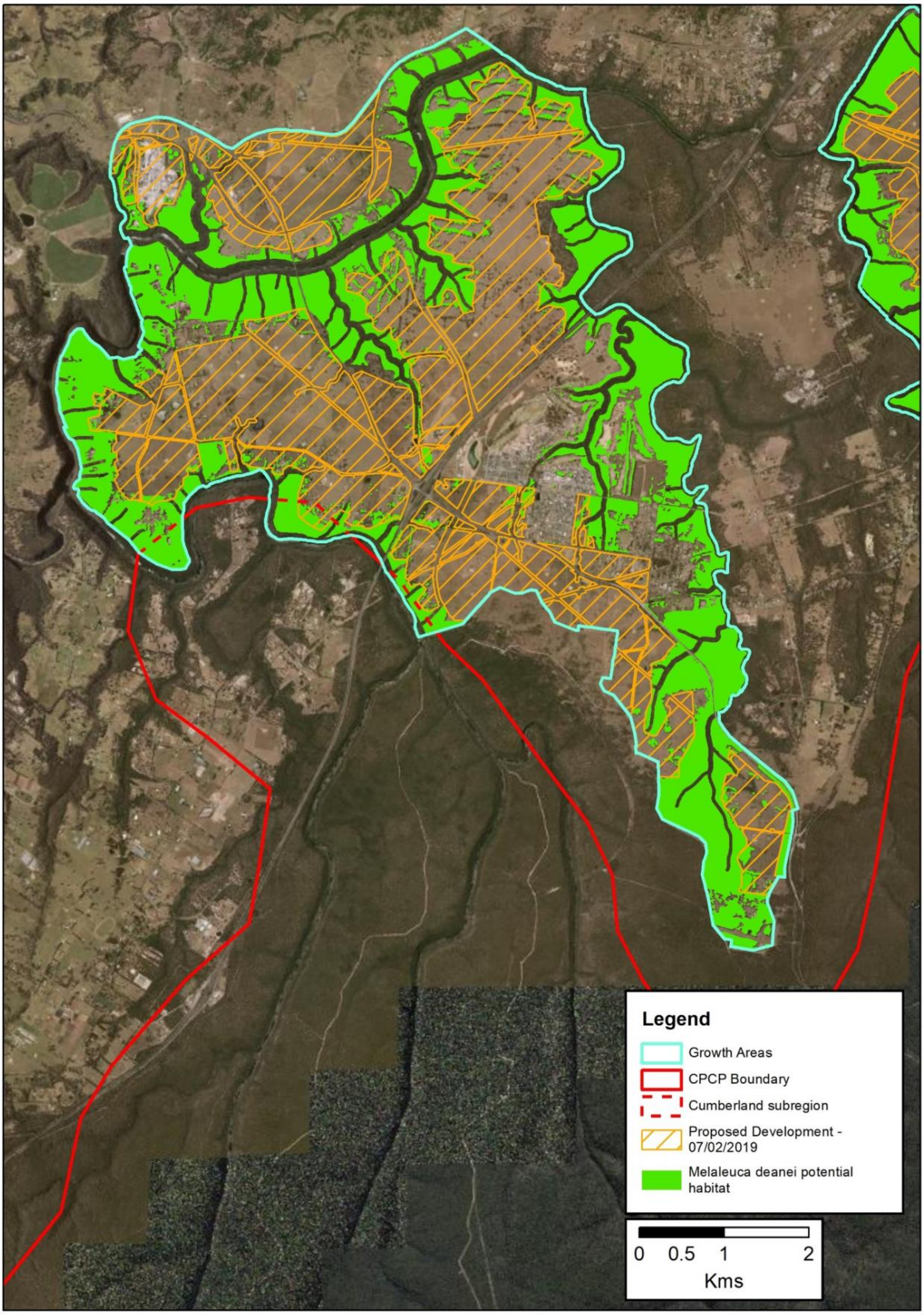
Table 12. Area of PCT-based potential habitat proposed for removal in each Growth Area

Growth Area	**Area of potential habitat (ha)**	**Area of potential habitat removal (ha)**	**% area of potential habitat removal by GA**
Greater Macarthur	1645.0	102.3	6.2
Wilton	1162.2	114.6	9.9
Transport corridors **(all GAs)**	-	0.0	0.0
TOTAL	**2807.2**	**216.9**	**7.7**

Map 9 Greater Macarthur - Potential habitat and proposed urban/transport habitat removal



Map 10 Wilton - Potential habitat and proposed urban/transport habitat removal



5. Summary and conclusion

Within the four Growth Areas, *Melaleuca deanei* is currently only known from the Wilton Growth Area, and that occurrence is outside the biocertification area. Potential habitat for this species exists in other parts of the WGA and in the GMGA, though in the latter case, the vast majority of that habitat is in the southern section. The species is not known or likely to occur in the GPECGA or WSAGA, and no potential habitat is identified in those Growth Areas in this Report.

Based on current information, the proposed urban footprint and associated transport corridors across the two relevant Growth Area would destroy 216.9 hectares of potential habitat for *M. deanei*. This equates to 7.7% of the area of potential habitat as defined in this Report. The actual extent of conflict between habitat for the species and proposed clearing for urbanisation is likely to be much smaller as the species is naturally rare and patchily distributed. Not all of the area proposed for removal is of equal value as potential habitat, and different PCTs and condition classes have different probabilities of supporting *M. deanei*.

Because this species is relatively tolerant of some types of disturbance, and it can persist in the soil seedbank, as well as surviving for some time as rootstock, it may occur in areas that might otherwise be disregarded as habitat. It may even persist in areas not mapped as native vegetation. It is likely that some modified sites might support the species in some form, but in general, these are of relatively low significance in the context of the much larger areas of more intact potential habitat that is excluded from urbanisation and associated clearing. It is also feasible that some forms of disturbance associated with urbanisation, particularly the creation of bushfire Asset Protection Zones (APZs) between bushland conservation areas and housing, could advantage this species, especially where the habitat has not burnt for many years. Thinning of the shrub layer by fire or mechanical means could favour the species. More frequent, moderate intensity burning of bushland that represents known or likely habitat for this species, may, within limits, also advantage it compared to low frequency and/or very cool burning.

The positioning of the bushland / urban interface and associated infrastructure such as APZs, should have appropriate regards to this species' habitat and ecology. Appropriate buffers and other strategies are required to prevent direct and indirect harm to this species as a result of the urbanisation of adjoining lands. For example, potential habitat should not be compromised by the placement of housing nearby as might prevent that habitat being managed for conservation, especially in terms of bushfire risk management. DPE has informed me that the intention is for APZs to be accommodated within the proposed urban footprint, not in the non-biocertified bushland areas that may adjoin it.

The absence of records of this species from areas of potential habitat does not mean it could not be present. This is because:

- not all areas have been surveyed historically or recently;
- all surveys have a range of limitations;
- not all discoveries of threatened species are disclosed; and
- large areas of potential habitat are highly likely to have fire regimes that do not favour this species, meaning it may currently occur in very low numbers or as seedbank, yet could appear in substantial numbers after an appropriate fire or equivalent disturbance.

These factors have been considered in the preparation of the species habitat polygons that will inform DPE in relation to biodiversity offset obligations.

6. Information used in the assessment

6.1 DPE or OEH resources

- BioNet data (internal access provided under license for use in this Expert Report and associated dataset cleaning for the purposes of species habitat modelling to meet EPBC Act requirements)
- Atlas of Living Australia on-line (partial use to check for records not in BioNet)
- EMU data (NSW Herbarium specimen database, provided by OEH)
- OEH on-line threatened species profile
- OEH Threatened Species Data Collection on-line
- OEH BioNet Vegetation Classification Database (previously known as VIS)
- EPBC Act Listing/Conservation Advice
- OEH PCT (vegetation) maps for Sydney Metropolitan and Cumberland Plain
- Field data from Biosis and Ecoplanning consultancies engaged by DPE
- GIS layers and maps provided by DPE and its contractors, or by OEH

6.2 References

Beadle, N.C.W., Carolin, R.C. & Evans, O.D., 1983. *Flora of the Sydney Region*, Reed Publishers, Frenchs Forest.

Benson, D. & McDougall, L. 1998. 'Ecology of Sydney plant species, Part 6: Dicotyledon family Myrtaceae', *Cunninghamia* 5(4): 808-907.

Cumberland Ecology, 2011. *Heathcote Ridge, West Menai – State Significant Site: Ecological assessment*. Cumberland Ecology, Carlingford Court. https://majorprojects.affinitylive.com/public/fac9361572a52306e5e4fcbcc438f799/Appendix%209%20-%20Ecological%20Asst%208059RP2.pdf [Date Accessed: 01 November 2018]

Department of Environment, Climate Change and Water (DECCW), 2010. *Recovery Plan for* Melaleuca deanei *(Deane's Paperbark)*, DECCW {now NSW Office of Environment & Heritage}, Sydney. On-line at http://www.environment.gov.au/system/files/resources/b4dfa6ba-6cd3-4235-9d31-f68c45c73b4d/files/melaleuca-deanei.pdf [Accessed 1 November 2018].

Department of Environment & Energy (Commonwealth), 2008 (August 22). *Species Profile and Threats Database:* Melaleuca deanei *– Deane's Paperbark*. http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?showprofile=Y&taxon_id=5818 [Date Accessed: 01 November 2018]

ESP Ecological Surveys & Planning, 1999. *Hornsby Shire Threatened Biota Management Plan*. Report prepared for Hornsby Shire Council. ESP, Hornsby, NSW.

Fairley, A., 2004. *Seldom Seen. Rare Plants of Greater Sydney*. New Holland, Sydney.

Fairley, A. & Moore, P. 1989. *Native plants of the Sydney District*, Kangaroo Press, Kenthurst.

Felton, S.A. 1993, *The distribution, abundance and seed ecology of the rare plant* Melaleuca deanei. Unpublished Honours thesis, University of Wollongong.

Hewitt, A., Holford, P., Renshaw, A., Haigh, A., and Morris, C. 2014a. 'Plant-level fecundity and andromonoecy in three common (*Melaleuca styphelioides*, *M. thymifolia*, *M. nodosa*) and one rare (*M. deanei*) *Melaleuca* (*Myrtaceae*) species of the Sydney region'. *Australian Journal of Botany* 62: 276-285.

Hewitt, A., Holford, P., Renshaw, A., Haigh, A., and Morris, C. 2014b. ‘Population structure, seed loads and flowering phenology on three common (*Melaleuca styphelioides*, *M. thymifolia*, *M. nodosa*) and one rare (*M. deanei*) *Melaleuca* (Myrtaceae) species of the Sydney region’. *Australian Journal of Botany* 62: 286-304.

Hewitt, A., Rymer, P., Holford P., Morris C. and Renshaw, A. 2019. ‘Evidence for clonality, breeding system, genetic diversity and genetic structure in large and small populations of *Melaleuca deanei* (Myrtaceae)’. *Australian Journal of Botany* 67: 36-45.

Martyn, J. 2018. *Rocks and Trees: a photographic journey through the rich and varied geology, scenery and flora of the Sydney region*. STEP Inc., Turramurra.

Maryott-Brown, K. & Wilks, D. 1993. *Rare and endangered plants of Yengo National Park and adjacent areas*. NSW National Parks and Wildlife Service, Hurstville.

Murphy, C.L. 1993. *Soil Landscapes of the Gosford-Lake Macquarie 1:100 000 Sheet Map,* Department of Conservation & Land Management, Sydney (now available from the Department of Land & Water Conservation, Sydney).

Myerscough, P.J. 1998. ‘Ecology of Myrtaceae with special reference to the Sydney region’, *Cunninghamia* 5(4): 787-807.

NSW Scientific Committee. 1999. Final determination to list the shrub *Melaleuca deanei* as a vulnerable species on Schedule 2 of the Act. The Committee, Hurstville.

Office of Environment & Heritage (OEH), 2017. *Deane’s Paperbark – profile*. https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10515 [accessed 6th November 2018].

SEWPaC, 2012. *Interim Biogeographic Regionalisation for Australia, Version 7*. Department of Sustainability, Environment, Water, Population and Communities. http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html

Specht, R. 1981. ‘Foliage projective cover and standing biomass’, in *Vegetation Classification in. Australia,* eds. A.N. Gillison & D.J. Anderson, CSIRO/Australian National University Press, Canberra.

Tozer, M.G., Turner, K., Keith, D.A., Tindall, Pennay, C., D. Simpson, C., MacKenzie, B., Beukers, P. & Cox, S. 2010. ‘Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands’. *Cunninghamia* 11(3): 359-406.

Tindall, D., Pennay, C., Tozer, M.G., Turner, K., & Keith, D.A. 2004. *Native vegetation map report series. No. 4. Araluen, Batemans Bay, Braidwood, Burragorang, Goulburn, Jervis Bay, Katoomba, Kiama, Moss Vale, Penrith, Port Hacking, Sydney, Taralga, Ulladulla, Wollongong NSW*, Department of Environment and Conservation and NSW Department of Infrastructure, Planning and Natural Resources, Sydney.

Travers Morgan Pty Ltd. 1990. *The regional distribution of Melaleuca deanei and five plants occurring in West Menai and the Southern Sydney region*. Report prepared for Department of Housing NSW.

Virtue, J.G. 1991. *Melaleuca deanei: ecological studies on a rare plant*. Unpublished B.Sc. thesis. University of Sydney.

Wrigley, J.W. & Fagg, M. 1993. *Bottlebrushes, paperbarks and tea trees and all other plants in the Leptospermum alliance.* Angus & Robertson, Pymble.

7. Acknowledgements

I acknowledge the contributions of DPE staff, particularly Dayle Green, Greg Steenbeeke and Christian Marando (GIS), and DPE contractor Darren James (GIS) in the preparation and refinement of this document and associated maps. My contractor, Rhys Grogan, also assisted with GIS output in the form of drafts of the 'species polygons'.

Consultant botanist, Robert Miller assisted with fieldwork at Kemps Creek, and provided information about field observations associated with searches for his target species and with opportunistic sitings of my target species.

OEH staff assisted with some aspects of data availability and with the processing of many amendments to BioNet records.

8. Statement of professional independence

Whilst I was engaged and funded by DPE to prepare this Expert Report, and series of draft reports and maps were reviewed by DPE staff, I was not coerced by DPE to amend my work in any manner that I did not otherwise agree with. I believe that I had appropriate professional independence in the preparation of this document and associated maps.

I also declare that I do not have any personal or commercial conflict of interest in the preparation of this Report. I do not own real estate or businesses with property in the Growth Areas, nor do I have other active clients with real estate or associated commercial interests in the Growth Areas.

9. Appendix 1. Author's *Curriculum Vitae*

Dr Steven Douglas (BSc., MEnv. Plan., PhD.)

I have over twenty years of experience as an ecologist and environmental planner, primarily in New South Wales, with some experience in the ACT, Victoria and South Australia. I have worked for all levels of government, for environmentalist non-government organisations (NGOs), and for a large number of private clients ranging from individuals to multinational firms, directly and as a subcontractor. I have often worked as a sole consultant but have also collaborated with other specialists and have sometimes been part of large teams involved in large-scale, even interstate projects.

I specialise in the detection, management and conservation of rare and threatened flora species and communities, and in associated ecological impact assessment and mitigation.

I have qualifications and experience in a range of general and specific ecological, social, organisational and 'sustainability' fields.

I have served on environment-related ministerial committees and have held other ministerial appointments in NSW, including those dealing with bushfire management.

I have published in journals dealing with plant conservation, environmental law and policy, social science, and ecological ethics. Aspects of my work have been published by government, prominent NGOs, and in the popular press and other media.

This CV only contains content directly related to my botanical expertise.

Employment summary

1996 to present:

Self-employed, trading as *Ecological Surveys & Planning* (www.ecologicalsurveys.net)

Through this enterprise, I have undertaken a large number of consultancies for public and private sector clients including environmental impact assessment and mitigation; threatened biota research, profiling and management; vegetation mapping; preparing management plans for conservation estate; providing environmental planning and catchment management advice; advising on bushfire risk management; acting as an expert witness in Land & Environment Court proceedings; and developing organisational sustainability policies and practices.

July 2017 to July 2018:

Senior Ecologist, NSW Office of Environment & Heritage (NVIS, Science Division)

My work on the project below led to OEH retaining my services to research and document problems with the description, interpretation and mapping of Threatened Ecological Communities (TECs) statewide. This project provides advice to OEH, the NSW Threatened Species Scientific Committee, and through those agencies, to the Commonwealth Threatened Species Scientific Committee. It identifies technical issues with the description of TECs and their mapping, as well as wider problems of how TECs are defined. It draws on a major project undertaken by OEH for the NSW EPA and Forestry Corporation, in which TECs of the east coast and ranges were assessed and mapped for regulatory purposes on forestry estate. However, my work includes many more TECs and recent information emerging from Save Our Species project panels.

November 2015 to July 2017:

Team Leader, NSW Office of Environment & Heritage (NVIS, Science Division)

This project in Wingecarribee Shire is the first in which OEH's vegetation mapping team has worked at a very fine scale for a single local government area. The project entails auto-segmentation of digital aerial photography; supervising contract vegetation sampling; conducting strategic sampling; modelling of most vegetation communities; describing new communities; and extensive remote and on-ground map validation. I was hired partly because of my extensive familiarity with much of the vegetation of this geodiverse and biodiverse region. The role included supervision of two staff; liaison with consultants; and substantial networking with OEH and Wingecarribee Council staff. An update of vegetation classification will occur from mid 2019 onwards, and I have drafted a peer-reviewed journal article about the project that will be submitted for publication.

1995/6:

Project consultant, then Project Manager, Urban Bushland Biodiversity Survey (NPWS)

The Urban Bushland Biodiversity Survey was undertaken by the NPWS to compile comprehensive data on indigenous flora and fauna in twelve local government areas in Western Sydney. Contracted initially as a consultant to design and scope the project, I was later employed as Project Manager. Responsibilities involved an extensive literature review, preparation of a project plan and a background paper for the Survey and the overall management of the project including up to twelve staff and several consultants. The major focus was on coordinating research work, fauna and flora field surveys, and a community liaison and media campaign. Extensive flora survey work and scientific data analysis was undertaken. I provided a tour of important vegetation sites for the South Creek Catchment Management Committee. I also wrote media releases and conducted various media events including a live-to-air interview on ABC Radio National, and filming of a story in the field for the Totally Wild program.

1994:

Catchment Environment Officer (*Hawkesbury City Council*).

The project was funded by a grant from the former Hawkesbury-Nepean Catchment Management Trust and had the objective of identifying land uses on riverside properties to assess their potential to generate water pollution. The information on land use and riparian vegetation was primarily gained from aerial photo interpretation, limited land-based inspections and several water-based inspections, and was recorded in a GIS. Work site inspections, pollution control on agricultural lands, community meetings, site visits with landowners, and facilitating the formation of a Landcare group in the Sackville area.

1993/4:

Technical Officer (*Hawkesbury-Nepean Catchment Management Trust*).

Work included assisting with the preparation of a vegetation management strategy for the Trust and the outline of a revegetation strategy for South Creek. Other responsibilities involved providing scientific advice for development assessments, the preparation of hard copy and computer-based catchment maps, and advising on the implementation of revegetation projects in the catchment.

Ministerial appointments

- Appointed a member of the **National Parks & Wildlife Service Regional Advisory Committee** (South Coast) (2010-mid 2018). I opted not to reapply for this role after serving two terms. The restructure of the NPWS meant that the Committee would operate from Wollongong to the Victoria border and inland to the Tablelands. This was logistically fraught, and the role of RACs was evidently being diminished, with larger areas to manage but less meetings held.
- Appointed a member of the **NSW Sustainability Network** (2001), part of the Sustainability Advisory Council reporting to the Minister for Planning. I did not take up this position due to my relocating to Victoria.
- Nature Conservation Council representative on the former NSW **Native Vegetation Advisory Council** (1999-2001) reporting to the Minister for Land & Water Conservation under the Native Vegetation Conservation Act. I served as a member of the Regional Vegetation Planning Subcommittee, which amongst other matters, reviewed draft Regional Vegetation Management Plans and Codes of Practice for activities such as native forestry and timber plantations. I was particularly involved in reviewing and recommending amendments to the Code of Practice for plantation forestry. I resigned due to my relocating to Victoria.
- Nature Conservation Council representative on the former **Southern Catchment Management Board** (June 2000 - March 2001). I resigned due to relocating to Victoria. I expressed my dissatisfaction with the design of the catchment boards and recommended to the Minister that they be replaced with the Catchment Management Authority model used in Victoria. The Boards were later replaced with such Authorities.
- Nature Conservation Council representative on Baulkham Hills and Hornsby-Ku-ring-gai **District Bushfire Management Committees** (1995-2001).
- Australian Conservation Foundation representative on the former **Environmental Works Community Audit Committee** reporting to the Minister for Environment in relation to the Special Environment Levy imposed by the then Water Board (1993-5). I completed my term when the Committee concluded its business and dissolved upon acceptance of its final report by the Minister.

Tertiary qualifications & titles

Adjunct Research Fellow

School of Philosophical, Historical & International Studies, Monash University, 2014-16

Doctor of Philosophy

Fenner School of Environment & Society, The Australian National University, 2004-7

The research was undertaken in the transdisciplinary Human Ecology Program and covered fields such as ecological philosophy, ecotheology, environmental policy-making, policy evaluation, organisational change, and critical systemic analysis. My thesis was passed unanimously and unamended by one Australian and two USA-based professors. I was awarded a $10,000 Publication Fellowship by the Fenner School and have since published aspects of my research.

Master of Environmental Planning

Macquarie University Grad. Sch. Env., 1994-96

This course included environmental law and politics, community involvement in planning, environmental education, development approval processes, urban planning, EIA, environmental science/fieldwork and heritage management. The dissertation component involved a pioneering report on the significant flora of the Greater Cattai Region (Cattai subcatchment) in north-western Sydney and led to my being offered employment with the NSW NPWS to design and manage a biodiversity survey of western Sydney.

Bachelor of Science

Macquarie University, 1990-93

My degree majors are Resource and Environmental Management, Land Management, and Plant Biology/Ecology.

Graduate Certificate of Research Information Literacy

The Australian National University, 2004-7

This course included advanced word processing, citation management, literature gathering (including on-line literary databases and other Internet sources), on-line publishing, presentation software, and thesis production.

Professional memberships

- Founding member of the Ecological Consultants Association of New South Wales (did not renew due to my relocating to Victoria and later to the ACT).
- Member of the NSW Environmental Defenders Office (EDO) Scientific Advisory Service (continuing).

Threatened biota experience

The following threatened plant species and populations and threatened ecological communities (TECs) have been engaged with in the various forms and processes listed below. The list is not complete, and some processes are on-going. I also successfully nominated three Key Threatening Processes under the TSC Act: Bushrock Removal; Clearing of Native Vegetation; Competition from European Honey Bee.

Species / population	Work conducted
Acacia bynoeana	Fieldwork, research, successful nomination, monitoring, advice to authorities, expert witness, rediscovered lost population, documented new population near range limit, PAS2 review, SOS review panel, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
A. gordonii	Fieldwork, successful nomination, advice to NPWS, PAS2 review, SOS research and monitoring program (fire ecology, BMtns NP), review and amendment of BioNet dataset.
A. prominens	Successful nomination of Endangered Population
A. pubescens	Fieldwork, contribution to Recovery Plan, confirmed disjunct southern populations, nominated population, PAS2 review, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Ancistrachne maidenii	Fieldwork, research, successful nomination, advice to NPWS, CAM review
Asterolasia elegans	Fieldwork, species profile, advice to Council and NPWS
Baloskion longipes	Research linked to *Carex klaphakei*, review of BioNet records, advice to OEH
Boronia deanei	Research, SOS review, CAM review, advice to OEH
Bossiaea oligosperma	SOS fieldwork, review of records (NW population), report to OEH, establishment of monitoring plots in Yerranderie SCA
Callistemon linearifolius	Fieldwork, research, successful nomination, advice to RMS and NPWS, PAS2 review
Callistemon megalongensis	Co-described new species, successful nominations (listing then upgrade), fieldwork, advice to Council and OEH, PAS2 review, SOS monitoring program (OEH, BMCC, on-going)
Callistemon purpurascens	Described new species, fieldwork, successful nominations, advice to Council and OEH, SOS monitoring project (2018 on-going)
Calotis glandulosa	Fieldwork (new and extended populations, Kosci NP), CAM review
Calotis pubescens	Fieldwork (new population, Kosci NP), CAM review
Carex klaphakei	SOS research project and recommendation for monitoring; resolved errors in BioNet records

Species / population	Work conducted
Commersonia prostrata	PAS2 / PKF research, fieldwork, advice to NPWS and OEH, documentation and monitoring of new and known populations for Forestry Corp, designed recovery actions for populations in Wingello and Penrose SFs
Cullen parvum	Fieldwork, located new NE population, report to NPWS
Dampiera fusca	Research, fieldwork, successful nominations, monitoring program for ACT Parks & Conservation, advice to NPWS and OEH, CAM review
Darwinia biflora	Fieldwork, research, contributor to Recovery Plan, PAS2 review, review and amendment of BioNet dataset.
Darwinia glaucophylla	Fieldwork, research, successful nomination, advice to NPWS, PAS2 review
Darwinia fascicularis ssp. *oligantha*	Fieldwork, research, successful nomination of population
Darwinia peduncularis	Research, successful nomination, CAM review
Dillwynia tenuifolia	Fieldwork, research, successful population nominations, advice to OEH
Epacris purpurascens var. *purpurascens*	Fieldwork, research, nomination, new SW range limit (Nattai NP), advice to NPWS/OEH
Eucalyptus aggregata	Research, successful nomination of species and population, fieldwork (Wingecarribee Shire) and advice to Council and OEH, CAM reviews
E. aquatica	Fieldwork, advice to Council and Forestry Corporation
E. sp. *Cattai*	Successfully argued for recognition of this entity as a new species, successful nomination, fieldwork, PAS2 review, advice to OEH, SOS project panel
E. kartzoffiana	Fieldwork, research, expert witness
E. macarthurii	Fieldwork, research, successful nominations, advice to Council and OEH
E. parvula	Fieldwork (Wadbilliga NP), CAM review
E. pulverulenta	Fieldwork (Bredbo Hills), CAM review
Galium australe	PAS2 research, recommended taxonomic review of most records in NSW based on Herbarium assessment, advice to OEH, CAM review
Grevillea juniperina ssp. *juniperina*	Fieldwork, research, advice to OEH (Colebee NR offset site)
Grevillea molyneuxii	Fieldwork, advice to OEH for CAM review
Grevillea parviflora ssp. *parviflora*	Fieldwork, research, expert witness, review and amendment of BioNet dataset.
Grevillea parviflora ssp. *supplicans*	Fieldwork, research, nomination, advice to NPWS
Grevillea raybrownii	Fieldwork, research, nomination and advice to NSWSC – listing pending
Gyrostemon thesioides	Successful nomination
Helichrysum calvertianum	Fieldwork, research, nomination, advice to NSWSC – listing pending
Hibbertia fumana	Research, minor fieldwork, expert witness
H. incana (syn. *superans)*	Successful nomination of population then species
H. praemorsa	ROTAP, researched, fieldwork (informal)
H. puberula ssp. *furcatula*	Fieldwork (incidental) documenting new occurrence, advice to OEH/NPWS
H. puberula ssp. *puberula*	Research, minor fieldwork with R. Miller, expert witness
Homoranthus binghiensis	CAM review (recommended changing to CE)
Keraudrenia corrolata var. *denticulata*	Successful nomination of population
Lasiopetalum joyceae	Fieldwork, research, successful nomination, species profiling for Council and NPWS, PAS2 review

Species / population	Work conducted
Leptospermum deanei	Fieldwork, research into hybridization with *L. trinervium*, advice to RBG, Council, OEH
Leucopogon fletcheri ssp. *fletcheri*	Fieldwork, research, successful nomination, advice to OEH and NPWS
Melaleuca deanei	Research, fieldwork, successful nominations, advice to NPWS/OEH and species profile for Council, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Olearia cordata	Fieldwork and report to NPWS, PAS2 review
Persoonia acerosa	Fieldwork, PAS2 review, SOS monitoring plots, advice to Council and OEH
Persoonia bargoensis	Fieldwork, research, successful nomination, PAS2 review, CAM review, review and amendment of BioNet dataset.
Persoonia hirsuta	Fieldwork, research, nominations of species and population, PAS2 review, review and amendment of BioNet dataset.
Persoonia glaucescens	Fieldwork, nomination, report to NPWS, PAS 2 review, CAM review, review and amendment of BioNet dataset.
Persoonia marginata	Fieldwork and report to OEH, CAM review
Persoonia mollis ssp. *revoluta*	Fieldwork, research, advice to OEH and Forestry Corp., nomination as Vulnerable - listing pending
Persoonia nutans	Fieldwork, nomination, advice to OEH, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Phyllota humifusa	PAS2 fieldwork and research; advice to NPWS, OEH, Council, Forestry Corp (monitoring plots, reduced APZ width), review of BioNet dataset.
Pimelea curviflora var. *curviflora*	Fieldwork, research, successful nomination, advice to OEH
Pomaderris brunnea	Incidental fieldwork and documentation of new populations and range extension; review and amendment of BioNet dataset.
P. cotoneaster	Fieldwork, research, advice to Council, NPWS, OEH, liaise with ANBG seed collectors, CAM review
P. sericea	PAS2 research (review of records and habitat), recommended consideration of Presumed Extinct or at least CE
Pultenaea elusa	PAS2 research (review of records and habitat), recommended Presumed Extinct
P. glabra	SOS fieldwork and monitoring plots. Review of Mts Wilson/Irvine records resulted in these being reallocated to an undescribed species given the interim name, *P. monticola*.
P. parviflora	SOS fieldwork and report to OEH (Colebee NR offset site); review and amendment of BioNet dataset.
P. pedunculata	Fieldwork, research, expert witness, CAM review
Solanum armourense	PAS2 fieldwork, research, report, advice to OEH, CAM review
S. celatum	Fieldwork, research, new populations (new range limit and habitat), advice to OEH, CAM review
Tetratheca glandulosa	Fieldwork, PAS2 review, advice to OEH and Cwlth DEE re conservation status
Triplarina nowraensis	SOS fieldwork, review of BioNet records, advice to OEH/NPWS, establishment of monitoring plots
Zieria involucrata	Fieldwork, input to Recovery Plan, CAM review
Zieria murphyi	Liaise with ANBG, fieldwork, advice to OEH

Threatened Ecological Communities (TECs)

My work for OEH in reviewing all NSW and EPBC Act TECs in the State has given me at least some familiarity with most of these entities and builds on already-strong knowledge of some. I have also been an expert witness in cases involving some of these communities – some entailing basic reviews and advice, and others involving in-depth considerations. All of the EPBC Act parallel listings are not included here unless I was involved in a particular nomination:

Ecological community	Nature of engagement
Blue Gum High Forest	Successful nomination, expert witness
Blue Mountains Basalt Cap Forest	SOS panel
Blue Mountains Shale Cap Forest	Successful nomination, SOS panel
Blue Mountains Swamps	Fieldwork, mapping, advice to BMtns Council, modelling
Castlereagh Scribbly Gum Woodland	Successful nomination, advice to DEE re Cwlth listing, expert witness
Cooks River / Castlereagh Ironbark Forest	Advice to DEE for EPBC Act listing
Cumberland Plain Woodland	Correction of OEH mapping, fieldwork, assessments, advice to Councils and NPWS
Eastern Suburbs Banksia Scrub	Major review for DEE Recovery Plan update, advice to OEH
Elderslie Banksia Scrub Forest	Major review for DEE Recovery Plan, SOS panel
Illawarra Lowlands Grassy Woodland	DEE review panel for EPBC Act listing
Lowland Grassy Woodland & Forest of SE Corner Bioregion	Successful nomination
Maroota Sands Swamp Forest	Successful nomination, SOS panel
Melaleuca armillaris Tall Shrubland	fieldwork, mapping, advice to OEH
Montane Peatlands & Swamps	Fieldwork, modelling and mapping, advice to OEH
Mount Gibraltar Forest	Detailed review for modelling and mapping, and advice about revised listing, advice to DEE re Upland Basalt Eucalypt Forest inclusion of NSW TECs
O'Hares Creek Shale Forest	Research and review for modelling and mapping
Pittwater & Wagstaffe Spotted Gum Forest	Successful nomination
Riverflat Eucalypts Forest on Coastal Floodplains	Successful nomination (component), research, modelling and mapping (limited extent)
Robertson Basalt Tall Open-forest	Modelling and mapping, advice to NSW SC
Robertson Rainforest	Modelling and mapping
Shale/Gravel Transition Forest	Mapping, TEC review
Shale/Sandstone Transition Forest	First to describe this concept c. 1996 based on Masters research. Formally published as a concept in NPWS (1997, UBBS). Successful nomination, research, major review and advice to DEE for EPBC Act listing, modelling and mapping
Southern Highlands Shale (Forest &) Woodland	Major contributor to DEE listing, drafting of Listing and Conservation Advices, advice to OEH about revision of NSW listing, modelling and mapping. Contracted to prepare listing for upgrade to CE.
Subtropical & Temperate Coastal Saltmarsh (EPBC Act)	Funded to prepare successful nomination
Sun Valley Cabbage Gum Forest	Successful nomination, mapping, advice to Council, SOS project panel
Swamp Sclerophyll Forest on Coastal Floodplains	Allied major research project cited in the Final Determination, TEC review (gap analysis)

Ecological community	Nature of engagement
Sydney Turpentine Ironbark Forest	Successful nomination, mapping, advice to Councils and to OEH/SC about revision
Tablelands Basalt Forest	Research, expert witness, advice to OEH about revision, modelling and mapping
Tablelands Snow Gum…Grassy Woodland	Fieldwork documenting new occurrences, modelling and mapping, advice to OEH
Upland Basalt Eucalypt Forest (EPBC Act)	Major contributor to DEE listing of this composite community that includes several NSW TECs. Draft Listing and Conservation Advices
Western Sydney Dry Rainforest and Moist Shale Woodland	SOS panel, TEC review

Publications / presentations / media

Ecology / conservation / environmental law & policy / ecological ethics

Refereed journal articles

Douglas, S.M. and Wilson, P.G. 2015. "Callistemon purpurascens (Myrtaceae): a new and threatened species from the Blue Mountains region of New South Wales, Australia". *Telopea* 18: 265-272

Douglas, S.M. 2000. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link". *Australasian Journal of Natural Resources Law & Policy*, 6(2)

Conference proceedings

Douglas, S.M. 2003. "Ecological offsets – what's the idea?" in Morrison, C. (Ed.) *Urban bushland and remnant vegetation: toolkits for a sustainable future – conference proceedings*. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 2001. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link"; in Newton, S. (Ed.) *Bushland or buildings? The dilemma for biodiversity conservation in urban areas* – conference proceedings. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 1998. "The Threatened Species Conservation Act; a consultant's perspective" in *On the brink; your bush, their habitat, our Act.* Threatened Species Network, Nature Conservation Council of NSW, and Environmental Defenders Office, Sydney

Book chapters

Douglas, S.M. 1999. "Development & Sydney's threatened biota" in *Greenprint for Sydney: an environmental strategy for the 21st Century*. Total Environment Centre, Sydney, NSW

Professional reports

Douglas, S.M. & Anderson, J.R.B. 2002. Eucalyptus robusta *(Swamp Mahogany) communities and their conservation status in New South Wales*. Swamp Mahogany Project, Central Coast Community Environment Centre, Newcastle University Campus, Ourimbah

Douglas, S.M. 1997. "Local Government Area Reports: Baulkham Hills Shire", in James, T. (Ed.) *Urban Bushland Biodiversity Survey* (Stage 1, Western Sydney) Flora Appendices Vol. 2. NSW National Parks & Wildlife Service, Hurstville

Edited but not refereed publications

Douglas, S.M. 2014. "When biosecurity is threatened from within: the case of the native environmental weed, Pittosporum undulatum". *Australasian Plant Conservation*, 23(2)

Douglas, S.M. 2009. "Black Gum: a threatened tree of upland New South Wales and Victoria." *Australasian Plant Conservation*, 17(4)

Douglas, S.M. 2009. "Species profile and monitoring of Dampiera fusca". *Australasian Plant Conservation*, 17(3)

Douglas, S.M. 2006. "Endangered plant discovered" (St. Clements Retreat, Galong). *Biodiversity Research Newsletter*, 20, p.4, July, NSW Department of Environment & Conservation, Hurstville.

Douglas, S.M. 2006. "Endangered plant discovered (*Cullen parvum*) at St. Clements Retreat, Galong". News of Friends of Grasslands, November-December, p7

Douglas, S.M. 2005. "Phoenix flora: a post-fire discovery in the ACT". *Australasian Plant Conservation*, 13(3)

Douglas, S.M. 2004. "Phoenix flora" (re Dampiera fusca). *Journal of the Australian Native Plant Society Canberra Region*, 14(2), December

Douglas, S.M. 2003. "Mysteries of the Megalong Valley: another rare plant for the Blue Mountains." *Australasian Plant Conservation*, 12(1)

Douglas, S.M. 2001. "Land of the living dead – tree decline in urban areas". *Environment NSW* (newsletter of the Nature Conservation Council of NSW), September

Douglas, S.M. & Newton, S. 2000. "Bushland weeds – more on native weeds". *Environment NSW*, December

Douglas, S.M. 2000. "Regional Parks". *National Parks Journal* Vol. 44 (5 & 6) (journal of the National Parks Association of NSW)

Douglas, S.M. 1996. "Community biodiversity surveys". *National Parks Journal*, 40(3)

Douglas, S.M. 1996. "Mapping our urban bushland". *The Gardens*, Spring (journal of the Royal Botanic Gardens, Sydney)

Douglas, S.M., Bolesic, T. and Ware, K. 1994. "Healing the Hawkesbury: start with bushland protection". *National Parks Journal*. 38(4)

Public media coverage

2004, November 6. "Bright flowering spot after fire" - discovery of Dampiera fusca – a new genus and nationally significant species for the ACT and a new northern limit for the species. *Canberra Times*

2004. Live-to-air interview re discovery of *Dampiera fusca* in Namadgi NP, *ABC 666* AM Radio, Canberra

1996. Live to air interview re NPWS Urban Bushland Biodiversity Survey, *ABC 2BL* AM Radio, Sydney

1996. Pre-recorded TV segment re discovery of several nationally threatened plants in the one location during surveys for NPWS UBBS. *Totally Wild* program, Channel 10, Sydney

Consultancy projects

Short descriptions of the many larger projects that I have been involved in are available at http://ecologicalsurveys.net/?page_id=10, and a list of smaller projects is at http://ecologicalsurveys.net/?page_id=14

Voluntary and other works

- Assist **International Union for the Conservation of Nature (IUCN)** with a review of the conservation status of *Proteaceae* in eastern Australia (Melbourne, 2019).
- Assist **NSW Environmental Defenders Office** with a review of NPWS monitoring proposals to assess the effects of permitting horse riding in declared Wilderness areas (Kosciusko National Park) (2014).
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Noxious Weeds Act 1993 (in 2011)
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Threatened Species Conservation Act 1995 (in 2010)
- Assist discoverers (**Blue Mountains Bushcare**) of a previously undescribed *Epacris* species (*E. apungens* Coleby & Brown) in south Leura to prepare an article for the journal, *Telopea*, describing this species and its ecology
- Assist **NPWS** with a search for the ultra-endemic and rare rainforest plant, *Thismia clavarioides*, in Morton National Park (2010)
- Expert panel member assisting **Hawkesbury-Nepean CMA** with its Draft Climate Change Vulnerability Assessment for selected threatened ecological communities of the NSW Southern Highlands (2010)
- Assist PhD student, David Field (**University of Wollongong and CSIRO**) with information about the ecology, distribution, and conservation status of *Eucalyptus aggregata* (Black Gum) (2007)
- Fieldwork assisting with group preparation of vascular plant species lists in numerous NPWS and ACT Parks reserves in the Southern Tablelands area. **Australian Native Plants Society** (2003-2007)
- Searches for *Euphrasia scabra* (critically endangered) in Packers Swamp and Nunnock Swamp. Discovered new population (3rd in NSW) in unnamed swamp, SE Forests National Park. **Friends of Grasslands** (2004)
- Assistant part-time editor of "*Danthonia*" (now *Australasian Plant Conservation*), the journal of the **Australian Network for Plant Conservation** Inc., Canberra (2002-2003)
- Assist PhD student, David Clunas (**University of Wollongong**) with review of his research in the ecology of the nationally Rare, *Pultenaea villifera* var. *villifera* (2002)
- Provide technical assistance to four final year undergraduate Environmental Science students (**Australian Catholic University**) working in Marramarra National Park, (c. 2000)
- Discovery of and subsequent surveys for *Persoonia hirsuta* ssp. nov. 'Yengo NP'. **NPWS/RBG**
- Vascular flora and fauna (microchiropteran bats) surveys within Pilliga Nature Reserve. **NPWS** Coonabarabran
- Supervisor for undergraduate dissertation, "Environmental rehabilitation of Peats Crater and Peats Bight in Muogamarra Nature Reserve" (D. Maestri), **Southern Cross University** (1997)
- Co-supervisor for undergraduate dissertation "Riparian Vegetation of upper Cattai Creek" (D. Buckle). **Southern Cross University** (1997)
- Preliminary flora assessment for proposed subdivision and development; Red Gum Avenue, Pennant Hills. The bushland area was subsequently added to Berowra Valley Regional Park. **Friends of Berowra Valley Bushland**

- **NSW National Parks Association** (NPA) Biodiversity Audit, proposed Bargo River National Park. Team Leader, Vegetation - threatened flora
- Guided interpretive walk of Fred Caterson Reserve. **Cattai Catchment Management Committee**
- **NSW NPA** audit of Greater Sydney proposed conservation reserves and additions - assistant and author of NW Sydney reserve proposals
- **NSW NPA** Biodiversity Audit of the proposed Dyarrabin Nature Reserve (~2000 ha) - Project Co-ordinator
- **NSW NPA** Proposal for the creation of Dyarrabin Nature Reserve; revised submission and report of the second NPA Biodiversity Audit
- Preliminary flora study of Crown lands (Functional Area 1), Cattai Ridge Road, Halcrows Road, Hillside/Glenorie; submission to Director NPWS and to Baulkham Hills Council. **NSW NPA**
- Flora survey of Morans Rock Crown lands for proposed addition to Wollemi National Park. **NSW NPA**
- Proposed Welcome Reef Dam (Shoalhaven River north of Braidwood) - assist with flora and fauna surveys. **NSW NPA**. Much of the area is now within Nadgigomar Nature Reserve
- Flora survey of surplus Department of Education lands at Ellerman Park, Round Corner. The local community proposed that the area become a reserve to protect a critically endangered plant community present on the site. **Friends of Ellerman Park**
- Flora survey of Crown lands at South Maroota for proposed Crescent Reach Nature Reserve (later declared as the Maroota Ridge State Conservation Area), **NSW NPA**
- Calangara Nature Reserve Proposal in Kenthurst. Survey and report to **NSW NPA**
- Preliminary Survey of bushland in Holland Reserve, Glenhaven
- Survey of Crown Reserve (now part Scheyville NP), Pitt Town; report to **NSW NPA**

Expert report – *Persoonia nutans*

Expert report for *Persoonia nutans* (Nodding Geebung), Dr Steven Douglas, February 2019

ECOLOGICAL
SURVEYS & PLANNING

Expert Report For

Persoonia nutans

(Nodding Geebung)

Strategic Assessment for the Cumberland Plain Conservation Plan

Greater Macarthur, Greater Penrith to Eastern Creek, Wilton, and Western Sydney Aerotropolis Growth Areas

Prepared for NSW Department of Planning & Environment, February 2019

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1. Introduction

1.1 Purpose of the Expert Report

An Expert Report may be prepared under s.6.5 of the Biodiversity Assessment Method (BAM) in place of undertaking a threatened species survey of sufficient extent, intensity and duration as would otherwise be necessary to comply with the BAM. Use of an Expert Report may be beneficial where it is highly unlikely that a species may occur within a study area; where survey cannot meet BAM specifications; and/or the reliability of detecting the species is low. In respect of *Persoonia nutans*, insufficient survey extent; constraints on the effectiveness of survey; and unreliability of detection due to aspects of the species' ecology are the primary reasons for preparing an Expert Report.

The purpose of this Report is to provide an assessment of the current status and conservation requirements of *Persoonia nutans* within the four priority growth areas of Greater Macarthur (GMGA); Wilton (WGA); Greater Penrith to Eastern Creek (GPECGA); and Western Sydney Aerotropolis (WSAGA)to determine whether:

a) The species is unlikely to be present and would thus require no further assessment; or
b) The species is known or likely to be present, and the Expert Report must provide estimates of potential habitat within growth areas and development footprints as part of the biocertification process.

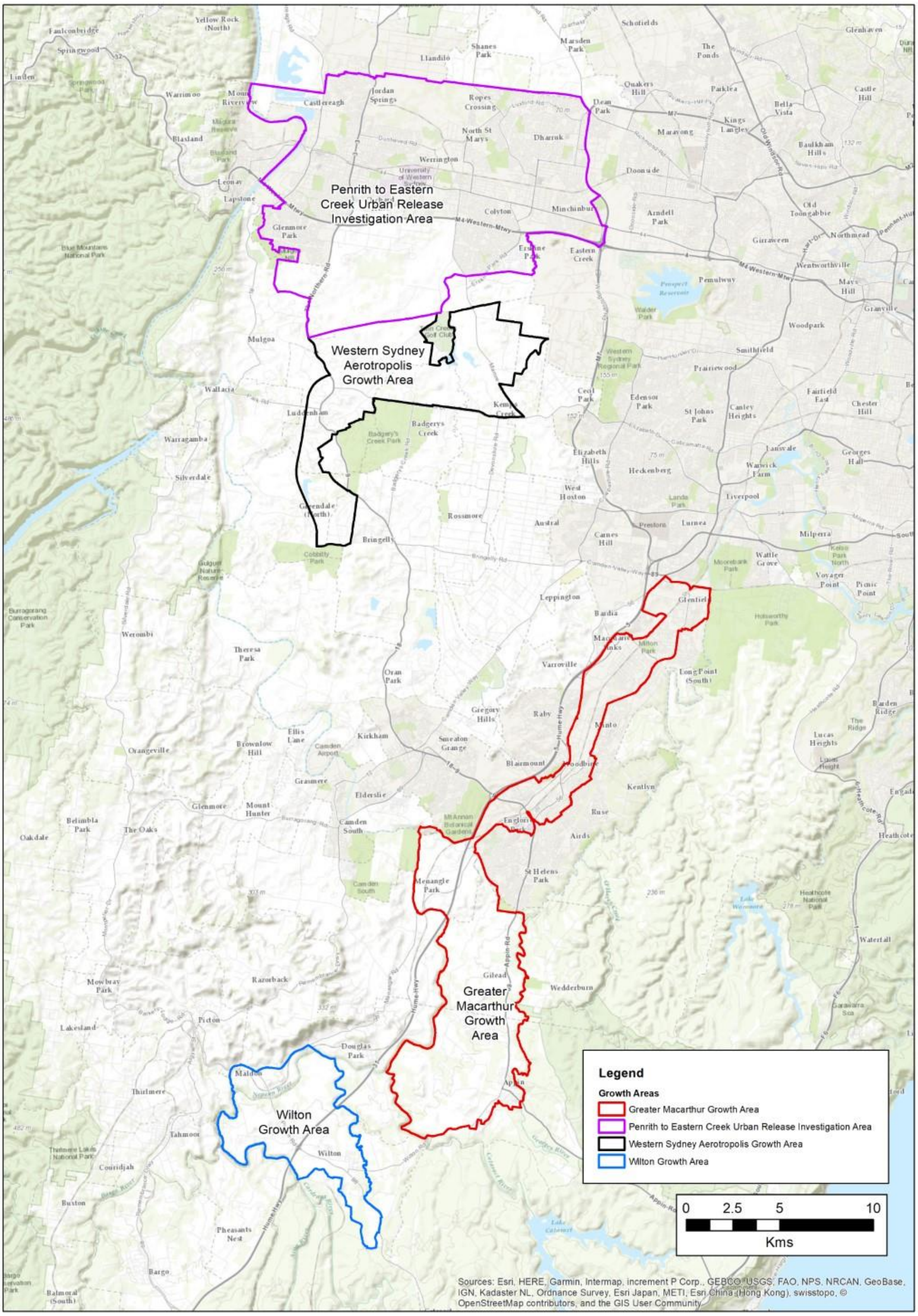
1.2 Project context

The NSW Government is identifying areas for future urban land use and associated infrastructure in western Sydney. The four priority growth areas are all located in the Cumberland Subregion under the Interim Biogeographic Regionalisation for Australia (IBRA) (SEWPaC, 2012).

As part of the planning for these areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify land use outcomes. A strategic assessment of this Plan is underway, and this Expert Report will assist in determining the extent and quantum of impacts of the proposed urban growth on *Persoonia nutans*.

Persoonia nutans (Nodding Geebung) with flower buds. © S. Douglas

1.3 Study area



Map 1. Growth Areas subject to this Expert Report

Greater Penrith to Eastern Creek Growth Area (GPECGA)

A large portion of this Growth Area is already urbanised, with several areas of industrial land use. Significant rural and peri-urban areas remain in the central north, the centre, and the southwest. Large areas of remnant vegetation are present in the far north (former Australian Defence Industries site, now in part Wianamatta Regional Park), and the Orchard Hills Defence facility. Mining of alluvium for sand and soil continues in the far northwest of the area in the Penrith Lakes locality.

The area has been extensively cleared because of its relatively arable terrain, based mainly on shale and alluvium. Some of the remaining vegetation is associated with the much less arable to infertile Castlereagh Forests & Woodlands and its older, leached and mineralised alluvium and shale-derived soils. Strips of remnant vegetation are present along some of the larger watercourses such as Eastern and South Creeks. Significant parts of the study area are or were flood-prone, and this has influenced the retention of vegetation in some affected areas.

Western Sydney Aerotropolis Growth Area (WSAGA)

This Growth Area adjoins the Greater Penrith to Eastern Creek area, extending south to the locality of Greendale, west of Bringelly. It is currently largely rural, with villages at Luddenham and Kemps Creek. Most rural areas are pastoral, but there are significant areas of more intensive rural use, including poultry and egg production, a large dairy and associated fodder cropping, and some market gardens and enclosed fruit and vegetable production. Quarrying occurs at the localities of Badgerys Creek and Kemps Creek.

This Growth Area is extensively cleared but retains native vegetation in areas where rural uses were constrained by steeper terrain, flooding along streams, or unsuitable soils.

Greater Macarthur Growth Area (GMGA)

The GMGA occurs in southwestern Sydney on predominantly shale soils that have been heavily cleared for agriculture and urban or industrial use. The northernmost section has long-established urban and commercial / industrial land use, while the southern section is largely rural (pastoral, minor cropping), with some villages and primarily subsurface mining (e.g. coal and coal seam gas). It extends from urban Glenfield in the north, to the rural village of Appin in the south.

In the southernmost section, geological uplift and erosion have exposed infertile sandstone terrain along gullies and valleys. Much of that terrain remains naturally vegetated because it is unsuited to agriculture, however it occupies only a small percentage of the total area of this heavily-cleared region. Between the infertile sandstone valleys and the relatively arable shale plateau and hills is a geological and ecological transition zone. Whilst much of the vegetation of the shale terrain has been cleared, a greater area of vegetation remains on the transition zone, primarily in the south. Both the shale and transition zones support Critically Endangered ecological communities that are potential habitat for some threatened plant and animal species.

Wilton Growth Area (WGA)

The Wilton Growth Area is the most southerly of the four Western Sydney Growth Areas dealt with in this Report. It extends from the village of Douglas Park in the north, to the village of Wilton in the south. It is primarily rural (pastoral) area with some more intensive agriculture, significant but mostly underground mining (primarily coal), and some long-established villages. The Hume Motorway dissects this Growth Area.

The pattern of clearing and vegetation retention is broadly similar to that of Greater Macarthur, with the majority of remnant vegetation associated with infertile but biodiverse sandstone gullies and the Nepean River gorge, and with associated transition into the heavily cleared shale landscapes.

1.4 Justification for the use of an Expert Report

An Expert Report for *Persoonia nutans* is required as part of the threatened biota assessment for the Cumberland Plain Conservation Plan because:

1) Survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH, 2016) for field traverses due to limitations on land access, particularly in the GMGA;
2) Survey quality was constrained by drought conditions. Whilst this species is perennial, under sufficiently severe drought and associated total grazing pressure (livestock, if relevant; native species; feral species), it can be reduced to surviving as seed bank. Drought was a major limitation on survey effectiveness in this instance. A known location of another threatened species that can occur with *P. nutans* was visited by fellow botanist, Robert Miller, but could not be detected, even though the habitat was still in place. This suggests that the surveys for both species will have under-detected them because of drought and associated increased grazing/browsing pressures;
3) Survey effectiveness was further constrained by parts of the study area having been long-unburnt. This can create an unnaturally dense shrub layer that limits access and that also creates conditions likely to suppress the species such that it may retreat to the seedbank until favourable conditions return (post-fire or equivalent disturbance).

Surveys associated with biocertification of the study areas and earlier projects in those areas have been insufficient to reliably determine the presence and extent of the species. An Expert Report is required to provide an assessment of the likely presence, location, and significance of occurrences of the species in those areas.

1.5 Credentials of expert

I have worked as an ecologist since the mid-1990s, primarily in the Greater Sydney region, but also in the ACT, Central Coast, southern NSW (coast, tablelands and slopes), throughout Victoria and into eastern South Australia. I have primarily been self-employed, with a mix of government, private, and corporate clients, and have also worked as a subconsultant to larger firms, including two university-based consultancies. I have also worked directly for the NSW NPWS, and more recently for OEH (Native Vegetation Information Science). I was approved by OEH as a species expert for *Persoonia nutans* in November 2018. A summary of my credentials as required under the BAM is provided below as Table 1. I was approved by OEH as a species expert for *Persoonia nutans* under s.6.5 of the BAM in November 2018.

Table 1. Credentials of Dr Steven Douglas as Expert in relation to *Persoonia nutans*

BAM section	BAM requirement	Details
s.6.5.2.8 (g)	Name of expert	Dr Steven Douglas
s.6.5.2.3 (a)	Expert's qualifications	Bachelor of Science (Plant Ecology, Land Management, Resource & Environmental Management), Macquarie University, 1993. Master of Environmental Planning, Graduate School of Environment, Macquarie University, 1996. Doctor of Philosophy, Australian National University, 2008. Graduate Certificate of Information Literacy, ANU, 2006. BAM Accredited Ecologist, 2018.
s.6.5.2.3 (b)	History of experience in ecological research and survey method for the relevant entity	Review of BioNet and incorporated NSW Herbarium database records of *P. nutans* (DPE, 2018). Provision of expert witness evidence in relation to *P. nutans* (QUBE proposal, Moorebank; included assessment of adequacy of biobanking arrangements) L&EC 2017/81889 (2017-18). Fieldwork and advice to NPWS in relation to the species' management profile (c. 1997). Review of historic outlying collection record of the species from Hornsby Shire as part of Hornsby Shire Threatened Biota Management Plan (record deemed to be a result of taxonomic changes not reflected in BioNet/Atlas at that time, subsequently reassigned) (1999). Contributed to the update of the 1996 Draft Recovery Plan. Research and/or successful nominations of allied *Persoonia* species (*acerosa*, *hirsuta*, *glaucescens*, *bargoensis*, *oxycoccoides*, *marginata*), under TSC Act and EPBC Act (1998-onwards). Some work commissioned by NPWS / DECCW / OEH. Plot-based monitoring of allied *P. acerosa* (Blue Mountains City Council for OEH) (2015 on-going). Numerous historic surveys in northwest and western Sydney including Hawkesbury, Blacktown, Liverpool and Penrith LGAs (1994-2000) as evidenced by BioNet and NSW Herbarium records. Particular attention paid to Castlereagh, Agnes Banks and Windsor Downs Nature Reserves and associated proposed extensions (1994-6). Project Manager, Urban Bushland Biodiversity Survey (Western Sydney), including surveys and reporting (1995-7).
s.6.5.2.3 (c)	Resumé detailing projects pertaining to the survey of the relevant entity	See Appendix 1. Relevant surveys and works listed above. Minor survey of predicted habitat at locality of Kemps Creek for DPE Expert Report. Meandering transect used.

s. 6.5.2.3 (d)	Employer's name and period of employment (if relevant)	Self-employed ecological consultant, 1996 to present (continuous other than for periods of study). Employed by OEH as contracted staff from November 2015 to July 2018 (Wingecarribee Shire vegetation map, South Coast Regional vegetation map, Review of mapping issues for TECs).
s.6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant entity	Consulted by OEH Authorised Officer regarding prospective surveys and review of conservation status for *Persoonia nutans* (2017). Consulted by OEH in major review of numerous threatened flora and communities as part of an update of BioBanking Tool (2006). Approved as a BAM species expert for *Persoonia nutans* by OEH in November 2018. Recruited by IUCN to assist in the Eastern Australia conservation status review of *Proteaceae* for the Red List publication of threatened species (February 2019)

2. Species information

2.1 Description

Persoonia nutans is "An erect to spreading shrub to 2.5 m high [rarely to 3.0 m] with hairy young branches. Leaves are well separated on mature stems, linear, 1 - 3 cm long, 1 - 1.8 mm wide, usually flat, with recurved margins. They are sparsely hairy when immature, and hairless when mature. Flowers are yellow, pendant to drooping on a stalk to 12 mm long… The species is similar to *P. bargoensis*, which is found in the [far] southern part of the Cumberland Plain and nearer the Southern Highlands" (OEH, 2017).

The plant is quite variable in height depending on the time since fire. In long unburnt habitat, it is a substantial but spindly shrub to 3 m high and ~ 2 m wide. More often, it is seen at ~ 1 m high and 0.5, 0. 75 m wide. Some variation in form is also likely as a result of different habitats e.g. how sandy, rocky or clayey the substrate.

2.2 Ecology

Emery & Offord (2018, Table 1) show that *P. nutans* has not been studied for breeding system, fruit set and/or seed germination. However, some information is available through earlier research. Flowering typically occurs from November to March (peak from December to January, NPWS, 2004), with sporadic flowering all year. Flowering is likely to be suppressed during drought, then intensified when drought breaks. The species is an obligate seed regenerator (NPWS, 1996; 2002a; 2004; DEC, 2005). Although listed as a short-lived species, much of the ecology is poorly known. Maturity is expected to be about 10 years. Plants appear to set abundant fruit. Seed is likely to be dispersed, after consumption of the fruit, by large birds such as currawongs and parrots, and large mammals such as wallabies, kangaroos and possums (OEH, 2017; DEC, 2005; Douglas, pers. obs.; McDougall, pers. comm., 2018; Weston, 2003, Auld et al., 2007, Barker & Vestjans, 1990). The introduced Honey Bee (*Apis mellifera*) may be a threat to the long-term viability of at least some *Persoonia* species because it is able to collect floral resources without pollinating the flower (Paton, 2000).

"Nothing is known of the longevity of the soil-stored seed bank of *P. nutans*. It appears germination is promoted, not only by fire, but also by physical disturbance (NPWS 1996; *sensu* Burcher *et al*., 2016). It is not known whether the seed bank is completely exhausted by a single fire. The extent to which germination occurs in the absence of disturbance is unknown, although observations during the 1996 survey (NPWS 1996) indicate such germination is likely to be rare" (DEC, 2005).

"Abundance at a site appears to be related to disturbance history. Sites with higher abundance also appear to be more disturbed" (OEH, 2017; *sensu* Burcher *et al*., 2016). However, too severe or too frequent disturbance would compromise or prevent one or more of germination, maturation, and reproduction, potentially resulting in local extinction. Too frequent fire has earlier been assessed as a significant threat to the species' viability (NPWS, 1996), and was consider the likely explanation for a low number of the species throughout much of the reserve (Burcher *et al*., 2016).

Similar to the Endangered *Persoonia hirsuta* mentioned by Emery & Offord (2018: 91), *P. nutans* can be found on disturbance margins such as edges of roads and trails, in former gravel (laterite) quarries, and in infrequently slashed perimeters of habitat, but is not restricted to them. Myerscough *et al.* (2000) suggest that soil disturbance may be a surrogate for the effects of fire, particularly in areas with low fire frequency. It also occurs in long-undisturbed habitat, but population demographics will be skewed to mature or senescent plants, as recruitment is strongly linked to fire or equivalent factors. Very long-unburnt sites will entail population decline as plants senesce and die, with recruitment being absent or minimal until suitable conditions return. Drought and subsequent return to average or above-average rain may have a similar, though likely weaker effect in this regard, as drought can suppress competing understorey species, with rains promoting recruitment in areas that have a reduced understorey cover.

Mature *Persoonia nutans*. © Ben Ford

2.3 Distribution and abundance

Persoonia nutans is restricted to western Sydney between Grose Wold in the northwest (apparently only 1 plant, collected twice); adjacent to the Georges River at Macquarie Fields in the south (Simmos Beach Reserve and environs); with the most easterly populations being near the Georges River at Pleasure Point, Voyager Point and East Hills (some in Council reserves), and at an industrial site in Villawood (very small and isolated). A naturally isolated, central population occurs at the locality of Kemps Creek, along with several other threatened plant species and ecological communities.

“The species has a disjunct distribution, with the majority of populations (and 99% of individuals) occurring in the north of the species range in the Agnes Banks, Londonderry, Castlereagh, Berkshire Park and Windsor Downs areas. Core distribution occurs within the Penrith, and to a lesser extent, Hawkesbury local government areas, with isolated and relatively small populations also occurring in the Liverpool, Campbelltown, Bankstown and Blacktown local government areas” (OEH, 2017; DEC, 2005; NPWS, 2004). Most of the outlying populations occur in distinctly different habitat to the others. “This species is restricted to part of the Sydney metropolitan area and most remaining populations are threatened by development for housing and mining” (Weston & Johnson, 1991).

As part of DPE’s obligations to assess the impact of proposed Growth Areas on threatened biota at State and Federal levels, I was commissioned by DPE to do a review of BioNet records for a subset of species deemed suitable for the modelling of potential habitat. This entailed addressing, where possible, a range of errors and inaccuracies. As part of this review, three records of *Persoonia nutans* were noted as being outside its accepted range. Two of these records plotted in the upper Cataract River catchment inland of the Illawarra Escarpment, west and southwest of Bulli, and were associated with upland swamps and at an elevation far higher than this species is known to occur. They were assessed as unlikely to be valid based on habitat, and they were unvouchered, meaning there was no specimen to support the identifications. They were determined to be a result of a data entry error (wrong species entered into the dataset). The third record was another unvouchered entry from incompatible habitat in Royal National Park, much further east than the species is known to occur. This record has since been invalidated, and likely relates to a common species that was misidentified or more likely, the wrong species code was entered into the dataset.

Persoonia nutans was probably never widespread across the Cumberland Plain, as it is largely confined to comparatively rare and localised Paleogene-Neogene age perched aeolian and alluvial sediments. In the north of its range, where the species can be locally abundant, these deposits are relatively extensive, though the aeolian deposits are much less so and have been extensively mined. Whereas in its central and southern habitats, the species occurs as relatively small and isolated populations because the associated deposits are far smaller in extent. Most of the outlying populations are associated with the quite different geology on the Wianamatta Shale / Hawkesbury Sandstone transition zone, usually near occurrences of Paleogene-Neogene alluvium. The Georges River (east) sites occur on a mix of Paleogene-Neogene alluvium and shale sandstone transition. The now extremely small Villawood population appears to be associated with an unmapped occurrence of Paleogene-Neogene alluvium based on descriptions of the associated vegetation. The Soil Landscape map shows that site as occurring on Wianamatta Shale, but the species is only associated with the edges of that geology where it adjoins Paleogene-Neogene alluvium or the Hawkesbury Group. Geology and Soil Landscape maps are produced at a coarse scale so are only ever indicative. Other ecological surveys in that vicinity have confirmed the presence of vegetation and geology indicative of Paleogene-Neogene alluvium (e.g. Ecological Surveys & Planning, 2013; Colin Gibson, pers. comm., 2018).

It is likely that the species' extent of occurrence prior to European settlement was broadly similar to its current extent, although there has very likely been some habitat removal in the north of the species' range due to mining (Agnes Banks area), rural and rural-residential land use (Londonderry area), and urbanisation (St Marys area). Habitat has been removed and degraded / fragmented in the central population due to clearing for schools, a sports field, rural and rural-residential uses, and some industrial uses. Habitat loss in the south is associated with industrial and housing activities, and potentially with military and infrastructural uses. The southernmost and much of the easternmost occurrences are partly within Council reserves but are threatened by the effects of adjacent urbanisation (*sensu* DEC, 2005; Douglas, pers. obs.). The isolated and tiny occurrence at Villawood is on an industrial site surrounded by long-established urban land use. It is conceivable that there were once other occurrences of the species between that location and the nearest populations near the Georges River to the south, but these were likely patchily distributed on small, unmapped occurrences of Paleogene-Neogene alluvium, and larger, mapped occurrences just to the west and southwest. There are no records of the species from those intermediate areas, but any associated populations could readily have been destroyed before any regard was given to the impacts of land uses on threatened flora.

Some habitat losses have been quantified in part by NPWS (2002b). Agnes Banks Woodland and Castlereagh Scribbly Gum Woodland are the vegetation communities that support the majority of *P. nutans*. These have been reduced to only 15.9% and 52.7% respectively of their pre-European settlement extent due mainly to mining and rural-residential land use. Assessment of more recent mapping by OEH (2013) indicates that these figures remain roughly correct. The mining of large areas that previously supported Agnes Banks Woodland would have resulted in the loss of considerable numbers of *P. nutans* (DEC, 2005).

NPWS (2002b) and DEC (2005) are now quite dated works, and more accurate vegetation maps now indicate that the PCT within the Threatened Ecological Communities with which the species is associated have been cleared as shown in Table 3 later in this Report. Data for the percentage of PCTs cleared is from the OEH BioNet Vegetation Classification Database (VCD, previously 'VIS') and relates to the extent of a PCT across its range, not just within the Cumberland Subregion. PCTs associated with *Persoonia nutans* are restricted to that area with the exception of 1081 and 1395 which extend to surrounding plateaux; and River-flat Eucalypt Forest, which extends along much of the coast and hinterland.

Known and inferred extinction of local populations are noted by DEC (2005). Further extinctions since 2005 are highly likely.

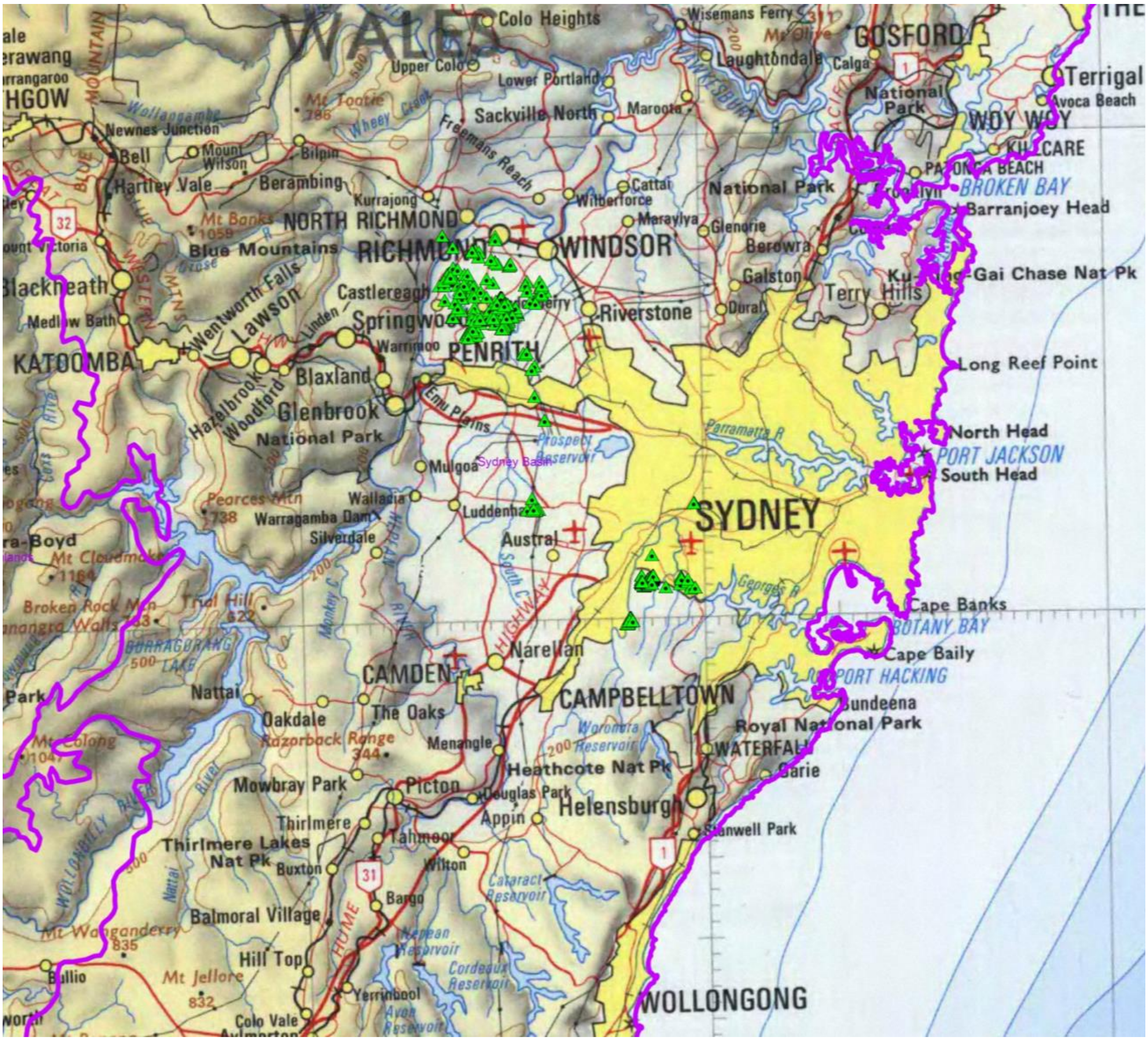
A small number of occurrences that are not documented in DEC (2005) are now known, including a substantial population just outside the far north of the GMGA at Moorebank. That area had been identified by DEC (2005) as potential habitat, but as it was then owned by the Department of Defence, it had not been surveyed. Most of that habitat is now set aside as a Biobanking reserve, but other parts of the site that included occurrences of *P. nutans* have been approved for clearing to accommodate an industrial facility. All of the Biobanking reserve was burnt severely in a suspected arson event in 2017. Whilst much of it was in need of fire to promote regeneration, the fire was extremely intense and extensive, and part of the habitat had been burnt only a few years earlier, meaning that some species would not have had time to regenerate and establish a new seed bank. The site remains at risk from too frequent fire as a result of it adjoining a main road, a railway, and suburban Wattle Grove, or conversely from too infrequent and/or too low intensity fire because of difficulties associated with fire management in such a compromised situation.

It seems likely that without significant intervention, the population at Villawood will not be viable in the long-term due to its isolation and very small population size, plus the nature of threats to what little remains of its habitat. Recent advice from botanists, Colin Gibson and Robert Miller (pers. comm., 2018), is that when the site was seen in 2014, only two plants remained – one healthy, one not, and two additional marked plants were dead – "nothing has been done to manage the site, which at that time, was in poor condition" – African Love Grass and Lantana are big problems. The associated and apparently contaminated ICI site was noted to "have been remediated [apparently in relation to chemical contamination] and bushland has been cleared."

The isolated Kemps Creek population occurs primarily on freehold tenure and is also apparently very small, though may prove to be larger were those habitats to be managed for conservation e.g. appropriately burnt then protected from weed invasion, feral animals, timber theft, and recreational damage. At present, the majority of habitat at this location is long unburnt, has an unnaturally dense regrowth tree layer, and is in slow decline. However, one young plant was recently observed north of the main habitat in an area disturbed by stocking with goats and then recent clearing for industrial land use. It occurs within a tiny linear remnant on that property's periphery and has some protection in the form of a s.88b covenant that sets aside this remnant to conserve threatened plant species and the threatened ecological community in which they occur. A Vegetation Management Plan was prescribed for that area as part of the development assessment, but the extent of threats from weeds and potential nutrient leachate from mulch stockpiled immediately adjoining the conservation area suggests that this Plan is not being implemented or is otherwise ineffective.

Across its range, the estimated area of potential habitat (i.e. suitable vegetation community and suitable soil type) for *P. nutans* is currently 5300 ha in the north of the species' range and 573 ha in the south of the species' range (DEC, 2005). "These values considerably overestimate the 'Area Of Occupancy' of *P. nutans* given that the species will not occupy all of these areas at a particular point in time, and some of this potential habitat may not be suitable habitat (e.g. may be subject to high fire frequency)" (DEC, 2005). These calculations also rely on the accuracy of regional-scale vegetation maps, which are themselves constrained by coarse scale geology and soil maps, inherently conferring a significant margin of error. There has also likely been considerable removal and degradation of habitat since 2005, both legal and illegal.

Persoonia nutans is an obligate seeder, and in the event of a fire, all affected *P. nutans* plants are killed and regeneration is dependent upon recruitment from a soil stored seed bank. *Persoonia nutans* populations are therefore relatively dynamic, particularly where fire is frequent. Fluctuations in space and time of above ground individuals is a natural occurrence. Consequently, the number of individuals and populations is difficult to estimate. Current information suggests there are 27 populations of *P. nutans* supporting greater than 5500 individuals in total. Only seven of these populations occur within conservation reserves, with the majority of populations occurring on private property and unoccupied Crown land" (DEC, 2005). Since 2005, further survey effort has documented some additional populations or at least extensions to known populations, and whilst an estimate of individuals is of relatively little merit because of the species' ecology, an updated estimate may be at least 50% greater than that given in DEC (2005).



Map 2. Cleaned BioNet occurrence data (extracted 26/11/18)

NB, each point may not designate a collection or observation at that location, as most very old records lacked any co-ordinates, or only supplied coarse co-ordinates, and may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

2.3.1 Reservation status

OEH has not published an updated estimate of *Persoonia nutans'* reservation status since that in DEC (2005). The work of Burcher *et al*. (2016) was not required to remedy this.

The species is known to occur in Castlereagh, Agnes Banks and Windsor Downs Nature Reserves, all in the north of its range (Table 2). More recently, it is known from the relatively new Wianamatta Nature Reserve and Wianamatta Regional Park. The security and even the boundaries of the latter reserve are unclear, as some official maps show it as an eastern and larger western portion, but one OEH map only shows the eastern portion. Reportedly, only the eastern portion is gazetted as reserve, and the western portions remain freehold. The currently proposed DPE urban footprint in the GPECGA shows a large transport corridor passing through the western portion, and this includes locations of two *P. nutans* records. Of the very few records of the species from that area, most are on or just outside the eastern portion's boundary.

The Kemps Creek population remains unreserved and is only known from freehold tenure and some Council-owned or managed land. It is not managed for conservation other than to a minor and fairly ineffective degree on Council land fringing a sports oval. It is partially and incidentally conserved on a freehold property on Clifton Avenue, which is ~1 km north of where the species was previously known in that locality. This currently occurs as a single young plant that was found in what is part of a small s.88b covenanted conservation area associated with an approved industrial land use. The species was not known from that site until found during fieldwork associated with the preparation of this Expert Report. The conservation area is very thin and vulnerable to edge effects, including weed invasion from that property and nearby. It was designated to conserve the threatened plant species, *Dillwynia tenuifolia* and *Pultenaea parviflora*, and the threatened ecological community in which they occur. It is now known to also contain the threatened plant, *Hibbertia puberula* ssp. *puberula* (dealt with in an Expert Report by Robert Miller), which had also not previously been detected on the site. The area is required to be managed in accordance with a Vegetation Management Plan prepared for the property, but the Plan did not appear to be adequately enacted when the site was visited in November 2018.

Part of the Moorebank population is now afforded some protection as a Biobanking offset site. The western records that formed a minority of the population at that site have now been destroyed, with most of the eastern records retained within the reserve. However, the reserved area was burnt in a very intense fire in 2017 during severe drought, and at this stage, the status of the *P. nutans* population there has not been documented. Part of the area had been burnt only 2-3 years prior to the fire, which could result in extinction of this species in the affected area. Conversely, other parts of the site may experience a large increase in numbers of *P. nutans* because fire will have removed over-mature and dense shrub growth and facilitated germination of seed bank.

Further information about other reserved populations of the species in Biobanking sites cannot be provided here because of confidentiality constraints governing that information.

OEH advised of another potential future reserve of this species in the north of its range where ~3000 individuals have been recently documented on land owned by the NSW Government and adjacent to Castlereagh Nature Reserve. Even if this area is conserved, the vast majority of the species' habitat and occurrences in the northern population remain unprotected and unmanaged on former Crown land in the Castlereagh/Londonderry area where threats are considerable e.g. recreational vehicle use, refuse dumping, arson and otherwise inappropriate fire regimes, weed invasion, timber theft, and feral animals. It is understood that an unresolved Native Title Act claim and competing land use intentions are factors in the former Crown land having uncertain status and an absence of protective management.

Counts of individuals are based on BioNet data plus Robert Miller's new records and information from DEC (2005). *Records with no value for the attribute, 'Number of Individuals' were assigned a count of 1. Most records that have population data are for a single plant, sometimes ranging to two or three plants and rarely to <10. Records in Agnes Banks NR were counted using GIS no allowance was made for records that may be within the Reserve but plot outside it due to minor spatial errors in GPS co-ordinates or inaccuracies in the actual Reserve boundary.

Table 2. Numbers of *P. nutans* within conservation reserves

Reserve	Records	Individuals*
Agnes Banks NR	582	825
Castlereagh NR	274	274 - 1500
Wianamatta NR	26	36
Wianamatta RP east portion	2	2
Wianamatta RP west portion	4	13
Windsor Downs NR	48	48 - 500

The species is not adequately reserved across its range. It is best reserved in the largest, northern occurrences where all of the NPWS reserves that contain it occur. These are vulnerable to arson, recreational misuse, and climate change. The central population at Kemps Creek is very much at risk. The southernmost population at Simmos Beach appears to be threatened by trail proliferation and a compromised fire regime due to it adjoining an urban area. It may also be at risk of inbreeding depression, as the population is small and relatively isolated.

2.4 Habitat

2.4.1 Geology and soil

Persoonia nutans occurs in a range of open forest and woodland communities on the Cumberland Plain and some of its margins. Most occurrences are associated with Paleogene-Neogene aeolian and alluvial sediments and the Castlereagh Forests and Woodlands group of vegetation communities, and with the Agnes Banks and Berkshire Park Soil Landscapes. However, the southernmost population at Simmos Beach is associated with the Wianamatta Shale/Hawkesbury Sandstone transition (incorrectly mapped as Blacktown Soil Landscape and edges of the alluvial South Creek Soil Landscape, but better mapped as Lucas Heights Soil Landscape, which is mapped nearby).

To the east, the composite site (likely a metapopulation) at Pleasure Point, Voyager Point and East Hills is variously mapped on the Berkshire Park and Lucas Heights Soil Landscapes.

The Villawood population is mapped on the Blacktown Soil Landscape (Wianamatta Shale) but apparently occurs on an unmapped occurrence of the Berkshire Park Soil Landscape.

The northwestern outlying population is mapped as occurring on the junction of the Luddenham (shale) and Gymea (sandstone) Soil Landscapes. Only one plant has been recorded there to-date on two occasions. At a finer scale, it could be mapped as a strip of Lucas Heights Soil Landscape between the shale and the sandstone lithologies.

The spatial accuracy of Soil Landscape and geology maps is coarse (often at best 1:100,000 scale) and is only useful for broad assessments. In many instances, the transition between Wianamatta Group and Hawkesbury Group-derived soils is not mapped because the transition zone is relatively small and can be difficult to define in coarse maps. Similarly, the boundary between the Paleogene-Neogene deposits and Wianamatta Shale can be complex and too difficult to map, even at a fine scale.

2.4.2. Associated vegetation communities and NSW TECs

Vegetation types associated with *P. nutans* include Castlereagh Scribbly Gum Woodland, Cooks River/Castlereagh Ironbark Forest, Shale Gravel Transition Forest, Castlereagh Swamp Woodland and/or Agnes Banks Woodland, and Shale Sandstone Transition Forest. The latter is only associated with one of the outlying populations, but two others occur in association allied communities. All of these vegetation types are Threatened Ecological Communities (TECs) ranging from Vulnerable to Critically Endangered.

The OEH Threatened Biodiversity Data Collection (July 2018) listed the following Keith Vegetation Classes as being associated with *P. nutans*:

- Coastal Valley Grassy Woodlands;
- Cumberland Dry Sclerophyll Forests; and
- Sydney Sand Flats Dry Sclerophyll Forests

The Threatened Biodiversity Data Collection indicates that *P. nutans* is potentially associated with 8 Plant Community Yypes (PCTs) across its range. Some of these are also associated with State and Commonwealth-listed Threatened Ecological Communities (TECs). Within the Growth Areas, relevant communities and NSW TECs, excluding apparent errors, are shown in Table 3. The associated PCTs are treated by OEH as *potential* habitat, and the species may not actually occur in all of those communities.

Associations between a species and Vegetation Classes and PCTs in the Threatened Species Data Collection were determined by the species' Accountable Officer within OEH some years ago, and staff were required to take a relatively inclusive approach in accordance with the precautionary principle (Steenbeeke, pers. comm.). This may mean that for some species, Vegetation Classes and PCTs have been associated with them even though there is little or no empirical evidence to support that, but where the officer believed that these attributes credibly represent *potential* habitat. Given the limitations of vegetation mapping and that in most cases, survey effort for threatened species is incomplete across their range, such an approach is understandable.

It appears that in some cases, the associations with Vegetation Class and PCTs in the Threatened Species Data Collection may have been amended after the assignments described above, and that some more recent associations may be influenced by spatial errors in species' records and/or errors in or limitations of vegetation maps. The apparent association between *Persoonia nutans* and Coastal Valley Grassy Woodlands is one example, and any association of this kind is weak when reviewed.

An assessment of the association between *P. nutans* and PCTs was undertaken to better understand the potential habitat for this species in terms of plant communities. The assessment is constrained by limitations of BioNet data and available vegetation maps. The assessment of the species' relationship with PCTs in and near the Cumberland Subregion used OEH vegetation maps that were publicly available at the time and did not use the updated vegetation maps produced within the Growth Areas by the biocertification process.

Some records of the species were seen to not be spatially associated with a PCT. This may be because:
- the record occurs in a site now cleared of native vegetation or too degraded to be captured by mapping;
- because the record is too spatially uncertain, so has been assigned generic co-ordinates, usually in a named town or suburb, and such settled areas often lack remnant native vegetation; and/or
- the record plots just outside an area of mapped vegetation because it is on a road verge, and even most GPS records are only accurate to 5m, meaning it could plot on the road, not on the vegetated verge.

To overcome this latter problem, those records were assigned a 10 m buffer so that they would associate with the nearest mapped vegetation polygon up to 10 m from the plotted location.

A further consideration is that survey effort for the species is not evenly distributed across the area subject to analysis. Some sites of potential habitat have had very little or no effort, often due to tenure constraints, yet others have had every apparent plant recorded (mostly in reserves or as part of ecological impact assessments). This creates very substantial biases in the data, which can create misleading weightings of association between the species and particular PCTs. Furthermore, most records do not include population data, such that a record might be for one plant or many. In short, this analysis is best used only for presence/absence i.e. whether the species has been recorded at a point that is mapped as a particular PCT, or not. Analysis beyond that is very constrained by deficiencies and biases in the datasets, especially in BioNet data.

The analysis of association with PCT in Table 3 deals only with records in the Cumberland Subregion plus a 10 km buffer. Records that associate with a PCT when a 10 m buffer is used are included in the counts of sightings below and are not shown separately. Two analyses were undertaken: All records in the target area without regard to spatial Accuracy score; and only records in that area with Accuracy score of 100 m or better. The latter analysis is considered more reliable, but both sets of figures are provided. Sightings with Accuracy <=100 m are shown in square brackets **[ ]** and in bold text. Where available, the combined count of individuals associated with the records is provided in parentheses { }. Those counts relate only to records with Accuracy <=100 m. Where a record doesn't contain population data, it is assumed to relate to a single plant.

Only PCTs mapped in the Growth Areas are dealt with in Table 3. Two PCTs mapped outside the Growth Areas: 958 (Agnes Banks Woodland) and 1067 (Castlereagh Swamp Woodland) were seen to be significantly associated with the species. Both are mapped north of the GPECGA by OEH. The updated vegetation map for this project did not identify either of these PCTs within any of the Growth Areas.

Some PCTs can appear to have a greater or lesser association than is actually the case. This is evident for this species in that an uncritical review of the raw data would associate this species with PCT 835*, which is a type of grassy riverflat forest on Quaternary alluvium that is not considered habitat for this species in any of the literature. In this case, there are very few records of the species associating with this PCT, and they are reasonably spatially accurate, but the vegetation map against which they have been assessed is inaccurate at that scale. The records plot in riverflat forest but the vegetation is most likely a unit with which the species is accepted to be associated - probably Shale Gravel Transition Forest.

Similarly, the apparently stronger association with PCT 849, a form of Cumberland Plain Woodland, is likely to be an artefact of spatial errors in the species' records and/or spatial or other inaccuracies of the vegetation map. The species is not accepted to occur in Cumberland Plain Woodland. The records that appear to be associated with that vegetation were more likely in Shale Gravel Transition Forest or Shale Sandstone Transition Forest, both of which can have a broad and indistinct ecotone with Cumberland Plain Woodland such that mapping of the boundary can be very difficult, even at quite a fine map scale.

Conversely, the species has a stronger, though still low and very tightly confined association with PCT 1081 than is indicated by the raw data in Table 3. The table shows that there are no records of the species with spatial accuracy of 100 m or better known from this PCT, and that there are only five records with lesser accuracy that are associated with this PCT. This is substantially an artefact of the fact that the native vegetation at the Simmos Beach population is assigned to PCTs 1787 and 1790 which are more prevalent on the Sydney Metropolitan vegetation map than the adjoining Cumberland Plain vegetation map. The latter is by far the most relevant to all of the Growth Areas. The OEH Threatened Species Data Collection report for *P. nutans* does not list PCTs 1787 or 1790 as being habitat for this species. However, availability of the associated vegetation map post-dates the last period in which OEH sought to ensure correlations between PCTs and threatened species were correct and current (Steenbeeke, pers. comm.).

Additionally, the two PCTs mapped at Simmos Beach Reserve are strongly allied with PCT 1081 (being confusingly described in the BioNet VCD as variously derived from or a parent unit of 1081), which occurs primarily on the Cumberland Plain map and is present in the Greater Macarthur and Wilton Growth Areas. Descriptions of vegetation at this site by Miller (pers. comm.), Steenbeeke (pers. comm.) and some of the observers of the species' BioNet records, along with the presence of PCT 1395 in close proximity, suggest that much of that habitat could be sensibly mapped as 1081.

On that basis, PCT 1081 goes from having no meaningful association with this species, to having a Low relative association based on the number of records with <=100m spatial accuracy and the number of plants recorded or assumed (one record = one plant unless other data provided) at the Simmos Beach site. Alternative figures for those parameters are provided as a second row for that PCT in Table 3.

PCT 1395 also shows no credible association with *P. nutans* in the raw data, irrespective of the spatial accuracy of the records. Yet there are records that describe the species as occurring in 'shale sandstone transition forest'. One such site is at East Hills Park, but the vegetation is mapped as a form of coastal shale sandstone transition forest that is quite distinctive from the PCTs that comprise the Shale Sandstone Transition Forest TEC (principally 1395). Assuming that the OEH vegetation map is correct, this site is not informative for the purposes of determining PCT associations with this species in the Growth Areas, as it does not occur in any of them. However, there are two other records (duplicate collections of the one plant) that also mention the species occurring in Shale Sandstone Transition Forest. Once moved to the correct location based on information from the first collector (Wotherspoon, 2002), they plot in credibly mapped PCT 1395, which is informative for this Report, as this community occurs in two of the Growth Areas. Whilst the relative association with 1395 is Very Low, and relates to a single outlying site, this PCT is included as potential habitat for the species within its accepted range, plus a precautionary buffer (south to Narellan Road). Alternative 'Sightings & Populations' figures for PCT 1395 are provided as a second row in Table 3[#].

2.4.2 Associated Commonwealth TECs

The Commonwealth Department of Environment & Energy (DEE) Species Profile and Threats Database website for *Persoonia nutans* shows that as of November 2018, the Department has not released an Approved Conservation Advice for this species. It relies on the joint NSW/Commonwealth Recovery Plan for this purpose, though that Plan is now quite dated (2005), and also references the NPWS (2004) EIA Guidelines and on-line profile (OEH, 2017) for this species. Consequently, there is not an official document that clearly shows which Commonwealth TEC are associated with *P. nutans*.

However, in this case, the NSW TECs with which the species is accepted to be associated are equivalent to or components of Commonwealth TECs.

2.4.3 Habitat condition

Degraded and significantly modified areas of the PCTs that are known or likely habitat for *P. nutans* can still support it due to its ability to persist in the soil seed bank. Modified sites may have reduced or no canopy and/or midstorey, and/or reduced understorey and some weed invasion. Some may be dominated by shrubs in areas of regrowth after earlier clearing or 'under-scrubbing'.

This species is known to occur in highly modified sites such as slashed bushfire Asset Protection Zones, and road and trail verges, and in former small-scale quarries (DEC, 2005, Burcher *et al*., 2016). Some forms of disturbance, even relatively severe forms that would be considered clearing of vegetation, appear to be beneficial to this species, within limits. This situation is recognised for numerous threatened plant species in and beyond the Sydney Basin Bioregion. It may be related to the fact that modern fire regimes are likely to be significantly different to those prior to 1788, and that some native animal species that had a role in seed dispersal and understorey modification are now extinct.

The condition of potential habitat for this species is not, in itself, a reliable indicator of the species' presence, and accordingly, **all condition states except derived grassland are considered in determining potential habitat** i.e. intact, thinned, scattered, and derived shrubland. Derived grassland is not included, as in large part, PCTs that are known habitat for *P. nutans* are not subject to pastoralism, so have generally not been cleared of trees to support grazing. However, the species can survive grazing depending on the livestock type and stocking rate, and because it can survive as seedbank. Sites with long and intensive grazing history will be unlikely to retain the species in any form, especially given that fertiliser is likely to be used to promote and maintain fodder cover on the low fertility soils that this species prefers. Fertiliser use alone could suppress or eliminate this species. Only sites with relatively recent grazing history or very low stocking rates may retain the species as plants and/or seed.

Table 3. BioNet records of *P. nutans* and counts of individuals relative to mapped PCTs

PCT	PCT Name	Associated TECs (NSW BC Act)	% Cleared (VCD)	Sightings & Population	Relative association	Adjusted relative association#
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Shale Gravel Transition Forest (E)	75	71 **[64]** {101}	Moderate	Moderate
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Cooks River/Castlereagh Ironbark Forest (E)	95	51 **[43]** {61}	Moderate	Moderate
808	Derived shrubland on Tertiary Gravels of the Cumberland Plain	Shale Gravel Transition Forest (E) Cooks River/Castlereagh Ironbark Forest (E)	75-95 inferred from 724/725	Not mapped, no empirical data	Moderate (inferred)	Moderate (inferred)
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	River-flat Eucalypt Forest of Coastal Floodplain (E)	93	8 **[4]** {4}	Very Low	Nil
849	Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CE)	93	34 **[13]** {15}	Low	Nil
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Castlereagh Scribbly Gum Woodland (V) Castlereagh Swamp Woodland (E)	50	670 **[641]** {3626}	Very High	Very High
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Not a TEC but some areas may be within Shale Sandstone Transition Forest (CE)	40	5 **[0]** {0} 37 **[27]** {34}*	Nil	Low – one atypical occurrence
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (CE)	80	5 **[0]** {0} 5 **[2]** {2}#	Nil	Very Low – one atypical occurrence

3. Description of the study area

3.1 Landscape context and land use history

All of the Growth Areas have been significantly cleared for earlier activities, primarily timber production associated with opening areas for agriculture and pastoralism, minor areas of surface resource mining, and to varying degrees, for urban and commercial/industrial use. They are proposed to accommodate phased increases in urban land use, primarily within existing cleared or highly modified lands. Increased urban use is planned as a response to population growth.

3.1.1. Greater Macarthur Growth Area (GMGA)

The GMGA extends from Glenfield in the north to Appin in the south. It is largely within the Campbelltown LGA with the southernmost section within the Wollondilly LGA. The northern half comprises an urban renewal corridor centred on the Sydney to Southern Highlands railway line. It encompasses the existing industrial and residential suburbs of Glenfield, Macquarie Fields, Minto, Leumeah and Campbelltown. The GMGA is associated with extensively cleared, gently undulating shale terrain typical of the Cumberland Plain, and contrasts the sandstone gorges of the Woronora Plateaus across the Georges River to the east. The northern portion of the GMGA is already substantially urbanised, with remnant vegetation largely restricted to creek-lines or small patches associated with designated open space. Vegetated creek-lines include Bunbury Curran Creek, Bow Bowing Creek, Leumeah Creek, Fishers Ghost Creek and Spring Creek.

The more extensive southern half of the GMGA, south of Rosemeadow, comprises proposed urban land releases at Menangle Park, Mount Gilead and Appin. Menangle Park and Mount Gilead are subject to separate planning processes, so are not within the scope of this biocertification. In the north-west, Mount Sugarloaf (213 m AHD) forms the southern end of a hilly ridge on the Luddenham Soil Landscape above the Menangle floodplain that extends north to Denham Court, then to Cecil Hills and Prospect Hill. Some native vegetation persists, although it is often invaded by African Olive. The floodplain is dissected by Menangle Creek and its tributaries, including Nepean Creek, Woodhouse Creek and Leafs Gully.

The southern GMGA is primarily semi-rural and agricultural land, with creek corridors and some larger patches of remnant vegetation located between the Nepean and Georges Rivers. Geologically, the area comprises gently undulating hills on Wianamatta Shale intergrading via a shale sandstone transitional zone (can include the Mittagong Formation) with steeper and infertile terrain on Hawkesbury Sandstone along the rivers. Transitional and sandstone geologies are sometimes exposed along the smaller creek lines.

3.1.2. Wilton Growth Area (WGA)

The WGA is a relatively smaller area that occurs to the south of the GMGA, extending from the vicinity of Douglas Park in the north, Maldon in the north-west, and beyond Wilton in the southeast. The boundaries closely follow the Nepean River in the north and west, a tributary Allens Creek in the east, and the Cordeaux River in the south. Away from the Nepean River and gullies, a higher, gently undulating zone has been largely cleared for agriculture. The Woronora Plateau forms the southern boundary and includes the northernmost section of the large Upper Nepean State Conservation Area, with unreserved but closed areas of the Water NSW Special Area (Sydney water supply catchment) extending to the east and southeast. The Hume Motorway dissects the WGA roughly north to south, and Picton Road traverses it roughly northwest to southeast.

The WGA includes both shale, shale sandstone transition and sandstone environments. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The flatter shale terrain has soils of the Blacktown Soil Landscape, which is derived from Ashfield Shale (a member of the Wianamatta Group), and typically supported the now Critically Endangered Cumberland Plain Woodlands. Much of this area is cleared or modified for agriculture and hobby farms. It comprises native/exotic grassland with smaller areas of Derived Native Grasslands in relatively better condition. Areas above the gullies feature soils of the Lucas Heights Soil Landscape derived from the Mittagong Formation (a transitional bed between the Wianamatta and Hawkesbury Groups). These support variable shale sandstone transition woodlands and forest, some of which are also Critically Endangered. In the steeper gullies, the Hawkesbury Soil Landscape dominates, and supports Hawkesbury Sandstone Gully Forest types with Ridgetop Woodlands on some of the upper slopes.

3.1.3. Greater Penrith to Eastern Creek Growth Area (GPECGA)

The GPECGA is a relatively large area that extends from Rooty Hill, Minchinbury and Hassell Grove in the east, across the Cumberland Plain to the Hawkesbury-Nepean River in the northwest, then south through Jamisontown, Glenmore Park, to the intersection between The Northern Road and the Warragamba Water Supply Pipelines in the far south-west.

The predominant geology is Wianamatta Shale on flat to gently undulating terrain that has been extensively cleared for agriculture, and later for housing and industrial use, with some remnant vegetation on current and former Defence holdings. The shale soils support(ed) Cumberland Plain Woodlands. Overlying the extensive shale deposits are small areas of weathered Paleogene-Neogene alluvium e.g. Shalvey and Willmot, that are much more common to the north. These support(ed) the Castlereagh Forests & Woodlands complex of vegetation types, which is strongly associated with several threatened plant species. More common are broadly linear deposits of Quaternary alluvium along watercourses such as South Creek and Eastern Creek, and on the flood terraces of the Hawkesbury-Nepean River. Other lithologies occur but are very rare and of very small extent.

Very little of the GPECGA is reserved in NPWS estate. Wianamatta Regional Park (which emphasises recreational uses) encloses small areas of former Defence land in the far north. Adjacent to the southwestern boundary is the small Mulgoa Nature Reserve (emphasises biodiversity values). Two Biobanking sites adjacent to the Nature Reserve have increased the area under conservation.

3.1.4. Western Sydney Aerotropolis Growth Area (WSAGA)

The WSAGA abuts the GPECGA's southernmost border near the locality of Sovereign (east of Mulgoa), then extends south past Greendale, northeast to the locality of Badgerys Creek, east to Kemps Creek, and northward to the vicinity of Mount Vernon, excluding Twin Creeks Golf Course and associated settlement.

The lithology and soils are broadly similar to that of the GPECGA, being effectively just an extension of that area to the south to incorporate the developing Badgerys Creek Airport and environs. The area is even more severely cleared of native vegetation, except along some streams and on rare occurrences of steeper terrain. It contains no NPWS reserves, with the nearest being the small Kemps Creek Nature Reserve, outside the Area to the southeast. Gulguer Nature Reserve and Bents Basin State Conservation Area occur to the southwest of Greendale.

3.2 Geology and remnant vegetation

The dominant lithology across all of the Growth Areas is Wianamatta Shale (Ashfield and Bringelly Shales), with much smaller areas of Paleogene-Neogene alluvium occurring largely outside these boundaries, and much larger areas of Quaternary alluvium associated with floodplains of the many watercourses.

The terrain varies from almost flat through to steeply hilly areas associated with minor volcanism and more often, in association with shale ranges. In the far south, the more elevated shale landscapes have been eroded down to the underlying Hawkesbury Sandstone in a series of gullies and gorges. A transition zone between the shale and the sandstone is discernible in some areas.

On the dominant shale geology, the associated Critically Endangered Cumberland Plain Woodlands are still present in all of the four Growth Areas but have been disproportionately cleared for rural and later urban and allied uses. Much of what remains of this ecological community occurs as paddock trees and areas of remnant native ground-layer vegetation in pastoral and other contexts, with the exception of some substantial, though fragmented and isolated remnants. Remnant vegetation in these relatively fertile and arable landscapes is often in poor condition. In the most heavily cleared areas, it can be restricted to strips along watercourses. Some forms are dominated by *Casuarina* species. Weeds are common and sometimes severe in the moister situations. Weeds often extend into higher and drier terrain, especially in the form of African Olive and African Love Grass, both of which can occur on a landscape scale.

Small areas of the biodiverse Castlereagh Forests and Woodlands persist in all but the Wilton Growth Area on often-laterised Paleogene-Neogene alluvium. These variable woodlands and open forests support a particularly high number of threatened plant species, and because their soils are less suitable for agriculture and grazing, are better conserved than the Cumberland Plain Woodlands. Nonetheless, they are all listed as threatened ecological communities.

In the two southern Growth Areas, vegetation of the shale sandstone transition zone is relatively common and tends to remain in less arable areas adjoining the largely cleared former Cumberland Plain Woodlands. It is often found fringing the largely uncleared sandstone-based terrain, and ranges from highly intact to significantly modified and degraded, largely due to grazing and weed invasion. The associated Shale Sandstone Transition Forest is recognised as Critically Endangered due to extensive clearing across its substantial range, and because of the severity of other threats. Very little is present in formal conservation areas.

In the two southern Growth Areas, diverse, sandstone-based vegetation persists in association with most of the many incised watercourses. This vegetation is broadly the same as what occurs in extensive conservation estate around urban Sydney, but some communities adjoining current or former Shale Sandstone Transition Forest are not well-conserved and are threatened by further clearing and degradation.

3.2.1 Plant Community Types

The following section lists the Plant Community Types mapped in each Growth Area with brief notes about their distribution in those Areas. The list is not restricted to PCTs associated with *P. nutans*. Biobanking reserves are not dealt with fully here due to confidentiality constraints relating to their location and attributes.

3.2.1.1 Greater Macarthur Growth Area (GMGA)

The predominant ecological communities in the GMGA are or were Cumberland Plain Woodland (CPW), Shale Sandstone Transition Forest (SSTF) and River-flat Eucalypt Forest (RFEF), all of which are Threatened Ecological Communities. All have been extensively cleared and degraded, primarily by agriculture and weed invasion, but also by urban and allied uses. There are no NPWS reserves in this Growth Area. However, the very small Leacock, Edmondson and William Howe Regional Parks occur just outside the border and are managed primarily for recreation rather than conservation. Dharawal State Conservation Area and National Park border the southern portion of the Growth Area to the east.

A summary of the mapped ecological communities is found in Table 4. The maps used here are based on OEH products that have been updated by Biosis for DPE.

Table 4. Summary of all ecological communities within the Greater Macarthur Growth Area

PCT	PCT Name	Distribution & notes
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Small patch at Menangle Sugarloaf on SE slopes.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Along creek lines in shale areas in northern and central parts of GMGA.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Small patches on shale soils throughout GMGA but mostly in northern and central parts.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches on shale soils throughout GMGA, more common in southern parts on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	4 polygons, Macquarie Fields, most of which have long been historically mown (Milton Park Softball Complex). They are now subject to regeneration.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	One small occurrence mapped around the margins of bushland associated with Smiths Creek at Leumeah.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Nepean River north from Menangle Bridge.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Narrow zone along Nepean & Georges Rivers and tributary gullies and a small zone along Smiths Creek at Leumeah.
1292	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Restricted to parts of the riparian zones of the more incised and larger watercourses. Very restricted extent in this Area.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Relatively small remnants extend from Glenfield into the far south where it is extensive on transitional soils mostly south from Rosemeadow. Can intergrade with 849 and 1081.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Only mapped to a very minor extent as highly linear remnants between Glenfield and Macquarie Fields (along the railway) and at Ingleburn (adjoining roads).

3.2.1.2 Wilton Growth Area (WGA)

The predominant ecological communities in the WGA are or were Cumberland Plain Woodland (CPW) and Shale Sandstone Transition Forest (SSTF) both of which are Threatened Ecological Communities. Sandstone-based communities occur in and surrounding the more incised watercourses. There are no NPWS reserves in this Growth Area, though Upper Nepean State Conservation Area occurs immediately to the south. There is a Biobanking site on the northern side of the river near Douglas Park (within the WGA), and three more such properties to the immediate north (including St Marys Towers) and those associated with coal mines (Steenbeeke, pers. comm.).

Table 5. Summary of all ecological communities within the Wilton Growth Area

PCT	PCT Name	Distribution & notes
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	On shale soils of higher, gently undulating terrain of northern and central areas. Small patches with scattered trees (farming properties) adjoining more extensive exotic and native grasslands.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	One patch in a derived grassland (treeless) condition in the west, and a much larger portion in the far north.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Limited to a few patches in the north between 1395 on plateau edges and 1181 in sandstone gullies.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Common on slopes and plateau edges above and around incised sandstone-based watercourses that surround most of the Area.
1292	Water Gum – Coachwood riparian scrub along sandstone streams	Restricted to a very narrow riparian strip along the Nepean River.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	The most extensive community on shale sandstone transition soils between 849/850 and sandstone communities along gullies. Variable floristics.

3.2.1.3 Greater Penrith to Eastern Creek Growth Area (GPECGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Shale Gravel Transition Forest and Castlereagh Forests & Woodlands. River-flat Eucalypt Forest was previously much more extensive along the Hawkesbury-Nepean River and adjoining primary floodplain, and it remains to varying degrees along many watercourses such as Eastern Creek, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. There is one NPWS reserve in this Growth Area: Wianamatta Regional Park, however it is already significantly fragmented and may be required to potentially accommodate a large transport corridor. The small Mulgoa Nature Reserve and associated Biobanking sites occur near the south-western border of this Growth Area. Yarramundi SCA occurs on the western boundary but across the Nepean River, and Wianamatta NR occurs near the NW corner.

Table 6. Summary of all ecological communities within the GPECGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Scattered as small remnants and one larger remnant in the central portion, but with greater extent in the central north, mainly in the western ungazetted portion of Wianamatta Regional Park.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	A few very small remnants present south of the M4, with larger remnants within and near the gazetted and ungazetted portions of Wianamatta Regional Park.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northwest, with some small remnants in the southwest, often associated with watercourses.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Present to a very minor extent on the southwestern edge adjoining Mulgoa Nature Reserve
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains through the south and central areas.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Common in and near Orchard Hills in the south, and former ADI lands in the central north, with some areas in the ungazetted portion of Wianamatta Regional Park. Other scattered remnants, particularly in the east.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Very small patches in the south west, primarily in pastoral settings and on steeper terrain.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Restricted to one linear polygon in the eastern portion of Wianamatta Regional Park.
1105	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	Only mapped along the Hawkesbury-Nepean River, primarily near Penrith Lakes.
1800	Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley	Present as mostly-linear remnants along South Creek and Eastern Creek and tributaries, with some scattered occurrences, including along the M4.

3.2.1.4 Western Sydney Aerotropolis Growth Area (WSAGA)

The native vegetation of this Growth Area has been extensively cleared, with what remains classified as Threatened Ecological Communities. The majority of the Area formerly supported Cumberland Plain Woodlands, with a much smaller area supporting Castlereagh Forests & Woodlands near the localities of Kemps and Badgerys Creeks, and potentially in the vicinity of the water pipeline crossing of Luddenham Road. Riverflat Eucalypt Forest remains to varying degrees along most watercourses, though frequently in poor condition, due largely to extensive weed invasion and a long interface with unsympathetic land uses. Swamp Oak Forest occurs mainly along South Creek and some tributaries. There are currently no NPWS reserves in this Growth Area. The small Kemps Creek Nature Reserve occurs just outside the south-eastern corner and Gulguer Nature Reserve and Bents Basin State Conservation Area are near the south-western corner.

Table 7. Summary of all ecological communities within the WSAGA

PCT	PCT Name	Distribution & notes
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Restricted to the Kemps and Badgerys Creek area as three patches of remnants.
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	As above: two patches with smaller remnants nearby and on slightly higher ground than 724.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion	Very limited extent, primarily in the far northeast, with one remnant in the centre.
835	Forest Red Gum – Rough- barked Apple grassy woodland on alluvial flats of the Cumberland Plain	Common along creek lines and associated floodplains but very little remains, and most occurrences are linear.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	The most common PCT in this Area, with remnants throughout on the dominant shale terrain.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Only very small patches in the far south.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain and Hunter valley	Present as mainly very linear remnants along most watercourses but largely absent from the southernmost portion.

4. Assessment of species' presence and suitable habitat

4.1 Existing records and surveys

The principle source of threatened flora records in NSW is the OEH BioNet database, which includes most records held by the NSW Herbarium (specimen-based), as well as sightings, including those associated with vegetation sampling for the purposes of mapping. Other databases, such as Atlas of Living Australia, largely mirror BioNet data within NSW, but are not used in this Report due to their having lower data quality control, and because they do not allow even a registered user to access data that may not have been generalised to obscure the exact location of a record. Very few flora records that are in ALA but not in BioNet are original – most are simply replicate records based on specimens held in other herbaria.

The preliminary assessment of threatened species records undertaken for the preparation of this Expert Report reiterated the merit of reviewing BioNet data and resolving a range of errors, rather than simply using data 'as held'. *Persoonia nutans* records within BioNet were reviewed, and numerous corrections were made, though the majority of these relate to the assigned spatial accuracy scores and to clarifying or correcting location placements and descriptions. Not all records were able to be checked in that stage, and a second review for records in or near the Growth Areas was conducted to further improve data quality. The reviews eliminated a range of errors and allowed many records that were otherwise too spatially vague, to be refined such that they were suitable for habitat modelling and for general reference. Not all records were reviewed, and inaccuracies remain in the dataset, but records within the Cumberland Subregion are now far more accurate in terms of their identification of the species, their location, and their spatial accuracy score.

BioNet data should only be treated as indicative, not least because there has not been comprehensive survey of all of the Growth Areas or environs, and surveys have been variously constrained. The absence of records from an area does not necessarily mean the species is absent, as it may not have been surveyed there, or survey conditions and methods may have been inadequate.

Field survey undertaken by consultancy firms engaged by DPE (Biosis and Ecoplanning) did not add any records of this species. Fellow botanist, Robert Miller and I undertook very limited survey in the Kemps Creek locality. Robert detected, and I recorded, one juvenile *Persoonia nutans* at a site on which it had not been previously recorded in two earlier consultancy assessments on behalf of the land owner and in a more recent vegetation mapping survey for DPE. The plant was likely not present during the earlier consultancy assessments, as it is clearly a young specimen that likely arose after threatening processes were removed from that habitat relatively recently. I believe that had I been given access to more freehold land in that area, I would have been able to record additional occurrences of this species. DPE made considerable and repeated efforts to obtain such access, but with very little success. However, all areas of known or potential habitat for *P. nutans* in that locality have been excluded from the proposed urban footprint / biocertified area.

4.1.1 Existing records by Growth Area

Persoonia nutans records in Greater Macarthur Growth Area

There are no records of the species from the GMGA, but there are several records associated with a population to the east at Simmos Beach on the edge of Macquarie Fields. There are a large number of records further to the northeast on an approved industrial development site on former Defence Department land at Moorebank, part of which is now within a Biobanking offset reserve.

Persoonia nutans records in Wilton Growth Area

The species has been never been recorded within the WGA. This is credible on the basis that this Area occurs at higher elevation and further south than the species is known to occur, and only one of the PCTs with which it is associated is present in this Area. That PCT, 1395, is only known to be habitat for this species at the edges of its distribution, and this Area is substantially beyond that distribution. Weston & Johnson (1991) indicate that *P. nutans*, which has a southern limit at Simmos Beach Reserve, is replaced by the allied and highly range-restricted *P. bargoensis* in the Wollondilly region in which the WGA occurs.

Persoonia nutans records in Greater Penrith to Eastern Creek Growth Area

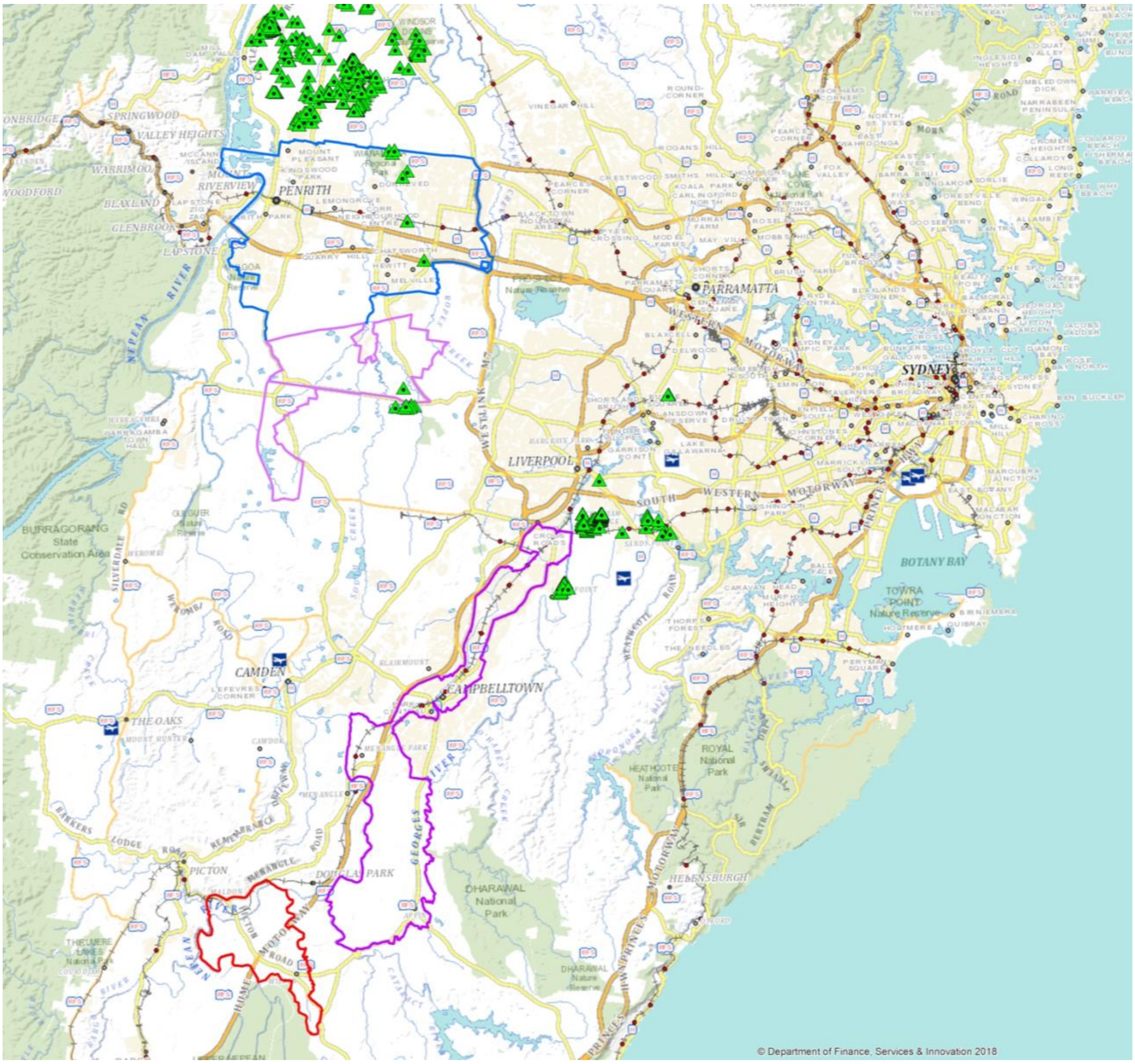
The species is known from this Growth Area in the form of both vaguely located historic records and spatially accurate recent records. Recent records occur in the central north of the Area in and near the eastern extent of the former ADI lands that are now partially urbanised and partially reserved (e.g. Wianamatta Regional Park). In the central section of this Growth Area, the very few records that exist are old or very old, and if they have any locational information, this only refers to "St Marys" or "east of St Marys", so are arbitrarily located. As part of the review of BioNet records, these were further consolidated and moved to a small strip of remnant vegetation where seedbank may remain. There are no records from the vicinity of St Marys since 1955, and the area is now extensively urbanised.

In the southeast of this Area, a single, modern record exists in a tiny patch of remnant bushland along the M4 Motorway, with records of the threatened *Acacia pubescens* nearby.

There was always relatively little habitat for this species in this Area, and even less remains today. Most of the remaining mapped potential habitat in this Area is restricted to the gazetted and proposed portions of Wianamatta Regional Park.

Persoonia nutans records in Western Sydney Aerotropolis Growth Area

There are several records of the species just outside the south east corner of this Growth Area in the locality of Kemps Creek. They are a mix of relatively old, spatially vague records; and modern, more spatially reliable records. All are associated with an isolated remnant of Paleogene-Neogene alluvium. The one record within this Growth Area was added during surveys to support this Report, and it occurs approximately 1 km north of the earlier records. Equivalent habitat remains between these records but has been progressively degraded and removed in recent years. Much of what little habitat remains is threatened by a range of legal and illegal land uses, and the fact that this species can be present in seed bank on long-unburnt sites but is too often disregarded if it is not detected during ecological assessments.



Map 3. BioNet records (cleaned as of 26/11/18) relative to Growth Areas

Each point on Map 3 may not designate a collection or observation at that location, as most very old records lacked any co-ordinates, or only supplied coarse co-ordinates, and may only have mentioned a town or locality. Such records will generally have a relatively poor Accuracy score (10-25 km) to indicate that the actual location of the species could be within a considerable distance of the designated point. Many such records are assigned the same indicative co-ordinates such that one point on a map may relate to several old records that were supplied with very little locational information.

4.1.2 Prior surveys within each Growth Area

There is no central or local registry of surveys and survey effort for threatened biota, and a large proportion of survey reports are not made public or only made public when lodged with a planning consent authority. This makes it extremely difficult, if not impossible to compile a list of surveys, methods and findings across the study area.

The OEH Authorised Officer for *P. nutans* was contacted in this regard. He advised that he does not hold a record of this information but did note some relevant results of a recent survey on public land (records now in BioNet) and referred me to the manager of threatened biota matters in the Greater Sydney OEH office for further assistance. She committed to providing the relevant information by consulting key staff. I was included in the associated emails. No additional information about this species was provided.

I separately became aware of some earlier surveys of threatened flora that OEH had commissioned for areas of NPWS estate near the GPECGA. With approval from the NPWS, the lead ecologist who undertook those surveys provided information about his work, which entailed targeted searches for *P. nutans* and the provision of a very brief report. The associated records were confirmed to have been lodged in BioNet.

Whilst seeking to obtain access to properties for fieldwork, DPE located and provided three ecological assessments relating to project proposals in the locality of Kemps Creek, north of Elizabeth Drive, within the WSAGA. These revealed that two consultants involved at one site has misidentified the PCT and TEC being assessed and had not detected all relevant threatened plant species. Those assessments did not find *P. nutans* on the site, but it was later detected during fieldwork for this Report. The third assessment relates to an adjoining development project that also reported that no threatened flora species were present. Part of that site was observed through a wire fence during fieldwork for this Report, and was seen to support a threatened *Hibbertia* species, with a very high likelihood that several other threatened plant species are present.

4.2 Summary of survey work undertaken for the biocertification assessment

4.2.1 Vegetation mapping

Vegetation mapping of the Cumberland Subregion was completed in stages by OEH in 2013 and 2016. These two vegetation layers have been used as the base to compile an updated vegetation community layer for each of the Growth Areas. This updated work has been completed by Biosis under contract to DPE. The mapping update includes checking plant community types and confirming the accuracy of boundaries to account for clearing or regrowth that may have occurred since the original mapping was completed. Field verification of the mapping was undertaken by Biosis and Ecoplanning, both of whom undertook vegetation surveys where access was permitted.

Vegetation in the Growth Areas was mapped and assessed based on five vegetation condition classes:

- Intact;
- Non-offsettable Grassland;
- Offsettable Grassland;
- Scattered Trees;
- Thinned.

4.2.2 Field survey effort

The information in section 4.2.2 has been provided by DPE but has been edited here to only deal with threatened flora where feasible. Further details are provided separately by DPE:

An initial 726 letters were sent to landholders within the Wilton and Greater Macarthur Growth Areas in late 2017 with a second letter following in March 2018. To increase the response rate, Biosis commenced targeted door-knocking in May 2018. From this, just under 20% of landholders within these Growth Areas allowed access to their property. However, this included access to large parcels of land owned by major developers, which allowed a reasonable amount of access, particularly for the Wilton Growth Area.

Floristic plot data collected:

- Wilton (86 plots across 6 PCTs)
- Greater Macarthur (82 plots across 9 PCTs)

Approximately 150 of the plots required to meet BAM requirements were obtained by supplementing Biometric plots from various recent assessments. This involved locating the previous plots and collecting additional data on stem classes, number of large trees, and litter cover to meet BAM requirements. The ecologists had no trouble locating the original survey sites and found that the additional data was quick and easy to collect (approximately 30 minutes per site).

The remaining plots in Wilton and Greater Macarthur, and all of the plots in Western Sydney Aerotropolis and Greater Penrith to Eastern Creek consisted of new plots surveyed for this project. All plots were sampled according to the methods prescribed by the BAM Manual (OEH 2017). This includes collecting information on species cover and abundance from 20 x 20 m or equivalent configuration plots within each vegetation zone.

A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Growth Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council.

Floristic plot data collected:

- Western Sydney Aerotropolis (53 plots across 6 PCTs)
- Greater Penrith to Eastern Creek (26 plots across 7 PCTs)

Targeted survey for threatened species

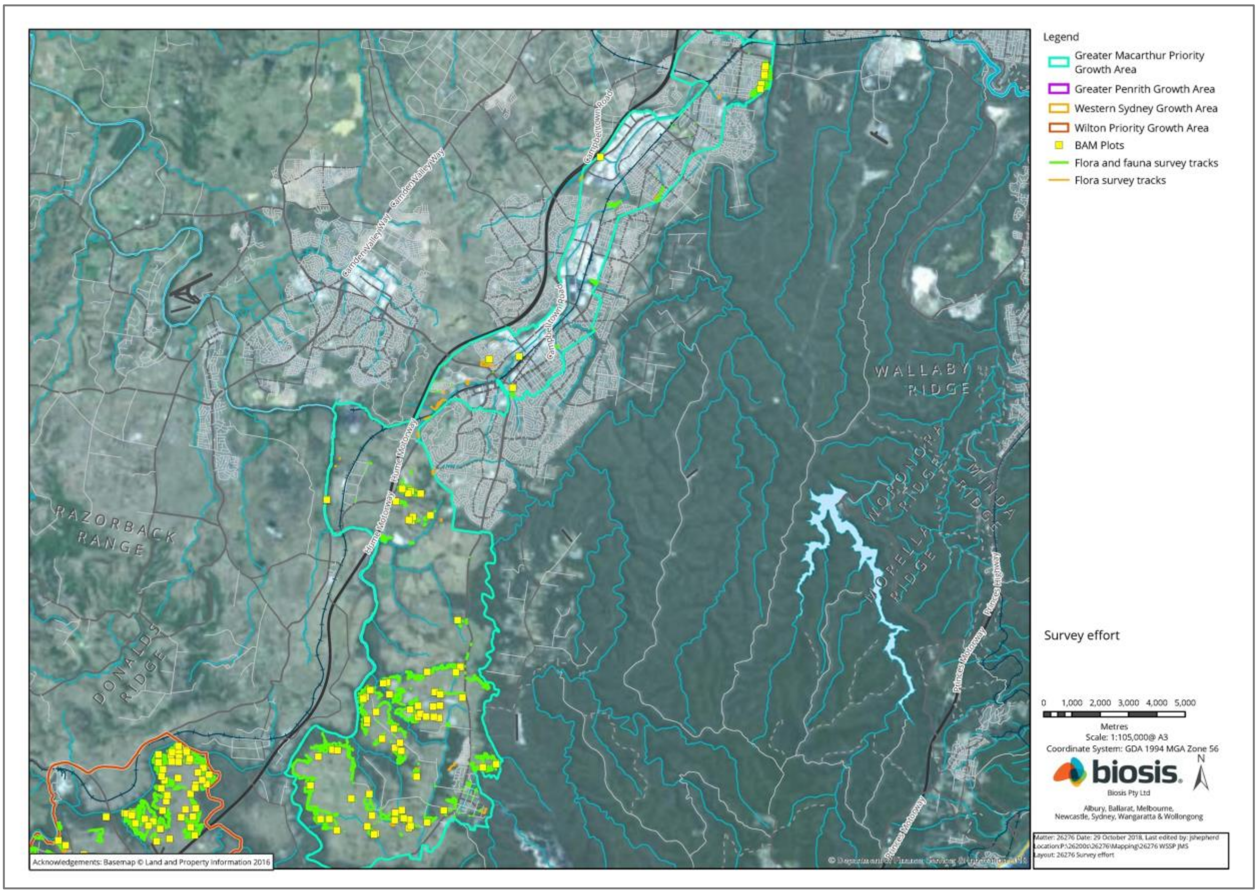
Targeted survey for threatened plant species has been conducted on lands where access has been granted. Vegetation transects and random meanders for threatened flora was conducted by Ecoplanning and Biosis in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey has included effort through each PCT and vegetation zone and has extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m).

Likely habitat for most threatened flora species comprised areas of lower disturbance. This includes areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora.

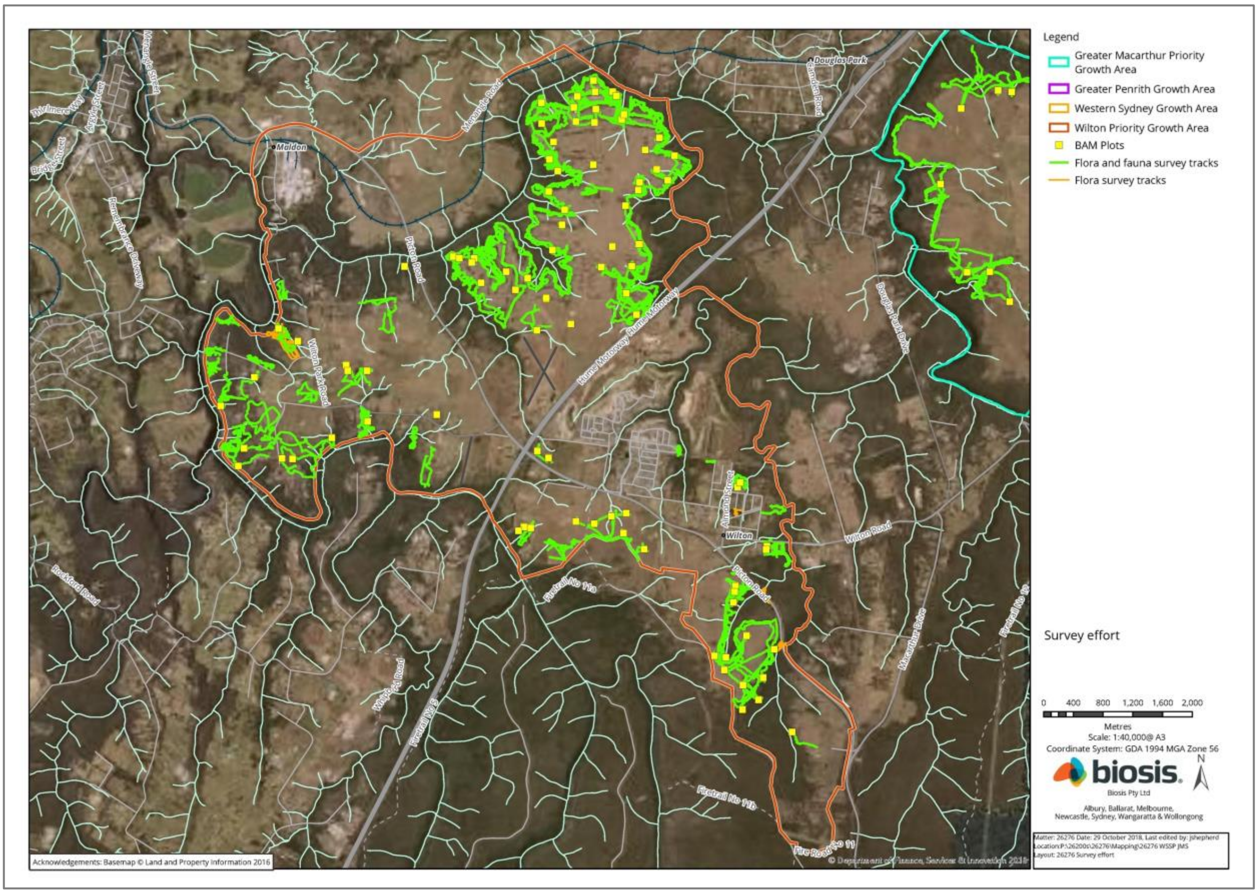
Table 8. Survey effort for threatened plant species *and* fauna habitat by PCT

PCT No.	Area of PCT in Growth Area (ha)	Area of PCT in urban zone (ha)	Field survey area (ha)	Percent of PCT surveyed within Growth Area (%)	Percent of PCT surveyed relative to urban zone (%)
724	191.3	57.0	12.1	6.3%	21.2%
725	167.4	51.4	6.9	4.1%	13.4%
781	68.9	5.6	0.9	1.4%	16.8%
830	21.6	0.8	1.7	7.8%	206.5%
835	1175.8	287.3	30.5	2.6%	10.6%
849	3078.3	637.6	125.0	4.1%	19.6%
850	522.9	294.3	36.1	6.9%	12.3%
883	7.4	0.0	0.5	6.8%	
1081	74.2	0.0	0.2	0.3%	
1105	138.6	0.0	0.0	0.0%	
1181	780.7	0.2	39.6	5.1%	19794.4%
1292	39.8	0.0	0.3	0.7%	
1395	3326.6	486.9	483.4	14.5%	99.3%
1800	232.6	20.2	7.3	3.1%	36.2%
TOTAL	**9826.1**	**1841.3**	**744.5**	**7.6%**	**40.4%**

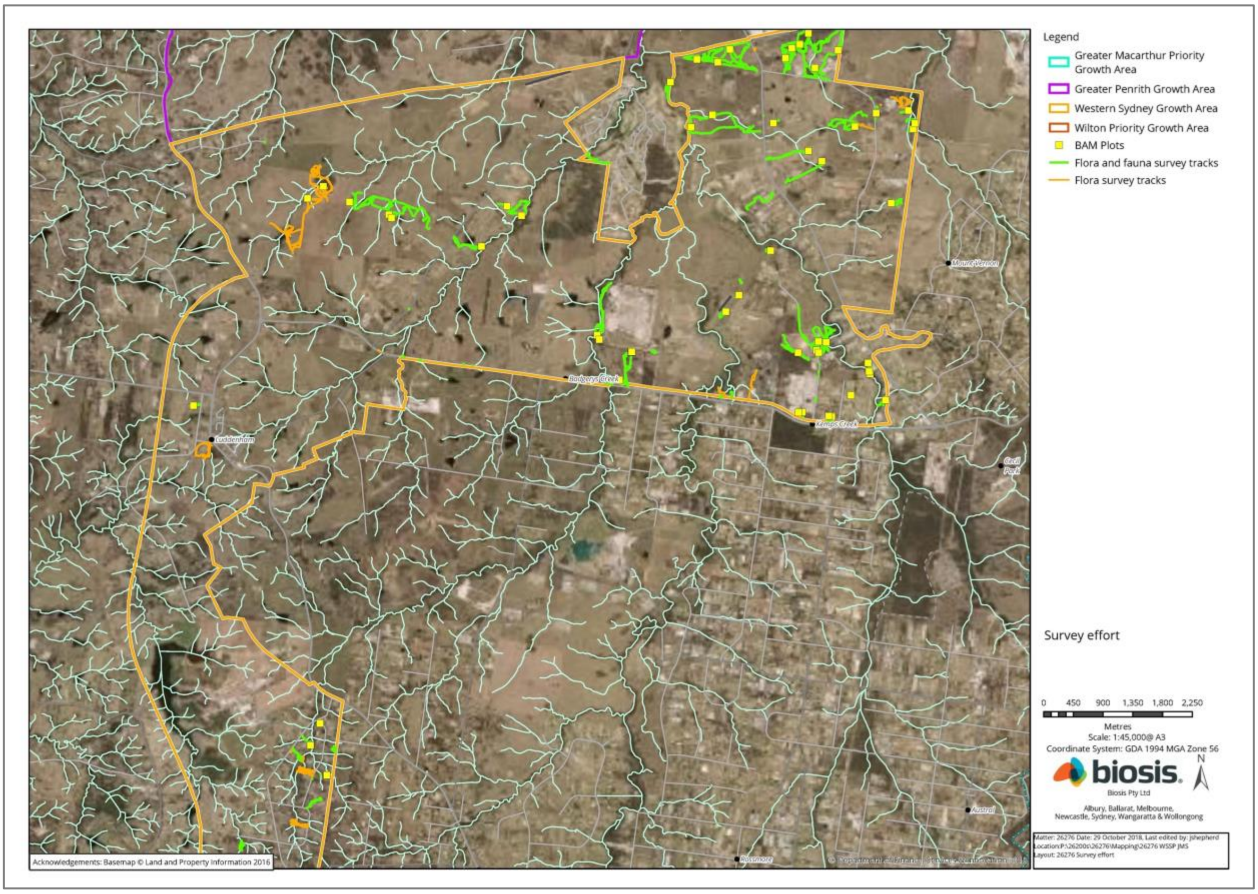
Field survey effort was not confined to the urban zone. Surveys occurred into nearby vegetation zoned for conservation. The urban zone has been revised over time and some areas where survey had already occurred were later removed. For these reasons, comparison of the survey area to the urban zone is indicative only. Survey effort has been calculated using a 20-metre buffer either side of GPS survey tracks. For the purposes of this analysis, the urban zone includes land zoned for future urban development plus transport corridors within the growth areas. It does not include any transport corridors outside the growth areas.



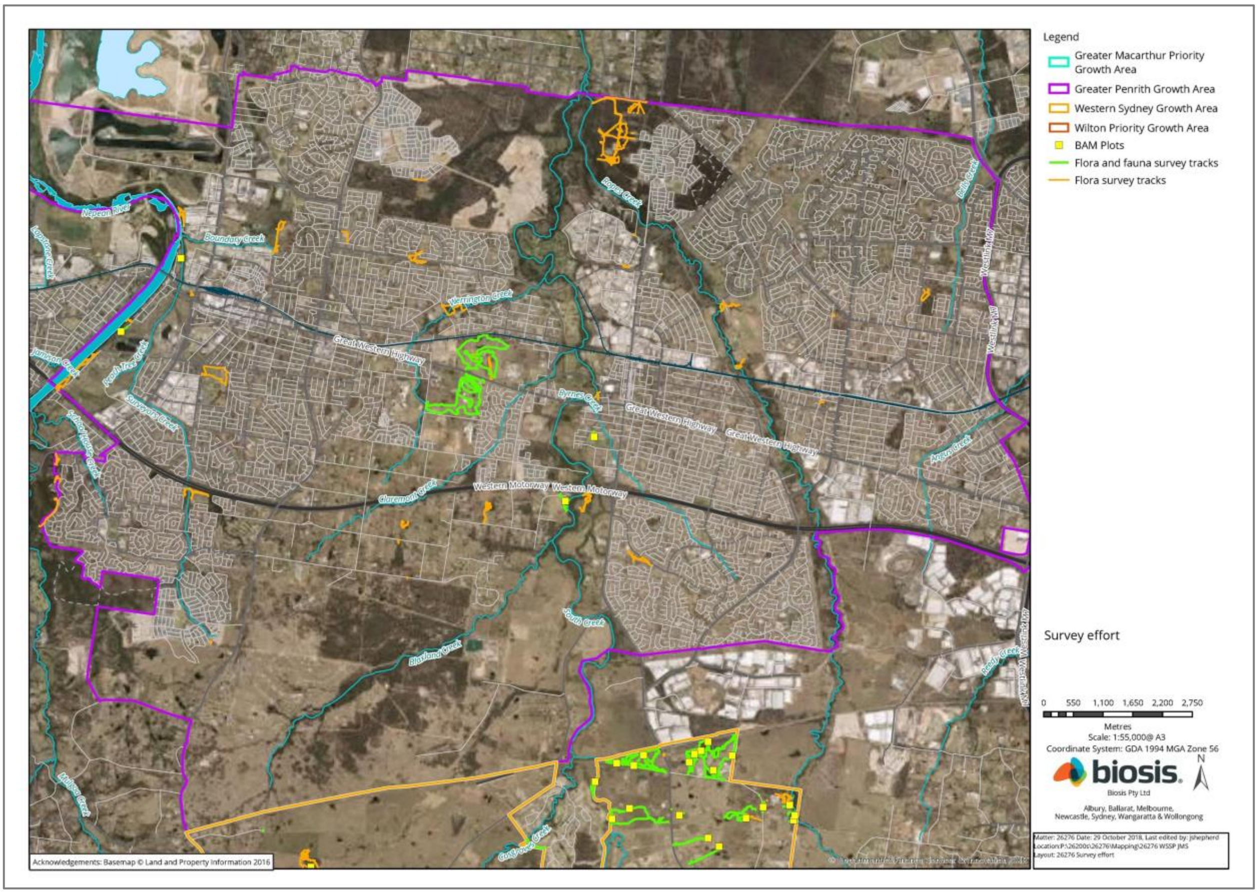
Map 4. GMGA survey effort (Biosis & Ecoplanning)



Map 5. WGA survey effort (Biosis and Ecoplanning)



Map 6. WSAGA ('Western Sydney') survey effort (Biosis and Ecoplanning)



Map 7. GPECGA survey effort (Biosis and Ecoplanning)

4.2.3 Survey constraints –timing / site conditions

As noted earlier, severe drought affected all of the study areas for some or all of the survey period. The Wilton and Greater Macarthur GAs were only surveyed during drought, whereas the Greater Penrith to Eastern Creek and the Aerotropolis GAs were surveyed both during intense drought and the subsequently slightly wetter conditions that followed in the Spring of 2018. Whilst wetter, drought remained present, and fellow Expert, Robert Miller, reported that vegetation was evidently drought-affected across all of the Growth Areas into November.

Drought, combined with increased intensity and extent of total grazing pressure, meant that affected surveys are likely to have under-recorded the target species compared to normal conditions. Whilst drought alone is unlikely to cause *P. nutans* to die back to rootstock or die and only remain as seedbank, when combined with increased herbivory due to drought, this is a far more likely outcome.

Irrespective of drought, surveys for this species are constrained by consideration of fire ecology, in that this species can be suppressed and even rendered apparently extinct at a site if the area has not been burnt for many years. Prolonged absence of fire is a constraint in some of the surveyed areas. Conversely, the species could be undetectable or not readily distinguished and identified in areas burnt recently. Areas burnt too often may also see the species suppressed or even eliminated. This is a factor in some of the survey sites closer to urban areas where a mix of hazard reduction burning and arson occur.

4.2.4 Survey constraint – surveys undertaken by generalists / non-experts

Whilst *P. nutans* is not regarded as a cryptic species, juveniles are small and infertile such that they could be missed, even by expert observers. It is more likely to be present but not recorded when surveyed by personnel not very familiar with the species and its ecology, particularly in terms of micro-habitat features. As an example, at least one young *Persoonia nutans* plant that was detected by fellow botanist, Robert Miller during survey for this Report had not been detected by consultants working for DPE, and who had recently been on that site.

Even when the prescribed OEH survey methods are used, a combination of site-based constraints, the species' ecology (e.g. dies back to seedbank without suitable disturbance), and a lack of familiarity with this species creates a situation where it is likely that it can present in plant form, but not recorded, or present only as seedbank, but not considered present because no plants were seen. *P. nutans* is one of several threatened plant species that should not be treated as absent, simply because it was not observed in plant form. If suitable habitat occurs, the species should be considered present unless there are clear reasons to rule otherwise. That approach is taken in this Report in relation to the designation of 'species polygons' (i.e. maps of where the plant is known or likely to occur).

4.3 Surveys completed specifically for this Report

I undertook a very brief survey of potential habitat for *P. nutans*, *A. bynoeana* and *A. pubescens* in the locality of Kemps Creek in mid-November 2018. Fellow botanist, Robert Miller was also present to survey for his target species. He examined some sites that I did not. He is very familiar with *P. nutans* and did not report its presence other than where he detected it and I subsequently reported it to the north of the previously documented occurrences.

The main remnant habitat in this locality is just to the south of the WSAGA but was checked by Miller for reference purposes (i.e. is the plant still present, is it still detectable during drought, what condition is the habitat in, etc.). That remnant was seen to be largely unmanaged and degrading due to several threats, and it is feasible that the species is now restricted to seed bank at that location, though it could be present on disturbance margins that were not traversed.

Relatively little potential habitat remains for this species in the WSAGA, and whilst little of this was available to be surveyed by me or by consultants engaged by DPE, all such habitat has been excluded from the proposed urban footprint.

Map 8. GPS track logs (purple lines)

I did not survey for any of my target species in the GPECGA because there is very little known and potential habitat for it there, and most of what remains is either reserved, or proposed for reservation by OEH. Surveying such areas would have added little or no information. Robert Miller did detect three new records of *P. nutans* in that area, one of which apparently duplicates an existing record. These were useful additions but do not alter my understanding of the species' ecology or distribution, and all are close to known occurrences. DPE offered access to a large area of remnant bushland in this Growth Area, but it is not mapped as suitable habitat for any of the species that I am addressing in Expert Reports, so I did not take up that offer.

I did not survey the WGA, as the species is not known from or likely to occur there.

I did not survey the GMGA, as only one small remnant of potential habitat exists there, and it was examined on my behalf by a Campbelltown Council officer familiar with the two relevant target species. A detailed survey was not undertaken and was not warranted given the nature of the habitat (highly modified and degraded, with much of it having a long history of being mown). Neither *P. nutans* or *Acacia bynoeana* was reported, but both were unlikely to be observable due to site conditions, though they may remain as seedbank. That habitat is on Council-managed parkland outside DPE's proposed urban footprint, so will not be biocertified. Having been alerted to the presence of a Threatened Ecological Community and potential habitat for these two threatened plant species, Council has recently commenced preliminary conservation work at this site.

4.4 Assessment of species' presence

4.4.1 Greater Macarthur Growth Area

The species is not known to be present in this Growth Area but may occur in or near four small patches of PCT 883 in Macquarie Fields, all of which is outside the proposed urban footprint. Other low-probability potential habitat occurs in the form of PCTs 1395 and 1081 north of Narellan Road. 1081 only occurs at one site in urban bushland associated with Smiths Creek in Leumeah. 1395 is more common but appears to be restricted primarily to generally small, often linear and likely degraded urban remnants from Glenfield, through Macquarie Fields, Ingleburn to Minto. It is unlikely to occur within the majority of this Growth Area because it was never suitable habitat or has been too heavily modified.

4.2.2 Wilton Growth Area

The species is not known nor likely to be present in this Growth Area due to it being outside the species' known geographic range by at least 20 km. The closely related *P. bargoensis* occurs in this Growth Area instead. Those species are separated by 40 km (Weston & Johnson, 1991). As of 2018, BioNet records for these species are separated by 24-28 km depending on the spatial accuracy of a record from Appin.

4.2.3 Greater Penrith to Eastern Creek Growth Area

The species is present in this Growth Area, but both known and likely habitat comprise a relatively small area in the central north, primarily with the gazetted or proposed sections of Wianamatta Regional Park. However, the proposed western addition appears to be at risk from further clearing and fragmentation to accommodate a large transport corridor. Potential and known habitat also occurs as patches along or near the M4 Motorway, roughly in the centre of this Area and to the east. The majority of this Growth Area was never suitable habitat for this species.

4.2.4 Western Sydney Aerotropolis Growth Area

The species is now known in this Growth Area from a single young plant, added during surveys associated with this Report. The extent of known and potential habitat is limited to a few patches of remnant vegetation in the localities of Kemps Creek and Badgerys Creek. Most of the WSAGA was always unsuitable habitat for this species based on geology, soil and plant community associations.

4.5 Assessment of suitable habitat for *Persoonia nutans*

4.5.1 Description and relative significance of potential habitat

As per the findings presented earlier in Table 3, combined with expert knowledge, the following PCTs are regarded as potential habitat for *P. nutans*. Not all of these PCTS are present in all Growth Areas, and not all occurrences or parts of these communities are likely to support the species in plant or seedbank forms. Wetter and sometimes more thickly vegetated areas associated with drainage lines are unlikely habitat, as this species prefers drier, more open conditions. Riparian buffer exclusions will be used as a component of the 'species polygons' discussed later. All vegetation condition classes are included except Derived Native Grassland:

Table 9. PCTs known or likely to be habitat for *P. nutans*

PCT	PCT Name	Relative significance
724	Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain	Moderate
725	Broad-leaved Ironbark - *Melaleuca decora* shrubby open forest on clay soils of the Cumberland Plain	Moderate
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Very High
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	Low
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain	Very Low

The following sections describe the relative habitat value and local occurrences of each PCT mapped in each Growth Area.

<u>Greater Macarthur Growth Area</u>

The vegetation mapping provided for use in the project indicates that there is **1903.97 ha** of potential habitat for this species in this Growth Area based only on the extent of the relevant PCT.

Table 10. Potential habitat in the GMGA

PCT	Distribution	Area (ha)	Relative habitat value of local occurrences
883	Four very small polygons in low condition at Macquarie Fields.	0.91	Very low to low. The species may regenerate here if issues of mowing, absence of fire, and intense weed invasion are remedied. Any resultant population would be isolated from core habitat and surrounded by unsympathetic land uses. However, there is some scope to improve the quality and quantity of habitat on this public land.
1081	Restricted to one remnant urban bushland surrounding Smiths Creek in Leumeah.	7.52	Low, as this PCT is only associated with this species at the atypical but nearby Simmos Beach population. The proximity of housing likely makes it difficult to burn this site with sufficient intensity to support this species in the long-term.
1395	Several remnants in the north of the Area from Glenfield to Minto. Other areas to the south are outside the species' accepted range.	1895.54	Very Low, as this PCT is also only associated with the species at an outlying site in the far north of its range. There are no records of the species from this PCT in or near any of the Growth Areas.

Wilton Growth Area

The species is not known or likely to occur in this Growth Area, which is outside its known or likely distribution, even though at least one of the associated PCTs is present here. That niche is occupied by the closely related *P. bargoensis* in this Area.

Greater Penrith to Eastern Creek Growth Area

The vegetation mapping provided for use in the project indicates that there is **272.35 ha** of potential habitat for this species in this Growth Area based only on the extent of the relevant PCTs. There was always very limited scope for the species to occur in this Area, and much less so as a result of historic and on-going land clearing.

Table 11. Potential habitat in the GPECGA

PCT	Distribution	Relative habitat value of local occurrences
724	Present primarily in the far central north but extending south in association with Eastern Creek, with very small patches near the M4 Motorway.	Moderate to High, and most of the spatially accurate records in this Growth Area are associated with this PCT.
725	Mapped only in the far north as small to medium patches that are largely within the gazetted and proposed parts of Wianamatta Regional Park	Moderate, though very small patches in urban areas are likely to be less viable.
883	Mapped to a very small extent only in the far central north. Only 1 polygon in Biosis map, and entirely within Wianamatta Regional Park's eastern portion.	Very High as a PCT, and there are records of the species nearby.

Western Sydney Aerotropolis Growth Area

The vegetation mapping provided for use in the project indicates that there is **92.80 ha** of potential habitat for this species in this Growth Area based only on the extent of the relevant PCT. Only a small area of habitat ever existed in this Area, and even less remains due to historic and on-going land clearing.

Table 12. Potential habitat in the WSAGA

PCT	Distribution	Relative habitat value of local occurrences
724	Present as several patches in the localities of Kemps and Badgerys Creeks, mainly surrounded by pastoral or industrial land use.	Moderate to High. Some areas have been degraded by overstocking of grazing livestock. Others have been cleared or largely-so.
725	Present as several small patches in the localities of Kemps and Badgerys Creeks, mainly surrounded by pastoral or industrial land use.	Moderate, though very small patches adjoining unsympathetic land uses are likely to be less viable. All remnants in this area appear to be degraded by earlier clearing, grazing and weeds.
883	No longer present in the revised PCT map but habitat intermediate with 725 is present.	Very High, if this PCT or similar vegetation is present in this Growth Area. Recent record nearby.

4.5.2 Species habitat polygons

Species habitat polygons generated by this report relate to the extent of potential habitat that is proposed to be cleared for urbanisation or related purposes, such as transport corridors. These habitat polygons and associated calculations were generated to inform biodiversity offset requirements. The data presented in this section does not deal with species habitat outside proposed urban zones as those areas are treated as conservation zones or are excluded from urban and associated transport zones for a range of reasons. For this species, species polygons (proposed clearing of habitat) are only recognised in Greater Penrith to Eastern Creek and Western Sydney Aerotropolis Growth Areas because the species is not predicted to occur in the Wilton Growth Area, and potential habitat in the Greater Macarthur Growth Area is outside the scope of proposed urban impacts.

The habitat polygons include all relevant condition classes of relevant PCTs as identified in this Report. In this case, all condition classes are included except Derived Native Grassland.

Graded riparian exclusion buffers were used in recognition that *P. nutans* does not occur in riparian vegetation or close to watercourses. The buffer distances used here increase with the mapped Strahler stream order as shown in Table 13. The accuracy of the buffers is limited by available data, including the mapped location of streams. The buffer is applied either side of the mapped stream centreline. Note that these riparian buffer distances are a different concept and serve a different purpose to those applied by DPE for the purposes of protecting streamside vegetation and watercourses in its planning within the Growth Areas.

Table 13. Stream exclusion buffers

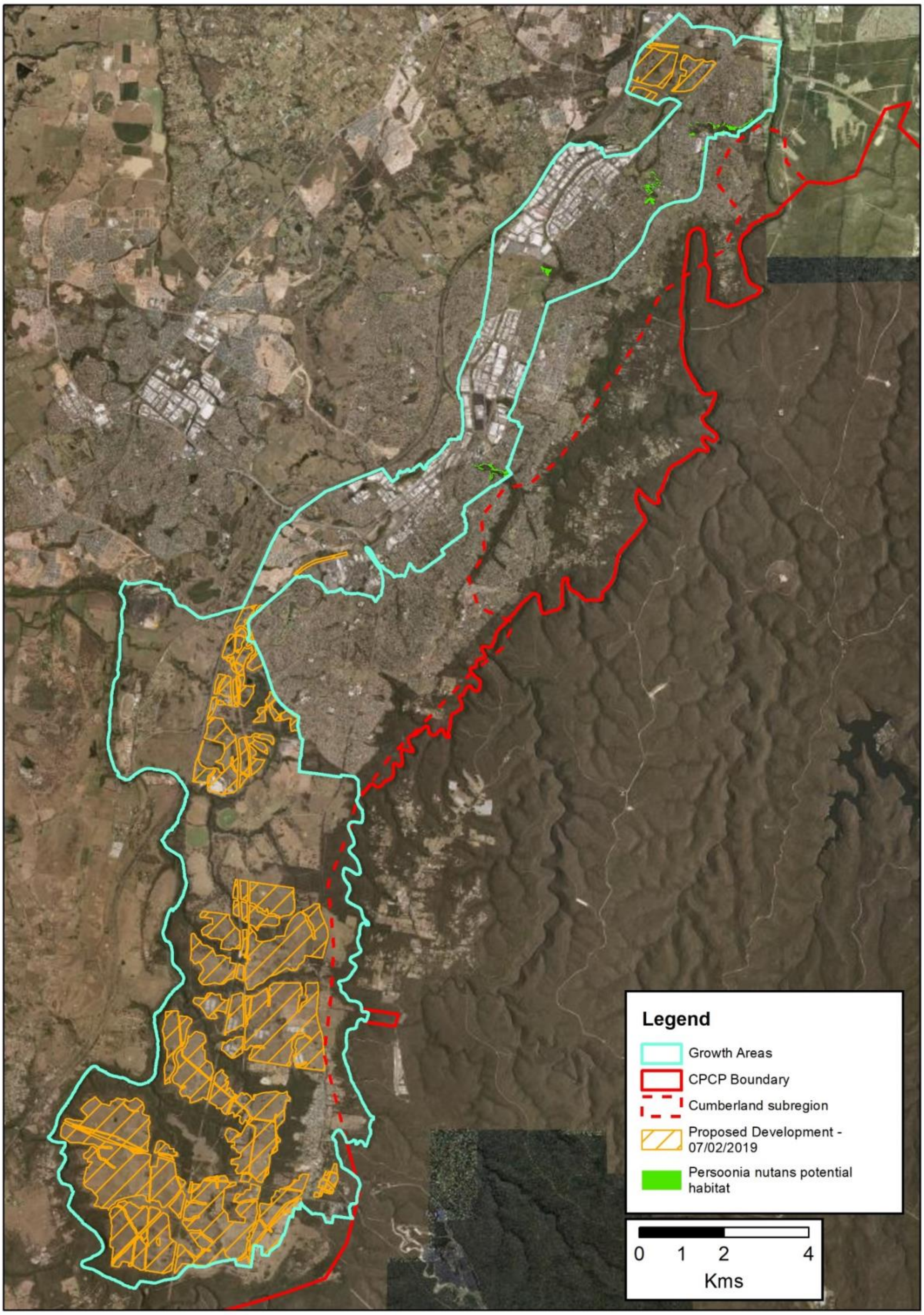
Stream order	Buffer distance (m)
1	5
2	10
3	20
4	30
5	40
6	50
7	70

Species habitat polygons in the form of GIS shape files were provided to the Biodiversity and Sustainability Branch of DPE in November 2018. The analysis of these shape files is presented in Table 14. These figures are based on precautionarily modelled *potential* habitat, and do not necessarily equate with *actual* habitat, nor do they provide any information of potential population sizes or population viability. It is unlikely that a large percentage of the potential habitat identified in this Report would actually support *P. nutans* because this species is naturally rare and patchily distributed, even though it can be locally abundant in favourable conditions.

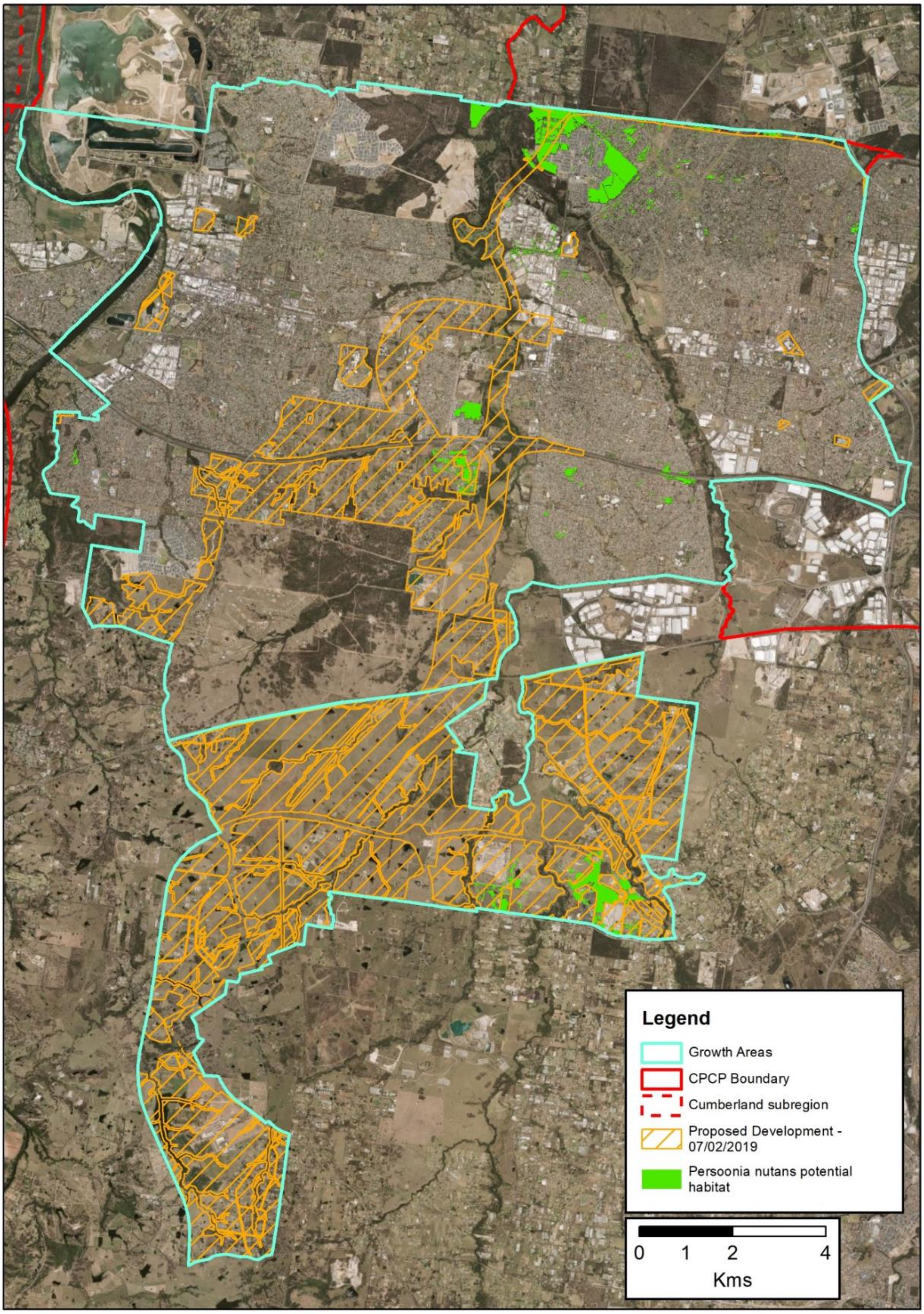
Table 14. Total of potential habitat and proposed removal of potential habitat

Growth Area	**Area of potential habitat (ha)**	**Area of potential habitat removal (ha)**	**% area of potential habitat removal by GA**
Greater Penrith to Eastern Creek	272.6	9.9	3.6
Western Sydney Aerotropolis	92.8	34.0	36.6
Greater Macarthur	23.6	0.0	0.00
Transport corridors **(all GAs)**	-	49.8	12.8
TOTAL	**389.0**	**93.7**	**24.1**

Map 9 Greater Macarthur - Potential habitat and proposed urban/transport habitat removal



Map 10 Greater Penrith & Eastern Creek plus Western Sydney Aerotropolis
– potential habitat and proposed urban/transport habitat removal



5. Summary and conclusion

Within the four Growth Areas, *Persoonia nutans* is currently only known from the Western Sydney Aerotropolis and Greater Penrith to Eastern Creek Growth Areas, with all currently known records outside the proposed urban areas, including transport corridors. Potential habitat for this species exists in all but the Wilton Growth Area, based on the species' known association with specified Plant Community Types, with other threatened plant species, and with Soil Landscapes, geologies, climate, etc. The most likely occurrences are within a subset of the Castlereagh Forests & Woodlands on Paleogene-Neogene alluvium. Atypical outlying populations are possible in habitat associated with the shale sandstone transition and the Mittagong Formation within the northern section of the Greater Macarthur Growth Area.

Based on current information, the proposed urban footprint and associated transport corridors of the three relevant Growth Areas would destroy 93.7 hectares of potential habitat for *P. nutans*. This equates to 24.1% of the area of potential habitat identified in those three Growth Areas. The actual extent of conflict between habitat for the species and proposed clearing for urbanisation is likely to be smaller as the species is naturally rare and patchily distributed. Not all of the area proposed for removal is of equal value as potential habitat, and different PCTs and condition classes have different probabilities of supporting *P. nutans*.

The greatest area of conflict between proposed urbanisation and the best quality / highest probability of occurrence potential habitat for this species is in the form of a proposed transport corridor through the western (apparently ungazetted) portion of Wianamatta Regional Park in the Greater Penrith to Eastern Creek Growth Area. Other significant conflicts arise in the form of the 'Urban Development Management Zone' of that Growth Area and to a greater extent, in the Western Sydney Aerotropolis Growth Area. Most such conflicts entail removal of vegetation condition classes below the Intact class. There is no conflict between potential habitat and proposed urbanisation in the Greater Macarthur Growth Area.

Because *P. nutans* is relatively tolerant, arguably dependent on some types of disturbance, and that it can persist in the soil seedbank, it may occur in areas that might generally be disregarded as potential habitat, and that may not be mapped as native vegetation. It is likely that highly modified sites that might support the species in some form are of relatively low significance for it in the context of the larger areas of more intact potential and known habitat that are excluded from urbanisation and associated clearing. It is also feasible that disturbance associated with urbanisation, particularly the creation of bushfire Asset Protection Zones (APZs) between bushland conservation areas and housing, could advantage this species, especially where the habitat has not burnt for many years. Thinning of the shrub layer by fire or mechanical means could favour the species, as may soil disturbance associated with fire trail construction. More frequent, moderate intensity burning of bushland that represents known or likely habitat for this species, may, within limits, also advantage it compared to low frequency and/or very cool burning.

The positioning of the bushland/urban interface and associated infrastructure such as APZs should have regard to this species' habitat and ecology, and appropriate buffers and other strategies are required to prevent direct and indirect harm to this species as a result of the urbanisation of adjoining lands. For example, potential habitat should not be compromised by the placement of housing nearby as might prevent that habitat being managed for conservation, especially in terms of bushfire risk management. DPE has informed me that the intention is for APZs to be accommodated within the proposed urban footprint, not in the non-biocertified bushland areas that may adjoin it.

The absence of records of this species from areas of potential habitat does not mean it could not be present because: not all areas have been surveyed historically or recently; all surveys have a range of limitations; not all discoveries of threatened species are disclosed or accurately mapped; and large areas of potential habitat are highly likely to have fire regimes that do not favour this species, meaning it may currently occur in very low numbers in dense and inaccessible habitat, or as seedbank, yet could appear in substantial numbers after an appropriate fire or equivalent disturbance. These factors have been considered in the preparation potential habitat maps and the associated generation of species habitat polygons that will inform DPE in relation to biodiversity offsetting obligations.

6. Information used in the assessment

6.1 DP&E or OEH resources

- BioNet data (internal access provided under license for use in this Expert Report and associated dataset cleaning for the purposes of species habitat modelling to meet EPBC Act requirements)
- Atlas of Living Australia on-line (partial use to check for records not in BioNet)
- EMU data (NSW Herbarium specimen database, provided by OEH)
- OEH on-line threatened species profile
- OEH Threatened Species Data Collection on-line
- OEH BioNet Vegetation Classification Database (previously known as VIS)
- EPBC Act Listing/Conservation Advice
- OEH PCT (vegetation) maps for Sydney Metropolitan and Cumberland Plain
- Field data and associated analyses from Biosis and Ecoplanning (consultancies engaged by DPE)
- GIS layers and maps provided by DPE and its contractors

6.2 References

Auld T.D., Denham A.J. & Turner K., 2007. "Dispersal and recruitment dynamics in the fleshy-fruited *Persoonia lanceolata* (Proteaceae)." *Journal of Vegetation Science* 18, 903-910.

Barker R.D. & Vestjens W.J.M., 1990. *The food of Australian birds 2. Passerines*. CSIRO Publishing, Australia.

Burcher, P., Lembit R., Walters, M. & Ford, B., 2016. *Targeted survey for* Persoonia nutans *in Agnes Banks Nature Reserve, Windsor Downs Nature Reserve, Wianamatta Regional Park and Castlereagh Nature Reserve*. Unpublished report to NSW OEH. Aquila Ecological Surveys, Cowan.

Department of Environment & Conservation (DEC), 2005. Persoonia nutans *(R.Br Nodding Geebung) Recovery Plan*. NSW DEC, Hurstville. http://www.environment.gov.au/system/files/resources/0558f476-00de-428b-887b-244aa58265b2/files/p-nutans.pdf [Accessed November 2018]

Ecological Surveys & Planning (S. David & S. Douglas), 2013. *Bushland Management Plan: 25 Miowera Road, Villawood*. Report prepared for Precision Paper Coatings and ARdesign. Ecological Surveys & Planning, Exeter NSW.

Emery N.J. & Offord, C.A., 2018. "Managing *Persoonia* (Proteaceae) species in the landscape through a better understanding of their seed biology and ecology." *Cunninghamia* 18: 089-107. https://www.rbgsyd.nsw.gov.au/getattachment/Science/Scientific-publications/Cunninghamia/BGD0520_Cunninghamia-2018-Emery-and-Offord.pdf.aspx?lang=en-AU [Accessed January 2019].

Fairley, A., 2004. *Seldom Seen. Rare Plants of Greater Sydney*. New Holland, Sydney.

Martyn, J. 2018. *Rocks and Trees: a photographic journey through the rich and varied geology, scenery and flora of the Sydney region*. STEP Inc., Turramurra.

McDougall, K. (November 2018), Senior Threatened Species Officer, OEH, Queanbeyan. *Personal communication in the context of an OEH review of* Persoonia marginata *for the purposes of updating the BAM Calculator and revising the species' conservation status*.

Myerscough P., Whelan R. & Bradstock R., 2000. “Ecology of Proteaceae with special reference to the Sydney region.” *Cunninghamia* 6, 951-1015.

National Parks and Wildlife Service (NPWS), 1996. *Conservation research statement and species recovery plan for* Persoonia nutans *R. Br.* Prepared for Australian Nature Conservation Agency by NSW NPWS, Hurstville.

National Parks and Wildlife Service (NPWS), 2002a. *NSW NPWS Fire Response database v1.3a*. NSW National Parks and Wildlife Service, December 2002.

National Parks and Wildlife Service (NPWS), 2002b. *Native vegetation maps of the Cumberland Plain, western Sydney*. NSW National Parks and Wildlife Service, Hurstville NSW.

National Parks and Wildlife Service (NPWS), 2004 (May). *Environmental impact assessment guidelines:* Persoonia nutans *R. Br.* NSW National Parks & Wildlife Service, Hurstville. http://www.environment.nsw.gov.au/resources/nature/PersooniaNutans0805EIA.pdf [Accessed July 2018]

NSW Department of Environment & Conservation (DEC), 2005. Persoonia nutans *(R.Br Nodding Geebung) Recovery Plan*. NSW DEC, Hurstville. http://www.environment.gov.au/system/files/resources/0558f476-00de-428b-887b-244aa58265b2/files/p-nutans.pdf [Accessed July 2018]

NSW Office of Environment & Heritage (OEH), 2013. Remnant vegetation of the western Cumberland subregion, 2013 update (VIS_ID 4207). https://datasets.seed.nsw.gov.au/dataset/e0bed919-8e8b-45a0-803d-bcfb2a2d47e3 [Accessed November 2018].

NSW Office of Environment & Heritage (OEH), 2017. *Nodding Geebung – profile*. https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10598 [Accessed November 2018].

Paton D.C., 2000. “Disruption of bird-plant pollination systems in southern Australia”. *Conservation Biology* 14, 1232-1234.

SEWPaC, 2012, *Interim Biogeographic Regionalisation for Australia, Version 7.* Department of Sustainability, Environment, Water, Population and Communities. http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/maps.html

Weston, P.H. and Johnson, L.A.S., 1991. ‘Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales’. *Telopea* 4(2): 269-305. http://plantnet.rbgsyd.nsw.gov.au/emuwebnswlive/objects/common/webmedia.php?irn=75767&reftable=ebibliography [Accessed November 2018]

Weston P., 2003. “Proteaceae subfamily Persoonioideae. Botany of the Geebungs, Snottygobbles and their relatives.” *Australian Plants* 22, 62-78.

Wotherspoon, D., 2002. *Flora and Fauna Report for Lot 12 London Place, Grose Wold: a proposed rural residential subdivision.* Unpublished report to Philips Fox. Blue Mountains Wilderness Services P/L, Springwood.

7. Acknowledgements

I acknowledge the contributions of DPE staff, particularly Dayle Green, Greg Steenbeeke and Christian Marando (GIS), and DPE contractor Darren James (GIS) in the preparation and refinement of this document and associated maps. My contractor, Rhys Grogan, also assisted with GIS output in the form of drafts of the species potential habitat polygons. OEH staff assisted with some aspects of data availability and with the processing of many amendments to BioNet records.

Consultant botanist, Robert Miller assisted with fieldwork at Kemps Creek, and provided information about field observations associated with searches for his target species and with opportunistic sitings of my target species. Consultant ecologist, Paul Burcher of AES, kindly provided access to his targeted survey data and associated report to OEH / NPWS; and provided images of the species taken by Ben Ford. Botanist and bush regenerator, Colin Gibson, provided important information about the history and current status of the Villawood population, and the exact location of associated plants. The latter enabled refinement of the associated BioNet data. Consultant ecologist, Danny Wotherspoon provided information about the species' northwestern outlier, which also allowed the NSW Herbarium records and BioNet entries to be spatially corrected.

8. Statement of professional independence

Whilst I was engaged and funded by DPE to prepare this Expert Report, and a series of draft reports and maps were reviewed by DPE staff, I was not coerced by DPE to amend my work in any manner that I did not otherwise agree with. I believe that I had appropriate professional independence in the preparation of this document and associated maps.

I declare that I do not have any personal or commercial conflict of interest in the preparation of this Report. I do not own real estate or businesses with property in the Growth Areas, nor do I have other active clients with real estate or associated commercial interests in the Growth Areas.

9. Appendix 1. Author's *Curriculum Vitae*

Dr Steven Douglas (BSc., MEnv. Plan., PhD.)

I have over twenty years of experience as an ecologist and environmental planner, primarily in New South Wales, with some experience in the ACT, Victoria and South Australia. I have worked for all levels of government, for environmentalist non-government organisations (NGOs), and for a large number of private clients ranging from individuals to multinational firms, directly and as a subcontractor. I have often worked as a sole consultant but have also collaborated with other specialists and have sometimes been part of large teams involved in large-scale, even interstate projects.

I specialise in the detection, management and conservation of rare and threatened flora species and communities, and in associated ecological impact assessment and mitigation. I have qualifications and experience in a range of general and specific ecological, social, organisational and 'sustainability' fields. I have served on environment-related ministerial committees and have held other ministerial appointments in NSW, including those dealing with bushfire management. I have published in journals dealing with plant conservation, environmental law and policy, social science, and ecological ethics. Aspects of my work have been published by government, prominent NGOs, and in the popular press and other media.

This CV only contains content directly related to my botanical expertise.

Employment summary

1996 to present:

Self-employed, trading as *Ecological Surveys & Planning* (www.ecologicalsurveys.net)

Through this enterprise, I have undertaken a large number of consultancies for public and private sector clients including environmental impact assessment and mitigation; threatened biota research, profiling and management; vegetation mapping; preparing management plans for conservation estate; providing environmental planning and catchment management advice; advising on bushfire risk management; acting as an expert witness in Land & Environment Court proceedings; and developing organisational sustainability policies and practices.

July 2017 to July 2018:

Senior Ecologist, NSW Office of Environment & Heritage (NVIS, Science Division)

My work on the project below led to OEH retaining my services to research and document problems with the description, interpretation and mapping of Threatened Ecological Communities (TECs) statewide. This project provides advice to OEH, the NSW Threatened Species Scientific Committee, and through those agencies, to the Commonwealth Threatened Species Scientific Committee. It identifies technical issues with the description of TECs and their mapping, as well as wider problems of how TECs are defined. It draws on a major project undertaken by OEH for the NSW EPA and Forestry Corporation, in which TECs of the east coast and ranges were assessed and mapped for regulatory purposes on forestry estate. However, my work includes many more TECs and recent information emerging from Save Our Species project panels.

November 2015 to July 2017:

Team Leader, NSW Office of Environment & Heritage (NVIS, Science Division)

This project in Wingecarribee Shire is the first in which OEH's vegetation mapping team has worked at a very fine scale for a single local government area. The project entails auto-segmentation of digital aerial photography; supervising contract vegetation sampling; conducting strategic sampling; modelling of most vegetation communities; describing new communities; and extensive remote and on-ground map validation. I was hired partly because of my extensive familiarity with much of the vegetation of this geodiverse and biodiverse region. The role included supervision of two staff; liaison with consultants; and substantial networking with OEH and Wingecarribee Council staff. An update of vegetation classification will occur from mid 2019 onwards, and I have drafted a peer-reviewed journal article about the project that will be submitted for publication.

1995/6:

Project consultant, then Project Manager, Urban Bushland Biodiversity Survey (NPWS)

The Urban Bushland Biodiversity Survey was undertaken by the NPWS to compile comprehensive data on indigenous flora and fauna in twelve local government areas in Western Sydney. Contracted initially as a consultant to design and scope the project, I was later employed as Project Manager. Responsibilities involved an extensive literature review, preparation of a project plan and a background paper for the Survey and the overall management of the project including up to twelve staff and several consultants. The major focus was on coordinating research work, fauna and flora field surveys, and a community liaison and media campaign. Extensive flora survey work and scientific data analysis was undertaken. I provided a tour of important vegetation sites for the South Creek Catchment Management Committee. I also wrote media releases and conducted various media events including a live-to-air interview on ABC Radio National, and filming of a story in the field for the Totally Wild program.

1994:

Catchment Environment Officer (*Hawkesbury City Council*).

The project was funded by a grant from the former Hawkesbury-Nepean Catchment Management Trust and had the objective of identifying land uses on riverside properties to assess their potential to generate water pollution. The information on land use and riparian vegetation was primarily gained from aerial photo interpretation, limited land-based inspections and several water-based inspections, and was recorded in a GIS. Work site inspections, pollution control on agricultural lands, community meetings, site visits with landowners, and facilitating the formation of a Landcare group in the Sackville area.

1993/4:

Technical Officer (*Hawkesbury-Nepean Catchment Management Trust*).

Work included assisting with the preparation of a vegetation management strategy for the Trust and the outline of a revegetation strategy for South Creek. Other responsibilities involved providing scientific advice for development assessments, the preparation of hard copy and computer-based catchment maps, and advising on the implementation of revegetation projects in the catchment.

Ministerial appointments

- Appointed a member of the **National Parks & Wildlife Service Regional Advisory Committee** (South Coast) (2010-mid 2018). I opted not to reapply for this role after serving two terms. The restructure of the NPWS meant that the Committee would operate from Wollongong to the Victoria border and inland to the Tablelands. This was logistically fraught, and the role of RACs was evidently being diminished, with larger areas to manage but less meetings held.
- Appointed a member of the **NSW Sustainability Network** (2001), part of the Sustainability Advisory Council reporting to the Minister for Planning. I did not take up this position due to my relocating to Victoria.
- Nature Conservation Council representative on the former NSW **Native Vegetation Advisory Council** (1999-2001) reporting to the Minister for Land & Water Conservation under the Native Vegetation Conservation Act. I served as a member of the Regional Vegetation Planning Subcommittee, which amongst other matters, reviewed draft Regional Vegetation Management Plans and Codes of Practice for activities such as native forestry and timber plantations. I was particularly involved in reviewing and recommending amendments to the Code of Practice for plantation forestry. I resigned due to my relocating to Victoria.
- Nature Conservation Council representative on the former **Southern Catchment Management Board** (June 2000 - March 2001). I resigned due to relocating to Victoria. I expressed my dissatisfaction with the design of the catchment boards and recommended to the Minister that they be replaced with the Catchment Management Authority model used in Victoria. The Boards were later replaced with such Authorities.
- Nature Conservation Council representative on Baulkham Hills and Hornsby-Ku-ring-gai **District Bushfire Management Committees** (1995-2001).
- Australian Conservation Foundation representative on the former **Environmental Works Community Audit Committee** reporting to the Minister for Environment in relation to the Special Environment Levy imposed by the then Water Board (1993-5). I completed my term when the Committee concluded its business and dissolved upon acceptance of its final report by the Minister.

Tertiary qualifications & titles

Adjunct Research Fellow

School of Philosophical, Historical & International Studies, Monash University, 2014-16

Doctor of Philosophy

Fenner School of Environment & Society, The Australian National University, 2004-7

The research was undertaken in the transdisciplinary Human Ecology Program and covered fields such as ecological philosophy, ecotheology, environmental policy-making, policy evaluation, organisational change, and critical systemic analysis. My thesis was passed unanimously and unamended by one Australian and two USA-based professors. I was awarded a $10,000 Publication Fellowship by the Fenner School and have since published aspects of my research.

Master of Environmental Planning

Macquarie University Grad. Sch. Env., 1994-96

This course included environmental law and politics, community involvement in planning, environmental education, development approval processes, urban planning, EIA, environmental science/fieldwork and heritage management. The dissertation component involved a pioneering report on the significant flora of the Greater Cattai Region (Cattai subcatchment) in north-western Sydney and led to my being offered employment with the NSW NPWS to design and manage a biodiversity survey of western Sydney.

Bachelor of Science

Macquarie University, 1990-93

My degree majors are Resource and Environmental Management, Land Management, and Plant Biology/Ecology.

Graduate Certificate of Research Information Literacy

The Australian National University, 2004-7

This course included advanced word processing, citation management, literature gathering (including on-line literary databases and other Internet sources), on-line publishing, presentation software, and thesis production.

Professional memberships

- Founding member of the Ecological Consultants Association of New South Wales (did not renew due to my relocating to Victoria and later to the ACT).
- Member of the NSW Environmental Defenders Office (EDO) Scientific Advisory Service (continuing).

Threatened biota experience

The following threatened plant species and populations and threatened ecological communities (TECs) have been engaged with in the various forms and processes listed below. The list is not complete, and some processes are on-going. I also successfully nominated three Key Threatening Processes under the TSC Act: Bushrock Removal; Clearing of Native Vegetation; Competition from European Honey Bee.

Species / population	Work conducted
Acacia bynoeana	Fieldwork, research, successful nomination, monitoring, advice to authorities, expert witness, rediscovered lost population, documented new population near range limit, PAS2 review, SOS review panel, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
A. gordonii	Fieldwork, successful nomination, advice to NPWS, PAS2 review, SOS research and monitoring program (fire ecology, BMtns NP), review and amendment of BioNet dataset.
A. prominens	Successful nomination of Endangered Population
A. pubescens	Fieldwork, contribution to Recovery Plan, confirmed disjunct southern populations, nominated population, PAS2 review, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Ancistrachne maidenii	Fieldwork, research, successful nomination, advice to NPWS, CAM review
Asterolasia elegans	Fieldwork, species profile, advice to Council and NPWS
Baloskion longipes	Research linked to *Carex klaphakei*, review of BioNet records, advice to OEH
Boronia deanei	Research, SOS review, CAM review, advice to OEH
Bossiaea oligosperma	SOS fieldwork, review of records (NW population), report to OEH, establishment of monitoring plots in Yerranderie SCA
Callistemon linearifolius	Fieldwork, research, successful nomination, advice to RMS and NPWS, PAS2 review
Callistemon megalongensis	Co-described new species, successful nominations (listing then upgrade), fieldwork, advice to Council and OEH, PAS2 review, SOS monitoring program (OEH, BMCC, on-going)
Callistemon purpurascens	Described new species, fieldwork, successful nominations, advice to Council and OEH, SOS monitoring project (2018 on-going)
Calotis glandulosa	Fieldwork (new and extended populations, Kosci NP), CAM review
Calotis pubescens	Fieldwork (new population, Kosci NP), CAM review
Carex klaphakei	SOS research project and recommendation for monitoring; resolved errors in BioNet records

Species / population	**Work conducted**
Commersonia prostrata	PAS2 / PKF research, fieldwork, advice to NPWS and OEH, documentation and monitoring of new and known populations for Forestry Corp, designed recovery actions for populations in Wingello and Penrose SFs
Cullen parvum	Fieldwork, located new NE population, report to NPWS
Dampiera fusca	Research, fieldwork, successful nominations, monitoring program for ACT Parks & Conservation, advice to NPWS and OEH, CAM review
Darwinia biflora	Fieldwork, research, contributor to Recovery Plan, PAS2 review, review and amendment of BioNet dataset.
Darwinia glaucophylla	Fieldwork, research, successful nomination, advice to NPWS, PAS2 review
Darwinia fascicularis ssp. *oligantha*	Fieldwork, research, successful nomination of population
Darwinia peduncularis	Research, successful nomination, CAM review
Dillwynia tenuifolia	Fieldwork, research, successful population nominations, advice to OEH
Epacris purpurascens var. *purpurascens*	Fieldwork, research, nomination, new SW range limit (Nattai NP), advice to NPWS/OEH
Eucalyptus aggregata	Research, successful nomination of species and population, fieldwork (Wingecarribee Shire) and advice to Council and OEH, CAM reviews
E. aquatica	Fieldwork, advice to Council and Forestry Corporation
E. sp. *Cattai*	Successfully argued for recognition of this entity as a new species, successful nomination, fieldwork, PAS2 review, advice to OEH, SOS project panel
E. kartzoffiana	Fieldwork, research, expert witness
E. macarthurii	Fieldwork, research, successful nominations, advice to Council and OEH
E. parvula	Fieldwork (Wadbilliga NP), CAM review
E. pulverulenta	Fieldwork (Bredbo Hills), CAM review
Galium australe	PAS2 research, recommended taxonomic review of most records in NSW based on Herbarium assessment, advice to OEH, CAM review
Grevillea juniperina ssp. *juniperina*	Fieldwork, research, advice to OEH (Colebee NR offset site)
Grevillea molyneuxii	Fieldwork, advice to OEH for CAM review
Grevillea parviflora ssp. *parviflora*	Fieldwork, research, expert witness, review and amendment of BioNet dataset.
Grevillea parviflora ssp. *supplicans*	Fieldwork, research, nomination, advice to NPWS
Grevillea raybrownii	Fieldwork, research, nomination and advice to NSWSC – listing pending
Gyrostemon thesioides	Successful nomination
Helichrysum calvertianum	Fieldwork, research, nomination, advice to NSWSC – listing pending
Hibbertia fumana	Research, minor fieldwork, expert witness
H. incana (syn. *superans)*	Successful nomination of population then species
H. praemorsa	ROTAP, researched, fieldwork (informal)
H. puberula ssp. *furcatula*	Fieldwork (incidental) documenting new occurrence, advice to OEH/NPWS
H. puberula ssp. *puberula*	Research, minor fieldwork with R. Miller, expert witness
Homoranthus binghiensis	CAM review (recommended changing to CE)
Keraudrenia corrolata var. *denticulata*	Successful nomination of population
Lasiopetalum joyceae	Fieldwork, research, successful nomination, species profiling for Council and NPWS, PAS2 review

Species / population	Work conducted
Leptospermum deanei	Fieldwork, research into hybridization with *L. trinervium*, advice to RBG, Council, OEH
Leucopogon fletcheri ssp. *fletcheri*	Fieldwork, research, successful nomination, advice to OEH and NPWS
Melaleuca deanei	Research, fieldwork, successful nominations, advice to NPWS/OEH and species profile for Council, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Olearia cordata	Fieldwork and report to NPWS, PAS2 review
Persoonia acerosa	Fieldwork, PAS2 review, SOS monitoring plots, advice to Council and OEH
Persoonia bargoensis	Fieldwork, research, successful nomination, PAS2 review, CAM review, review and amendment of BioNet dataset.
Persoonia hirsuta	Fieldwork, research, nominations of species and population, PAS2 review, review and amendment of BioNet dataset.
Persoonia glaucescens	Fieldwork, nomination, report to NPWS, PAS 2 review, CAM review, review and amendment of BioNet dataset.
Persoonia marginata	Fieldwork and report to OEH, CAM review
Persoonia mollis ssp. *revoluta*	Fieldwork, research, advice to OEH and Forestry Corp., nomination as Vulnerable - listing pending
Persoonia nutans	Fieldwork, nomination, advice to OEH, review and amendment of BioNet dataset. Nominated by DPE and recognised by OEH as a species expert under BC Act (Nov 2018).
Phyllota humifusa	PAS2 fieldwork and research; advice to NPWS, OEH, Council, Forestry Corp (monitoring plots, reduced APZ width), review of BioNet dataset.
Pimelea curviflora var. *curviflora*	Fieldwork, research, successful nomination, advice to OEH
Pomaderris brunnea	Incidental fieldwork and documentation of new populations and range extension; review and amendment of BioNet dataset.
P. cotoneaster	Fieldwork, research, advice to Council, NPWS, OEH, liaise with ANBG seed collectors, CAM review
P. sericea	PAS2 research (review of records and habitat), recommended consideration of Presumed Extinct or at least CE
Pultenaea elusa	PAS2 research (review of records and habitat), recommended Presumed Extinct
P. glabra	SOS fieldwork and monitoring plots. Review of Mts Wilson/Irvine records resulted in these being reallocated to an undescribed species given the interim name, *P. monticola*.
P. parviflora	SOS fieldwork and report to OEH (Colebee NR offset site); review and amendment of BioNet dataset.
P. pedunculata	Fieldwork, research, expert witness, CAM review
Solanum armourense	PAS2 fieldwork, research, report, advice to OEH, CAM review
S. celatum	Fieldwork, research, new populations (new range limit and habitat), advice to OEH, CAM review
Tetratheca glandulosa	Fieldwork, PAS2 review, advice to OEH and Cwlth DEE re conservation status
Triplarina nowraensis	SOS fieldwork, review of BioNet records, advice to OEH/NPWS, establishment of monitoring plots
Zieria involucrata	Fieldwork, input to Recovery Plan, CAM review
Zieria murphyi	Liaise with ANBG, fieldwork, advice to OEH

Threatened Ecological Communities (TECs)

My work for OEH in reviewing all NSW and EPBC Act TECs in the State has given me at least some familiarity with most of these entities and builds on already-strong knowledge of some. I have also been an expert witness in cases involving some of these communities – some entailing basic reviews and advice, and others involving in-depth considerations. All of the EPBC Act parallel listings are not included here unless I was involved in a particular nomination:

Ecological community	Nature of engagement
Blue Gum High Forest	Successful nomination, expert witness
Blue Mountains Basalt Cap Forest	SOS panel
Blue Mountains Shale Cap Forest	Successful nomination, SOS panel
Blue Mountains Swamps	Fieldwork, mapping, advice to BMtns Council, modelling
Castlereagh Scribbly Gum Woodland	Successful nomination, advice to DEE re Cwlth listing, expert witness
Cooks River / Castlereagh Ironbark Forest	Advice to DEE for EPBC Act listing
Cumberland Plain Woodland	Correction of OEH mapping, fieldwork, assessments, advice to Councils and NPWS
Eastern Suburbs Banksia Scrub	Major review for DEE Recovery Plan update, advice to OEH
Elderslie Banksia Scrub Forest	Major review for DEE Recovery Plan, SOS panel
Illawarra Lowlands Grassy Woodland	DEE review panel for EPBC Act listing
Lowland Grassy Woodland & Forest of SE Corner Bioregion	Successful nomination
Maroota Sands Swamp Forest	Successful nomination, SOS panel
Melaleuca armillaris Tall Shrubland	fieldwork, mapping, advice to OEH
Montane Peatlands & Swamps	Fieldwork, modelling and mapping, advice to OEH
Mount Gibraltar Forest	Detailed review for modelling and mapping, and advice about revised listing, advice to DEE re Upland Basalt Eucalypt Forest inclusion of NSW TECs
O’Hares Creek Shale Forest	Research and review for modelling and mapping
Pittwater & Wagstaffe Spotted Gum Forest	Successful nomination
Riverflat Eucalypts Forest on Coastal Floodplains	Successful nomination (component), research, modelling and mapping (limited extent)
Robertson Basalt Tall Open-forest	Modelling and mapping, advice to NSW SC
Robertson Rainforest	Modelling and mapping
Shale/Gravel Transition Forest	Mapping, TEC review
Shale/Sandstone Transition Forest	First to describe this concept c. 1996 based on Masters research. Formally published as a concept in NPWS (1997, UBBS). Successful nomination, research, major review and advice to DEE for EPBC Act listing, modelling and mapping
Southern Highlands Shale (Forest &) Woodland	Major contributor to DEE listing, drafting of Listing and Conservation Advices, advice to OEH about revision of NSW listing, modelling and mapping. Contracted to prepare listing for upgrade to CE.
Subtropical & Temperate Coastal Saltmarsh (EPBC Act)	Funded to prepare successful nomination
Sun Valley Cabbage Gum Forest	Successful nomination, mapping, advice to Council, SOS project panel
Swamp Sclerophyll Forest on Coastal Floodplains	Allied major research project cited in the Final Determination, TEC review (gap analysis)

Ecological community	Nature of engagement
Sydney Turpentine Ironbark Forest	Successful nomination, mapping, advice to Councils and to OEH/SC about revision
Tablelands Basalt Forest	Research, expert witness, advice to OEH about revision, modelling and mapping
Tablelands Snow Gum…Grassy Woodland	Fieldwork documenting new occurrences, modelling and mapping, advice to OEH
Upland Basalt Eucalypt Forest (EPBC Act)	Major contributor to DEE listing of this composite community that includes several NSW TECs. Draft Listing and Conservation Advices
Western Sydney Dry Rainforest and Moist Shale Woodland	SOS panel, TEC review

Publications / presentations / media

Ecology / conservation / environmental law & policy / ecological ethics

Refereed journal articles

Douglas, S.M. and Wilson, P.G. 2015. "Callistemon purpurascens (Myrtaceae): a new and threatened species from the Blue Mountains region of New South Wales, Australia". *Telopea* 18: 265-272

Douglas, S.M. 2000. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link". *Australasian Journal of Natural Resources Law & Policy*, 6(2)

Conference proceedings

Douglas, S.M. 2003. "Ecological offsets – what's the idea?" in Morrison, C. (Ed.) *Urban bushland and remnant vegetation: toolkits for a sustainable future – conference proceedings*. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 2001. "Local Government & the Threatened Species Conservation Act: the greatest potential; the weakest link"; in Newton, S. (Ed.) *Bushland or buildings? The dilemma for biodiversity conservation in urban areas* – conference proceedings. Nature Conservation Council of NSW, Sydney

Douglas, S.M. 1998. "The Threatened Species Conservation Act; a consultant's perspective" in *On the brink; your bush, their habitat, our Act.* Threatened Species Network, Nature Conservation Council of NSW, and Environmental Defenders Office, Sydney

Book chapters

Douglas, S.M. 1999. "Development & Sydney's threatened biota" in *Greenprint for Sydney: an environmental strategy for the 21st Century*. Total Environment Centre, Sydney, NSW

Professional reports

Douglas, S.M. & Anderson, J.R.B. 2002. Eucalyptus robusta *(Swamp Mahogany) communities and their conservation status in New South Wales*. Swamp Mahogany Project, Central Coast Community Environment Centre, Newcastle University Campus, Ourimbah

Douglas, S.M. 1997. "Local Government Area Reports: Baulkham Hills Shire", in James, T. (Ed.) *Urban Bushland Biodiversity Survey* (Stage 1, Western Sydney) Flora Appendices Vol. 2. NSW National Parks & Wildlife Service, Hurstville

Edited but not refereed publications

Douglas, S.M. 2014. "When biosecurity is threatened from within: the case of the native environmental weed, Pittosporum undulatum". *Australasian Plant Conservation*, 23(2)

Douglas, S.M. 2009. "Black Gum: a threatened tree of upland New South Wales and Victoria." *Australasian Plant Conservation*, 17(4)

Douglas, S.M. 2009. "Species profile and monitoring of Dampiera fusca". *Australasian Plant Conservation*, 17(3)

Douglas, S.M. 2006. "Endangered plant discovered" (St. Clements Retreat, Galong). *Biodiversity Research Newsletter*, 20, p.4, July, NSW Department of Environment & Conservation, Hurstville.

Douglas, S.M. 2006. "Endangered plant discovered (*Cullen parvum*) at St. Clements Retreat, Galong". News of Friends of Grasslands, November-December, p7

Douglas, S.M. 2005. "Phoenix flora: a post-fire discovery in the ACT". *Australasian Plant Conservation*, 13(3)

Douglas, S.M. 2004. "Phoenix flora" (re Dampiera fusca). *Journal of the Australian Native Plant Society Canberra Region*, 14(2), December

Douglas, S.M. 2003. "Mysteries of the Megalong Valley: another rare plant for the Blue Mountains." *Australasian Plant Conservation*, 12(1)

Douglas, S.M. 2001. "Land of the living dead – tree decline in urban areas". *Environment NSW* (newsletter of the Nature Conservation Council of NSW), September

Douglas, S.M. & Newton, S. 2000. "Bushland weeds – more on native weeds". *Environment NSW*, December

Douglas, S.M. 2000. "Regional Parks". *National Parks Journal* Vol. 44 (5 & 6) (journal of the National Parks Association of NSW)

Douglas, S.M. 1996. "Community biodiversity surveys". *National Parks Journal*, 40(3)

Douglas, S.M. 1996. "Mapping our urban bushland". *The Gardens*, Spring (journal of the Royal Botanic Gardens, Sydney)

Douglas, S.M., Bolesic, T. and Ware, K. 1994. "Healing the Hawkesbury: start with bushland protection". *National Parks Journal*. 38(4)

Public media coverage

2004, November 6. "Bright flowering spot after fire" - discovery of Dampiera fusca – a new genus and nationally significant species for the ACT and a new northern limit for the species. *Canberra Times*

2004. Live-to-air interview re discovery of *Dampiera fusca* in Namadgi NP, *ABC 666* AM Radio, Canberra

1996. Live to air interview re NPWS Urban Bushland Biodiversity Survey, *ABC 2BL* AM Radio, Sydney

1996. Pre-recorded TV segment re discovery of several nationally threatened plants in the one location during surveys for NPWS UBBS. *Totally Wild* program, Channel 10, Sydney

Consultancy projects

Short descriptions of the many larger projects that I have been involved in are available at http://ecologicalsurveys.net/?page_id=10, and a list of smaller projects is at http://ecologicalsurveys.net/?page_id=14

Voluntary and other works

- Assist **International Union for the Conservation of Nature (IUCN)** with a review of the conservation status of *Proteaceae* in eastern Australia (Melbourne, 2019).
- Assist **NSW Environmental Defenders Office** with a review of NPWS monitoring proposals to assess the effects of permitting horse riding in declared Wilderness areas (Kosciusko National Park) (2014).
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Noxious Weeds Act 1993 (in 2011)
- Assist **NSW Environmental Defenders Office** in the preparation of its submission to the NSW Government's review of the Threatened Species Conservation Act 1995 (in 2010)
- Assist discoverers (**Blue Mountains Bushcare**) of a previously undescribed *Epacris* species (*E. apungens* Coleby & Brown) in south Leura to prepare an article for the journal, *Telopea*, describing this species and its ecology
- Assist **NPWS** with a search for the ultra-endemic and rare rainforest plant, *Thismia clavarioides*, in Morton National Park (2010)
- Expert panel member assisting **Hawkesbury-Nepean CMA** with its Draft Climate Change Vulnerability Assessment for selected threatened ecological communities of the NSW Southern Highlands (2010)
- Assist PhD student, David Field (**University of Wollongong and CSIRO**) with information about the ecology, distribution, and conservation status of *Eucalyptus aggregata* (Black Gum) (2007)
- Fieldwork assisting with group preparation of vascular plant species lists in numerous NPWS and ACT Parks reserves in the Southern Tablelands area. **Australian Native Plants Society** (2003-2007)
- Searches for *Euphrasia scabra* (critically endangered) in Packers Swamp and Nunnock Swamp. Discovered new population (3rd in NSW) in unnamed swamp, SE Forests National Park. **Friends of Grasslands** (2004)
- Assistant part-time editor of "*Danthonia*" (now *Australasian Plant Conservation*), the journal of the **Australian Network for Plant Conservation** Inc., Canberra (2002-2003)
- Assist PhD student, David Clunas (**University of Wollongong**) with review of his research in the ecology of the nationally Rare, *Pultenaea villifera* var. *villifera* (2002)
- Provide technical assistance to four final year undergraduate Environmental Science students (**Australian Catholic University**) working in Marramarra National Park, (c. 2000)
- Discovery of and subsequent surveys for *Persoonia hirsuta* ssp. nov. 'Yengo NP'. **NPWS/RBG**
- Vascular flora and fauna (microchiropteran bats) surveys within Pilliga Nature Reserve. **NPWS** Coonabarabran
- Supervisor for undergraduate dissertation, "Environmental rehabilitation of Peats Crater and Peats Bight in Muogamarra Nature Reserve" (D. Maestri), **Southern Cross University** (1997)
- Co-supervisor for undergraduate dissertation "Riparian Vegetation of upper Cattai Creek" (D. Buckle). **Southern Cross University** (1997)
- Preliminary flora assessment for proposed subdivision and development; Red Gum Avenue, Pennant Hills. The bushland area was subsequently added to Berowra Valley Regional Park. **Friends of Berowra Valley Bushland**

- **NSW National Parks Association** (NPA) Biodiversity Audit, proposed Bargo River National Park. Team Leader, Vegetation - threatened flora
- Guided interpretive walk of Fred Caterson Reserve. **Cattai Catchment Management Committee**
- **NSW NPA** audit of Greater Sydney proposed conservation reserves and additions - assistant and author of NW Sydney reserve proposals
- **NSW NPA** Biodiversity Audit of the proposed Dyarrabin Nature Reserve (~2000 ha) - Project Co-ordinator
- **NSW NPA** Proposal for the creation of Dyarrabin Nature Reserve; revised submission and report of the second NPA Biodiversity Audit
- Preliminary flora study of Crown lands (Functional Area 1), Cattai Ridge Road, Halcrows Road, Hillside/Glenorie; submission to Director NPWS and to Baulkham Hills Council. **NSW NPA**
- Flora survey of Morans Rock Crown lands for proposed addition to Wollemi National Park. **NSW NPA**
- Proposed Welcome Reef Dam (Shoalhaven River north of Braidwood) - assist with flora and fauna surveys. **NSW NPA**. Much of the area is now within Nadgigomar Nature Reserve
- Flora survey of surplus Department of Education lands at Ellerman Park, Round Corner. The local community proposed that the area become a reserve to protect a critically endangered plant community present on the site. **Friends of Ellerman Park**
- Flora survey of Crown lands at South Maroota for proposed Crescent Reach Nature Reserve (later declared as the Maroota Ridge State Conservation Area), **NSW NPA**
- Calangara Nature Reserve Proposal in Kenthurst. Survey and report to **NSW NPA**
- Preliminary Survey of bushland in Holland Reserve, Glenhaven
- Survey of Crown Reserve (now part Scheyville NP), Pitt Town; report to **NSW NPA**

Expert report – *Pimelea spicata*

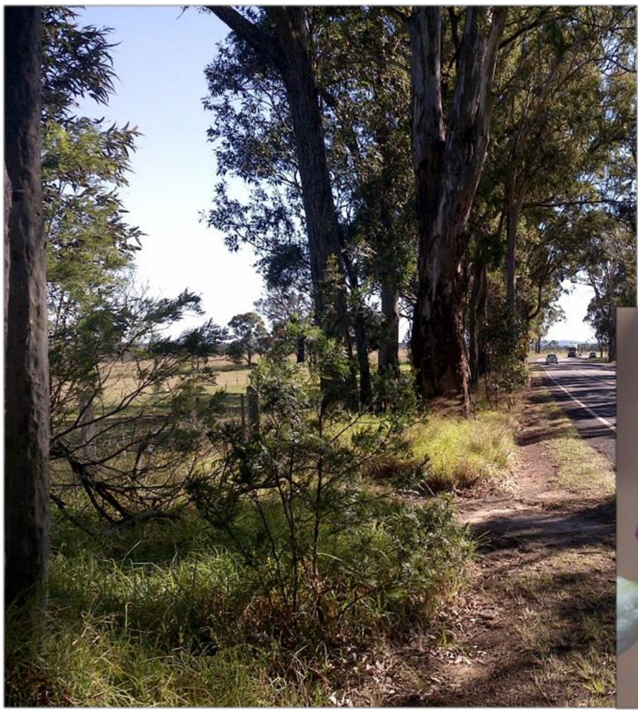
Expert report for *Pimelea spicata* Spiked Rice-flower – GMAC and Wilton, Teresa James, August 2018

Expert report for *Pimelea spicata* Spiked Rice-flower – GPEC and WSA, Teresa James, April 2019

Strategic Assessment for Cumberland Plain Conservation Plan

Greater Macarthur and Wilton Growth Areas

Expert Report for *Pimelea spicata* Spiked Rice-flower



Prepared for NSW Department of Planning & Environment

Teresa James August 2018

Contents

Introduction

1.1 Purpose of the expert report

An expert report may be prepared under section 6.5 of the Biodiversity Assessment Method (OEH 2017) in place of undertaking a threatened species survey. Use of an expert report may be beneficial where it is highly unlikely that a species may occur within the study area, survey effort is inadequate and/or the reliability of detecting the species through survey is low. In respect of *Pimelea spicata*, low survey effort and unreliability of survey are the primary reasons for preparing an expert report.

The purpose of this report is to provide scientific assessment of the current status and conservation needs of *Pimelea spicata* within the Greater Macarthur and Wilton priority growth areas of western Sydney. Specifically, the report is to determine whether:

- The species is unlikely to be present and in this case no further assessment is required, or
- The species is likely to be present and in this case the expert report must provide estimates of habitat area both within the growth and biocertified or development footprint areas.

1.2 Project context

The NSW Government is identifying areas for future urban development and associated infrastructure in western Sydney. There are four priority growth areas: Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These new growth areas are all located within the Cumberland Interim Biogeographic Regionalisation for Australia (IBRA) sub-region.

As part of the planning for the priority growth areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify development and conservation outcomes for the growth areas. A strategic assessment of this plan is underway and this expert report will assist the biodiversity assessment to assess the conservation benefits and development impacts of the Plan in respect of *Pimelea spicata*.

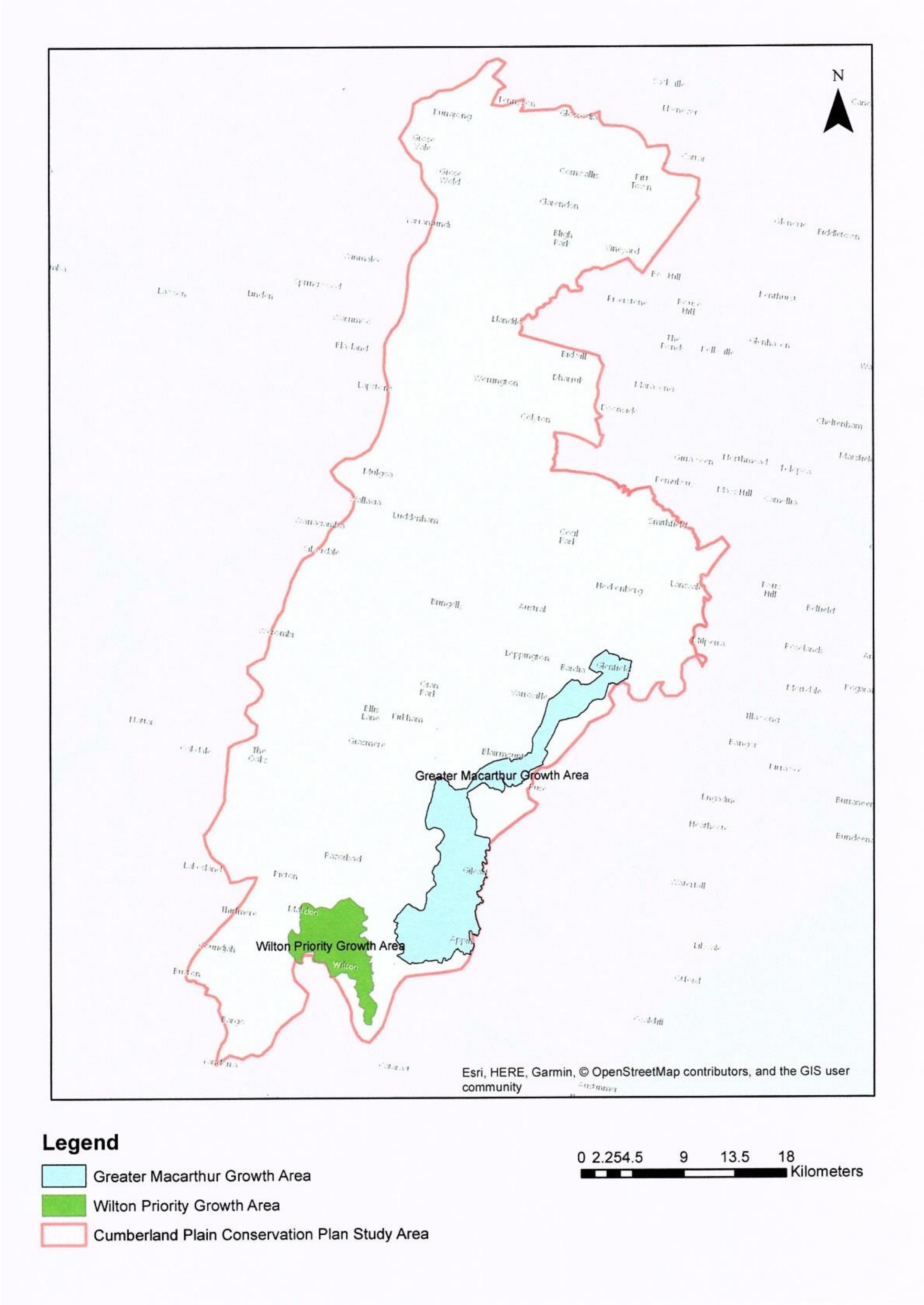
1.3 Study area

The study area for this report comprises the growth areas of Greater Macarthur (Campbelltown and Appin) and Wilton (see Figure 1). It is located within the Cumberland subregion on Triassic Wianamatta Group Shales and transitional shale/sandstone areas in south-eastern parts of the Cumberland Plain, western Sydney. The eastern and southern margins are within the Sydney Cataract subregion defined by the Triassic Hawkesbury Sandstone plateau. The study area is within the Hawkesbury-Nepean and Georges River catchments.

<u>Greater Macarthur Growth Area</u>
The Greater Macarthur PGA extends from Glenfield in the north to Appin in the south. The northern zone is already well developed with remnant vegetation largely restricted to creek-lines or small patches associated with open space reserves. Southern parts of the area, south of Rosemeadow, comprise primarily agricultural lands with larger patches of remnant vegetation associated with the Nepean and Georges Rivers, and associated tributaries.

<u>Wilton Growth Area</u>
The Wilton PGA occurs to the south of the Greater Macarthur Growth Area extending from Douglas Park in the north to south of Wilton. The boundaries closely follow the Nepean River in the north and west, and a tributary Allens Creek in the east. Away from the river and creeks the higher areas are largely cleared for agriculture and hobby farms. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The Woronora sandstone plateau (within the Upper Nepean State Conservation Area) forms the southern boundary. The Hume Highway dissects the growth area.

Figure 1. Greater Macarthur and Wilton Priority Growth Areas



1.4 Credentials of expert - Teresa James (BSc Combined Honours)

I am a botanist/ecologist with over forty years of experience in vegetation survey, plant identification, conservation assessment and threatened species, particularly in western Sydney. I have worked within the NSW government (National Herbarium of NSW, NSW National Parks & Wildlife Service) and for the last twenty years as a consultant (sole trader). A summary of my credentials as required under the Biodiversity Assessment Methodology (2014, 2016) is provided in Table 1.

Table 1. Credentials of Teresa James

BAM section	BAM requirement	Details
BAM s 6.5.2.8 (g)	Name of expert	Teresa James
BAM s 6.5.2.3 (a)	The expert's qualifications	Bachelor of Science (Honours), University of Exeter 1978 Accredited BioBanking Assessor (awarded 2008, renewed 2013)
BAM s 6.5.2.3 (b)	History of experience in ecological research and survey method, for the relevant species	Field surveys and other relevant studies: • Populations of *Pimelea spicata* across western Sydney e.g. Denham Court Road, Campbelltown (1999, 2012), Alpha Road Park, & Grey Box Reserve, Holroyd (2011), Cobham Road Reserve & Power Street Reserve, Fairfield (2016-17), Greendale (near Wallacia), private property (2016-7), Cranebrook Reserve, Penrith (2017). • Threatened community and threatened species (including *Pimelea spicata*) roadside surveys through Campbelltown LGA for Campbelltown City Council (2013) • Targeted survey for *Pimelea spicata* along Denham Court Road, near Camden Valley Way for SMEC (2012) • Expert report to DECCW: Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland at a property on Appin Road, Gilead (2011). • Targeted survey for *Pimelea spicata* at Menangle Park Offset Strategy for GHD (2009, 2010) • Biobanking Pilot Project at Wilton (2007). • Survey & monitoring of Cumberland Plain Woodland and *Pimelea spicata* at Faulkland Crescent Reserve, Blacktown (2004, 2007) for Blacktown City Council.
BAM s 6.5.2.3 (c)	A resume detailing projects pertaining to the survey of the relevant species	Resume attached at Appendix 1. Relevant field surveys listed above.
BAM s 6.5.2.3 (d)	Their employer's name and period of employment (where relevant)	Self-employed ecological consultant Teresa James Flora Consultant 1998 to present
BAM s 6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant species to which the survey relates	1. Author of several botanical guides to the flora of Western Sydney: • James, T.A., McDougall, L & Benson, D. (1999). Revised edition. *Rare Bushland Plants of Western Sydney.* Royal Botanic Gardens, Sydney. • James, Teresa (2013) Flora of Cumberland Plain Woodland – an identification guide. • James, Teresa (2015) Threatened Flora of the Fairfield LGA.

		• James, Teresa (2016) Native Flora of Shale Soils of the Cumberland Plain Woodland – An Identification Guide. 2. Author of flora component of Urban Bushland Biodiversity Survey of Western Sydney (1997). Included compilation of information on *Pimelea spicata* and its habitat across western Sydney local government areas. 3. Contributed information to the *Pimelea spicata* Approved Recovery Plan (2006). 4. Has acted as Expert witness in NSW Land and Environment Court in relation to threatened communities in western Sydney including: • Expert advice to OEH and Land & Environment Court in relation to alleged clearing of endangered ecological communities (Cumberland Plain Woodland and Shale Sandstone Transition Forest) at Gilead, western Sydney. Proceedings 50604 of 2011. • Expert advice to Liverpool City Council ats Muslim League of NSW – 264 Wilson Road, Green Valley. Land & Environment Court Proceedings No 10394 of 2005. Issues relating to Cumberland Plain Woodland. • Expert advice to Liverpool City Council ats AV Jennings – Stage 24 Dalmeny Drive, Prestons. Land & Environment Court Proceedings No 10395 of 2006. Issues relating to Cumberland Plain Woodland. 5. PAS2 Expert Interviews for several NSW threatened species with OEH (February-August 2012) including a range of Cumberland Plain species 6. Member of SOS Project Panel (2018) – Cumberland Plain Woodland, Western Sydney Dry Rainforest, Moist Shale Woodland, River-flat Eucalypt Forest, Agnes Banks Woodland and Castlereagh Ironbark Forest 7. Member of NPWS Cumberland Plain Recovery Team (1998)

Through this experience I have developed a good knowledge and understanding of the life history and habitat requirements of *Pimelea spicata* and associated habitats within the growth areas.

1.5 Justification for use of expert report

An expert report for *Pimelea spicata* is required as part of the threatened species assessment for the Cumberland Plain Conservation Plan for the following reasons:

1. The survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH 2016) for field traverse surveys due to limitations imposed by land access particularly within the Greater Macarthur Growth Area. Around 69% of total potential habitat for *Pimelea spicata* has been able to be accessed for survey with only 56% in the Greater Macarthur Growth Area.
2. Inadequate survey timing. *Pimelea spicata* is difficult to detect particularly when not in flower. Flowering is unpredictable and considered dependant on good rains (Environmental Impact Assessment Guidelines NPWS 2004, and personal knowledge). During dry periods the species is often invisible above ground but may persist in the soil as rootstock and seed. Dry, hot spring/summers have been a particular feature of the western Sydney environment in the last few years.

3. The cryptic nature of the species and extent of disturbance across the growth areas significantly reduces the likelihood of detecting the species. Many populations have only been recorded once the disturbance factor e.g. mowing, grazing or weed infestation has been removed. Many of the sites surveyed have been heavily grazed or mown.

Survey for *Pimelea spicata* has been insufficient to reliably determine the presence and extent of the species within the growth centres. An expert report is necessary to provide a more comprehensive and reliable level of scientific assessment.

1.6 Species surveys

1.6.1 *Summary of survey work undertaken*

To assess the impacts of development within the growth areas both existing and new biometric data has been used together with general and targeted survey. Extensive field sampling has been undertaken with assessment based on vegetation zones consistent with the Biodiversity Assessment Methodology (BAM 2017). Quantitative plot data has been collected to sample variability within each vegetation zone (Ecoplanning, Biosis 2017-18). More general flora and fauna survey has also been undertaken including targeted survey for threatened species including *Pimelea spicata* (Biosis). Surveys have been undertaken by Ecoplanning and Biosis.

Survey effort has varied across the study area. The northern extent of the Greater Macarthur growth area has been well surveyed by Biosis (general and targeted survey) reflecting the small areas and easy access. The only plot sampling (Ecoplanning), however, was in Georges River Reserve at Glenfield. The southern extent of the Greater Macarthur growth area has been less well surveyed with around 50% of habitat polygons surveyed (due primarily to limited access) and again mostly through general/targeted survey by Biosis. Many of the areas surveyed were reported to be heavily grazed (Bruce Mullins pers. comm.). The Wilton Growth Area has been relatively well-surveyed particularly in the north-eastern plateau area with both general and targeted survey (Biosis) and plot sampling (Ecoplanning).

The location of survey areas, tracks and plots are shown in Figures 9-11.

1.6.2 Land access

An initial 726 letters were sent to landholders within the Growth Areas in late 2017 followed by a second letter in March 2018, and targeted door knocking in May 2018 (DPE *pers.comm*.). Just under 20% of landholders responded. Surveys were undertaken on all areas of land where landowners granted access. Of the 14,984 hectares within the Wilton and Macarthur Growth Areas, of which 5,385 ha is potential native vegetation that could be impacted by development, DPE has completed surveys across 3,360 hectares (62% of the total survey area).

There is 765 hectares of total potential habitat (Cumberland Plain Woodland only) available for *Pimelea spicata* across the Wilton and Greater Macarthur Growth Areas. Of this area 530 hectares or 69% has been able to be accessed for survey. While nearly all available habitat was surveyed in the Wilton Growth Area, only 56% of potential habitat was able to be accessed in the Greater Macarthur Growth Area. Table 2 summarises the total area of habitat for *Pimelea spicata* that was surveyed.

1.6.3 Survey timing

Surveys for *Pimelea spicata* should be undertaken when flowering. Flowering is sporadic throughout the year and is likely to be in response to climatic conditions, particularly rainfall (DEC 2006). At other times plants are difficult to see or may only be present as rootstock or seed. Surveys have occurred between November 2017 to May 2018 and no sighting of this species has been recorded within the growth areas. Spring/summer was hot and dry with unfavourable conditions. Many of the Cumberland Plain Woodland sites surveyed were also heavily grazed.

Table 2. Total area of *Pimelea spicata* habitat surveyed (data provided by Dept. Planning & Environment)

Growth Area	Vegetation community	Total area (ha)	Survey area (ha)	Percent surveyed %
Greater Macarthur	849	293	204	70
	850	206	73	35
Sub-total		499	277	56
Wilton	849	236	222	94
	850	31	31	100
Sub-total		267	253	95
TOTAL		**766**	**530**	**69**

2. Species Information

2.1 Species description

A small, slender to spreading shrub or sub-shrub to c. 50 cm high; stems 1-several, glabrous. Older stems are often seen intertwining with grasses and herbs. *Pimelea spicata* has an underground carrot-like tap root recorded up to 18 cm in length that gives plants the ability to re-sprout after defoliation and periods of drought stress (NSW NPWS 1997). The leaves are mostly opposite, narrow-elliptic to elliptic in shape, to 20 mm long and 8 mm wide, spreading, soft and often bluish-green. Inflorescence is a raceme, dense when young, elongated and interrupted at maturity, bracts absent. Flowers tubular, white to pink tinged, 7-10 mm long with four spreading lobes. Fruit is a narrow-ovoid nut, c. 3 mm long, 1-seeded, mostly green.

Pimelea spicata leaves & flowers (left)
fruit (above)

2.2 Biology/ecology

Pimelea spicata is incapable of effective vegetative spread (Benson and McDougall 2001) although more recent observations suggest that mature individuals can spread over short distances through underground rhizomes (OEH 2017). Seed production, however, is the primary means of recruitment. Flowering is sporadic throughout the year and is likely in response to climatic conditions, particularly rainfall (DEC 2006). Flowering and fruiting has been observed in plants 1.5-2 years old (NPWS 1997); flowers continue to be produced as fruits mature. Native bees are known pollinators and moths may also contribute to pollination (DEC 2006). The species may also be capable of spontaneous self-pollination (DEC 2006). Fruiting is highly variable depending on environmental conditions. Seed viability has been recorded as relatively high ranging from 83% - 86% (Nash & Matthes 1995, Willis et al. 2003 cited in DEC 2006). Seed dispersal is highly localised with the majority of seedlings observed within 30 cm of adult plants following fire (Hogbin pers. obs. cited in DEC 2006). *Pimelea spicata* maintains a long-lived soil-stored seed bank resulting in potential for considerable recruitment following disturbance. The soil seed bank can survive under infestations of invasive weeds (Willis et al cited in DEC 2006).

Seed germination can be triggered by disturbance including fire, slashing/mowing, grazing and soil disturbance (NPWS 1997, Willis et al 2003 cited in DEC 2006). Monitoring of seedlings following fire revealed 80% survival in the first year (NPWS 1997 cited in DEC 2006). Ex-situ trials found that smoke application increased seed germination (Tozer & Robertson 1998), however, Willis et al. (2003) cited in DEC (2006) found only a 20-30% germination rate for seed in any trial.

Re-sprouting from the taproot occurs following defoliation caused by fire, drought or physical damage (NPWS 1997). The species can survive periods of drought stress or weed infestation by dying back to the tap root and re-sprouting when favourable conditions return. It is unknown at what age the tap root has to be of a sufficient size to facilitate re-sprouting.

2.3 Distribution and abundance

Pimelea spicata occurs in two disjunct regions of the Sydney Basin IBRA bioregion, the Cumberland Plain in western Sydney and the coastal region of the Illawarra, south of Sydney.

<u>Cumberland Plain</u>
On the Cumberland Plain *Pimelea spicata* is found on clay soils derived from Wianamatta Group Shales. The current known distribution extends from Freeman's Reach in the north to Douglas Park in the south and west from Penrith to Georges Hall in the east. *Pimelea spicata* has been recorded in the following vegetation communities:

PCT 849 – Grey Box – Forest Red Gum grassy woodlands on flats of the Cumberland Plain
PCT 850 - Grey Box – Forest Red Gum grassy woodlands on shale of the southern Cumberland Plain
PCT 806 & 807 – Derived grasslands on shale hills and shale plains of the Cumberland Plain
PCT 830 – Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain

These communities are equivalent to the Cumberland Plain Woodland and Moist Shale Woodland threatened ecological communities.

The recovery plan for *Pimelea spicata* (DEC 2006) identified 25 populations on the Cumberland Plain. Currently there are approx. 70 sites (Bionet Atlas records, June 2018). The main concentration of sites is found in the Blacktown, Prospect, Bankstown and Narrellan districts. More recent records (post 2014) are from near Wallacia and Horsley Park - Cecil Park. Populations in Campbelltown and Wollondilly LGAs are close to the south-eastern limit of the specie's geographical range.

<u>Coastal Illawarra</u>
In the Illawarra *Pimelea spicata* is associated with coastal headlands and hill tops from Mount Warrigal south to just north of Kiama. The recovery plan for *Pimelea spicata* (DEC 2006) identified 5 populations in the Illawarra.

In 2006, the total population of *Pimelea spicata* across 30 known populations was estimated to be around 4300. Populations varied from a few individuals to >500 plants although larger populations were rare with over half with <50 individuals and small habitat areas of less than 0.5 ha (DEC 2006, Dept. Environment & Heritage 2016*)*. Since 2006 several populations are likely to have been lost to development or habitat modification. At several sites survey has failed to re-locate plants including at Menangle and along Denham Court Road near Camden Valley Way (*James* 2009, 2010, 2012). Prolonged periods of drought, increased weed invasion and heavy grazing are likely to be the main causes. Counterbalancing losses are several new records and increased abundance at some existing sites. There have been new records within Fairfield, Liverpool and Penrith LGAs (mostly <50 individuals). Increased population sizes are noted at Narellan and Prospect.

2.4 Habitat

Pimelea spicata is found in grassy woodlands on shale on the Cumberland Plain and on grassy coastal headlands in the Illawarra.

Cumberland Plain
On the Cumberland Plain *Pimelea spicata* occurs in Cumberland Plain Woodland, Moist Shale Woodland and derived grasslands. Associated canopy trees are Grey Box *Eucalyptus moluccana*, Forest Red Gum *E. tereticornis,* Narrow-leaved Ironbark *E. crebra* and Spotted Gum *Corymbia maculata*. The mid-storey typically contains *Acacia parramattensis, A. decurrens, Bursaria spinosa*, *Acacia implexa, A. falcata, Dillwynia sieberi* and *Indigofera australis*. Common groundcover grasses and herbs associated with occurrences include Kangaroo Grass *Themeda triandra,* Weeping Grass *Microlaena stipoides,* Kidney Weed *Dichondra repens*, Woodruff *Asperula conferta* and Blue Trumpet Flower *Brunoniella australis*.

Pimelea spicata prefers moist soil and often occurs on gentle lower slopes where groundwater seepage maintain soils damper for longer (*T. James pers. obs.*). A relatively open groundcover maintained by occasional disturbance e.g. fire or infrequent/low intensity grazing/slashing provides favourable habitat. Although the species can survive (and flower) among taller grasses and perennial weeds (e.g. at Cobham Street Road, Horsley Park) it is likely to disappear above ground under dense weed infestations. The Denham Court Road population in 2003, for example, was estimated to be hundreds yet in 2011 no plants were found where plants were previously plentiful (*T. James pers. obs.)*. The road reserve had become increasingly degraded with weed infestation in both the mid-storey layer (African Olive, Box Thorn and Lantana) and the ground-layer (Bridal Creeper, Prickly Pear, Blackberry & Mother-of Millions). The species was likely still present in the soil seed-bank.

Frequent or intensive grazing, slashing or mowing will restrict the growth of plants with re-sprouting controlled by the frequency of disturbance and environmental conditions. Frequent cutting creates open, dry and hot conditions at the soil surface resulting in die-back of plants above ground. The species can persist for many years under such a regime as a tap root and seed in the soil. There are many examples of regeneration following cessation of mowing and slashing in council reserves e.g. Faulkland Crescent Reserve and Melrose Park in Blacktown and Power Street Reserve in Fairfield.

Habitat of *Pimelea spicata* along unformed road reserve (Cobham Road, Horsley Park)

Illawarra

In coastal habitat of the Illawarra *Pimelea spicata* occurs in a wider range of geologies and soils derived from the Permian Shoalhaven (sandier than the clay soils of western Sydney). The favoured sites are on grassy headlands and hilltops with Kangaroo Grass *Themeda triandra*, Mat-grass *Lomandra longifolia* and Blady Grass *Imperata cylindrica*, often with Coast Banksia *Banksia integrifolia*. Woodland is also often dominated by Forest Red Gum *Eucalyptus tereticornis* and Thin-leaved Stringybark *E. eugenioides* above Kangaroo Grass, species also occurring in *Pimelea* habitat in western Sydney. Habitat in the Illawarra includes the endangered ecological community *Themeda Grasslands on Seacliffs and Coastal Headlands* (PCT 898).

3. Description of the study area

3.1 Landscape context and land use history

3.1.1 Greater Macarthur Growth Area (GMGA)

The Greater Macarthur PGA extends from Glenfield in the north to Appin in the south. It is largely within the Campbelltown LGA with the southernmost section within the Wollondilly LGA. The northern half of the growth area comprises an urban renewal corridor centred on the Sydney to Southern Highlands railway line. It encompasses the existing industrial and residential suburbs of Glenfield, Macquarie Fields, Minto, Leumeah and Campbelltown. The Growth Area is associated with extensively cleared, gently undulating shale terrain typical of the Cumberland Plain and contrasting with the sandstone gorges and plateaus along the Georges River to the east. The northern zone is already well developed with remnant vegetation largely restricted to creek-lines or small patches associated with open space lands. Vegetated creek-lines include Bunbury Curran Creek, Bow Bowing Creek, Leumeah Creek, Fishers Ghost Creek and Spring Creek. Bushland reserves containing Cumberland Plain Woodland and River-Flat Eucalypt Forest TECs include Bunburry Curran Reserve, Pembroke Park and John Kidd Reserve (Blair Athol).

The more extensive southern half of the PGA, south of Rosemeadow, comprises proposed land release areas at Menangle Park, Mount Gilead and Appin. In the north-west Mount Sugarloaf (213 m asl) forms the southern end of a hilly ridge on the Luddenham soil landscape above the Menangle floodplain that extends north up to Denham Court. Some native vegetation persists although invaded by African Olive. The floodplain is well dissected by Menangle Creek and its tributaries including Nepean Creek, Woodhouse Creek and Leafs Gully. These are primarily semi-rural and agricultural land, with creek corridors and some larger patches of remnant vegetation, located between the Nepean and Georges Rivers. Geologically the area comprises gently undulating hills on shale intergrading via a shale/sandstone transitional zone with steeper terrain on Hawkesbury sandstone along the rivers. Transitional and sandstone geologies are sometimes exposed along the smaller creek lines.

3.1.2 Wilton Growth Area (WGA)

The Wilton PGA occurs to the south of the Greater Macarthur PGA extending from Douglas Park in the north, Maldon in the north-west and to south of Wilton. The boundaries closely follow the Nepean River in the north and west, a tributary Allens Creek in the east and the Cordeaux River in the south. Away from the Nepean River and gullies a higher gently undulating zone has been largely cleared for agriculture. The Woronora sandstone plateau (within the Upper Nepean State Conservation Area) and part of the Sydney Water Catchment forms the south-western boundary. The Hume Highway dissects the PGA north to south and Picton Road NW to SE.

The WPGA includes both shale, shale/sandstone transitional and sandstone environments. Remnant vegetation occurs predominantly along the watercourses and on associated slopes. The flatter shale terrain has soils of the Blacktown soil landscape, which is derived from Ashfield Shale and typically support shale woodlands. Much of this area is cleared or modified for agriculture and hobby farms. It comprises native/exotic grassland with smaller areas of better condition Derived Native Grasslands. Steeper slope areas above the gullies are comprised of soils of the Lucas Heights soil landscape derived from the Mittagong Formation (located between the Ashfield Shale and Hawkesbury Sandstone). The Lucas Heights soils are a mix of clays and sands and occur within the shale/sandstone transition zone, they support variable transitional woodlands and forest. In the steeper gullies the Hawkesbury soil landscape dominates and supports Hawkesbury Sandstone Gully Forest types.

3.2 Native Vegetation

3.2.1 Greater Macarthur Growth Area

The predominant vegetation communities are Cumberland Plain Woodland (CPW), Shale Sandstone Transition Forest (SSTF) and River-flat Eucalypt Forest (RFEF), all threatened ecological communities. A summary of mapped communities based on maps provided by NSW Planning & Environment is found in Table 3.

Table 3. Summary of vegetation communities within the Greater Macarthur Growth Area

PCT No	PCT Name	TEC / Non-TEC	Distribution & notes
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Moist Shale Woodland (MSW)	Small patch at Menangle Sugarloaf on SE slopes (map 4)
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	River-flat Eucalypt Forest (RFEF)	Along creek lines in shale areas in northern and central parts of GMGA (maps 1-5)
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CPW)	Small patches on shale soils throughout GMGA but mostly in northern and central parts
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Cumberland Plain Woodland (CPW)	Very small patches on shale soils throughout GMGA, more common in southern parts
806	Derived grasslands on shale hills of the Cumberland Plain	Cumberland Plain Woodland (CPW)	On shale soils in central and southern parts on agricultural & semi-rural lands.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (SSTF)	Most extensive community on shale /sandstone transition soils mostly south from Rosemeadow (maps 5-7) intergrading with CPW. Along smaller creek-lines and upper slopes of Nepean River & Georges River.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	SSTF – higher shale influence examples otherwise not a TEC (Sydney Hinterland Transition Woodland)	One small patch mapped e.g. along Smiths Creek at Leumeah (map 3). Higher shale influenced forms are consistent with SSTF TEC.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Not a TEC, (Hinterland Sydney Sandstone Gully Forest)	Narrow zone along Nepean & Georges Rivers and tributary gullies (maps 5-7) and small zone along Smiths Creek at Leumeah (map 3)

3.2.2 Wilton Growth Area

The predominant vegetation communities within the growth area are Cumberland Plain Woodland (& Derived Grasslands) on the shale and Shale Sandstone Transition Forest in shale/sandstone transitional areas, both listed as critically endangered ecological communities in NSW. Cumberland Plain Woodland and Shale Sandstone Transition Forest are also listed under the EPBC Act (1999). A summary of mapped communities based on maps provided by NSW Planning & Environment and Cumberland Ecology (2016) is found in Table 4.

Table 4. Summary of vegetation communities within the Wilton Growth Area

PCT No	PCT Name	TEC / Non- TEC	Distribution & notes
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CPW)	On shale soils of higher gently undulating terrain of northern central parts of WGA (mostly map 2). Small patches with scattered trees (farming properties) adjoining more extensive exotic and native grasslands.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Cumberland Plain Woodland (CPW)	Small patch in western part of WGA (map 1).
806	Derived grasslands on shale hills of the Cumberland Plain	Cumberland Plain Woodland (CPW) (NSW)	On shale soils of higher gently undulating terrain of northern central parts of WGA (mostly map 1 & 2).
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (SSTF)	The most extensive community on shale/sandstone transition soils between CPW and sandstone communities along gullies in the WGA (maps 1-3). Variable floristics.
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	SSTF - high shale examples only otherwise not a TEC (Sydney Hinterland Transition Woodland)	Few patches restricted to flatter land (often spurs) downslope of SSTF & above gully. Higher shale influenced forms are consistent with SSTF TEC.
1181	Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of west & south Sydney	Non-TEC Hinterland Sydney Sandstone Gully Forest	Narrow zone along Nepean River and tributary gullies (maps 1-3)
1292	Water Gum – Coachwood riparian scrub along sandstone streams	Non-TEC Riparian Forest	Very narrow zone along Nepean River (maps 1 & 2).
862	Grey Gum – Hard-leaved Scribbly Gum woodland of the Cox's Valley	Non-TEC Burragorang-Nepean Hinterland Woodland	Small patches mapped by Cumberland Ecology (2016) in NE of WGA above Allens Creek. These patch are included in SHTW in the DPE mapping.

3.3 Potential habitat for *Pimelea spicata*

Pimelea spicata is known to occur in the following vegetation communities:

PCT 849 – Grey Box – Forest Red Gum grassy woodlands on flats of the Cumberland Plain
PCT 850 - Grey Box – Forest Red Gum grassy woodlands on shale of the southern Cumberland Plain
PCT 806 & 807 – Derived grasslands on shale hills and shale plains of the Cumberland Plain
PCT 830 – Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain

Potential habitat may also occur in low sandstone forms (at the shale end of the transition) of Shale Sandstone Transition Forest, *Narrow-leaved Ironbark – Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain* (PCT 1395) which is structurally and floristically very similar to Cumberland Plain Woodland at the shale end of the transition (see Section 4.3.1).

Degraded examples of these communities (i.e. reduced canopy and/or mid-layer cover or weedy areas) can still provide habitat for the species due to its long-term persistence as woody rootstock (tap root) and in the soil seed bank. The communities identified above are equivalent to the Cumberland Plain Woodland, Moist Shale Woodland and Shale Sandstone Transition Forest threatened ecological communities.

3.3.1 Greater Macarthur Growth Area

Cumberland Plain Woodland (including Derived Grasslands) comprises >50% of remnant vegetation mapped in northern parts of the GMGA (south to around Rosemeadow) and around 20% (may be higher depending on extent of derived grasslands) in the southern section. There is around 70 ha of Moist Shale Woodland mapped in the vicinity of Mount Sugarloaf. High and low sandstone influenced SSTF has not been mapped separately (can be useful) in the mapping provided, however, SSTF occurring adjacent to CPW or in shale areas away from creek-lines may provide potential habitat.

Table 5. Potential habitat in the Greater Macarthur Growth Area

Vegetation community	Distribution	Habitat value
Cumberland Plain Woodland (all conditions including mowed or slashed as long as meet final determination)	Throughout but mostly in northern parts south to Rosemeadow.	High: most records from CPW both Shale Plains and Shale Hills
Moist Shale Woodland	Highly localised at Mount Sugarloaf	High: moist conditions favour the species
Shale Sandstone Transition Forest (low sandstone influence)	Throughout but mostly in southern parts	Moderate: not typically recorded from this community, however, at the shale end of the transition examples of CPW and SSTF are difficult to distinguish
Derived Native Grasslands (including mowed, slashed or grazed)	Throughout comprising grazing lands, roadsides & council reserves	Moderate to high: several records from over-cleared CPW or derived native grasslands

3.3.2 Wilton Growth Area

Due to the smaller area and reduced influence of shale with a corresponding increase in influence from sandstone at the edge of the Cumberland Plain, the extent of potential habitat for *Pimelea spicata* is less in the WPGA than the GMPGA.

Table 6. Potential habitat in the Wilton Growth Area

Vegetation community	Distribution	Habitat value
Cumberland Plain Woodland (all condition states)	Mostly in northern parts.	High, most records from CPW both Shale Plains and Shale Hills
Shale Sandstone Transition Forest (low sandstone influence)	Throughout	Moderate, not typically recorded from this community but at shale end of the transition examples of CPW and SSTF are difficult to distinguish.

Vegetation community	Distribution	Habitat value
Derived Native Grasslands (including mown, slashed or grazed)	Mostly northern areas comprising grazing lands, roadsides & council reserves	Moderate to high. Several records from over-cleared CPW or derived grasslands with varying levels of native species

4. Assessment of species presence and suitable habitat

4.1 Species records, habitat assessments and prior surveys

4.1.1 Species records

Records used in this report have been sourced from the NSW Bionet Atlas. Only four records relating to two sites exist for the Greater Macarthur Priority Growth Area (GMPGA) and none for the Wilton Priority Growth Area (see Table 7). One record from Glenfield in the far north of the GMGPA is suspect. See Figures 2 & 3.

Table 7: *Pimelea spicata* records from within Greater Macarthur Growth Area

Location	Date of record	No. of individuals	Notes
Minto Industrial Estate	2004	?	CP2 of Recovery Plan (DEC 2006) - original population destroyed & plants translocated to buffer area
Minto Industrial Estate	12/07/2012 – 13/02/2013	1	Apparently location close to CP2, now also cleared & developed based on current imagery
Minto Industrial Estate	7/03/2013	28	Habitat 10 m x 10 m in outlying stand of *Eucalyptus crebra* (CPW)
Western end of Glenfield Waste Services site at northern edge of GMGA (based on coordinates) but location given on record is Catholic school grounds, Leacock Lane, Casula	01/03/1992	?	Coordinates likely inaccurate. The Glenfield location is not identified in the recovery plan.

The Minto population is located within a 30 m wide strip of Cumberland Plain Woodland along Pembroke Road near the intersection with Ben Lomond Road. This habitat is part of a conservation area connected to a 60 m wide strip along Ben Lomond Road. The conservation area comprises a total area of c. 2.3 ha and is subject to a Bushland Plan of Management (Anne Clements & Associates 2010). The long-term security of this population is doubtful considering the narrow vegetation zones subject to extensive edge effects and long-term health of the remnant will depend on ongoing management.

There are several records located just outside of the Greater Macarthur Growth Area within the Liverpool -Campbelltown & Camden LGAs at Casula, Denham Court, Narellan and Mt. Annan. Records in Wollondilly are limited to one site just north-east of Douglas Park (ref Appin Mine VS#6). Information relating to the closest and highest density of records is summarised in Table 8.

Table 8. *Pimelea spicata* records just outside of the Greater Macarthur Growth Area

Location	Date of record	No. of individuals	References/notes
Appin Mine VS#6 c. 1-2km west of GMGA	2012-14	c. 100	Many records within an area of c. 5 ha on SSW facing slope. Site was subject to grazing, slashing & weeds. In Shale Hills Woodland.
Mt Annan Botanic Garden & surrounds 2 km west	1991 - 1998	Locally abundant	Conservation Area Mt Annan Botanic Gardens. Population CD1 of recovery plan.
All Saints Catholic College school grounds, Leacock Lane, Casula c. I km to the north	1992	Scattered colonies in 0.5 sq. km area	Population L2 of the recovery plan. Dry hilltops. Current status unknown, no plants see in 2003 (recovery plan), no subsequent records.

The largest and most recently recorded population is located within a secure offset site for the Appin Mine No 6 Ventilation Shaft (Niche Environment & Heritage 2011). Populations at Mount Annan (and surrounding areas) are well documented, those within the Mt Annan Botanic Gardens conservation area are likely to be secure. Other sites at Casula and Denham Court occur on private land and current status is unknown.

4.1.2 Habitat assessments and prior surveys in Greater Macarthur Growth Area

<u>Menangle Park</u> – targeted survey for *Pimelea spicata* (James 2009, 2010). Three remnants of Cumberland Plain Woodland totalling an area of c. 7 ha were surveyed in 2009 & 2010. They form part of Map 4 of the GMPGA and occur within the proposed urban development footprint. Based on current imagery these remnants appear to be in similar condition to that observed in 2009-10 i.e. of similar size and landscape context with ongoing grazing pressure. All sites contained potential habitat for *Pimelea spicata* although no plants were recorded. The survey was limited by prolonged dry conditions (particularly in 2009) and heavy grazing from horses. Plants are unlikely to be visible if present until grazing ceases and groundcover improves. These conditions are likely typical of similar habitat within the growth areas. Details of the sites are provided in Table 9. These sites were re-surveyed by Biosis for the strategic assessment.

It is noted that these remnants of Cumberland Plain Woodland are mapped in the strategic assessment mapping as PCT 1395 (SSTF) and not Cumberland Plain Woodland vegetation. I disagree with the mapping.

Table 9. Menangle habitat assessment sites

Site Id	Location [GDA94 MGA56]	Size	Habitat details	Survey effort & findings
1	South of Menangle Road at junction with Cummins Road 292394E, 6223452N	2 ha	CPW Grey Box – Forest Red Gum Small patch surrounded by grazing land (horses); gentle south-facing slope. Saline often bare soils. Weed invasion at shrub and ground-layer. Heavy grazing pressure. Low condition.	• 1 hour 30 mins random meander • No plants found • Conditions dry, unsuitable for survey • Low potential habitat
2	Eastern side of Cummins Road 292468E, 6223863N	2.5 ha	CPW Narrow-leaved Ironbark Small patch surrounded by grazing land (horses); moderate west-facing slope. *Bursaria spinosa* in shrub layer with *Indigofera australis*, ground cover with mix of native & exotic species. Moderate condition. Moderate grazing pressure.	• 2 hours 45 mins random meander • No plants found • Conditions dry, unsuitable for survey • Potential habit present

Site Id	Location [GDA94 MGA56]	Size	Habitat details	Survey effort & findings
3	Eastern side of Cummins Road, just north of Station Road intersection	5 ha	CPW Forest Red Gum - Narrow-leaved Ironbark; small patch surrounded by grazing land; gentle north-west facing slope. Shrub layer dominated by African Olive & Box Thorn; ground cover with mix of native & exotic species & much bare ground. Low condition with heavy grazing pressure, horses & rabbits.	• 1hour random meander • No plants found • Conditions dry, unsuitable for survey • Low potential habit present

Mt Gilead Biodiversity Assessments – NPWS (1997), Eco Logical (2017)

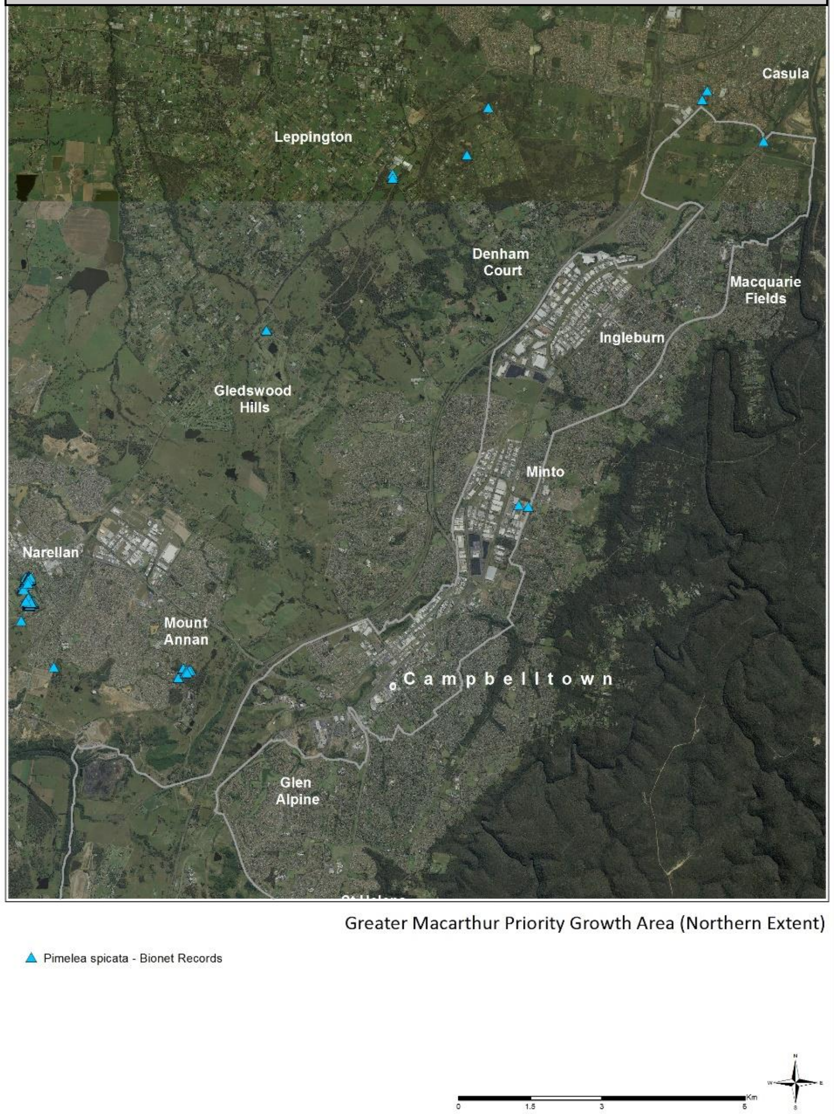
As part of the Mt Gilead *Biodiversity Certification Assessment & Biocertification Strategy* (2017) detailed survey and community verification was undertaken in 2015-2016 between Noorumba Council Reserve and Beulah Biobank Site (eastern boundary along Appin Road). Although these surveys were limited to the north-eastern section of Mt. Gilead, previous surveys had been undertaken in 2006 and 2013 across larger areas and over several months.

Table 10. Previous studies undertaken at Mt. Gilead

Previous study	Survey area	Effort (flora)	Results
ELA 2006	Mt Gilead (810 ha)	• 4-day survey Feb & March 2006 including flora, fauna & riparian health • Validation of vegetation communities, random meander • Threatened flora survey, random meander	• 4 vegetation communities (3 EECs – RFEF, CPW, SSTF) • No *Pimelea spicata* recorded
ELA 2014	Part of Mt. Gilead (210 ha)	• 4-day survey March, April, June, Sept 2013 including flora, fauna • Validation of vegetation communities, random meander & 18 Biometric plots • Threatened flora survey, random meander	• 3 EECs recorded RFEF, CPW, SSTF • No threatened flora species
ELA 2017	Part of Mt. Gilead (209 ha)	• Jan, Feb, April Sept, October 2015; Jan, Feb, Mar, August 2016 • 20 Biometric plots (9 same as in 2014) • Threatened flora survey, random meander	• 3 EECs recorded RFEF, CPW (8.75 ha), SSTF (20.62 ha) • No *Pimelea spicata* recorded

Although the land could not be accessed for the strategic assessment, survey effort has been comprehensive over several years in parts of the site. No plants of *Pimelea spicata* were recorded. Detection of plants, however, has and continues to be limited by ongoing clearing, slashing and grazing across much of the area. The extent of Cumberland Plain Woodland is also limited due to a higher sandstone influence particularly along creek-lines.

Figures 2 & 3. *Pimelea spicata* atlas records for GMGA & surrounding areas



Greater Macarthur Priority Growth Area (Northern Extent)

Greater Macarthur Priority Growth Area (Southern Extent)

Glenfield Waste Services (EPS 2015)
The Glenfield Waste Services site is located in the far north of the Greater Macarthur growth area along Cambridge Avenue at Glenfield. Known *Pimelea spicata* sites occur to the north and south at Casula and Minto. The location of a record just west of the site is considered dubious. Community verification and targeted survey was undertaken in 2012 and 2013. Suitable habitat occurs at the site but no plants were recorded.

Table 11. Glenfield flora survey

Previous studies	**Survey area**	**Effort (flora)**	**Results**
EPS (2015)	Glenfield Waste Services site (60 ha)	May & July 2012 random meander & 8 quadrats Dec 2013 – random meander targeted survey for Pimelea (12 hours, 1 hr per ha)	12 ha of Shale Plains Woodland & potential habitat No plants of Pimelea found. No details of conditions at time of survey.

Campbelltown LGA roadside habitat survey (James 2013)

Approximately 93 km of roadside habitat was surveyed over three weeks during September 2013. Sections of roadside surveyed relevant to this report are listed below:

- Glenfield – Cambridge Avenue (east of Railway Parade)
- Macquarie Fields – Victoria Road adjoining Bunbury Curran Reserve, Canterbury Road, Minto Road
- Menangle – Menangle Road (from Callaway Avenue to LGA boundary)
- Gilead – Appin Road (Noorumba Reserve to LGA boundary sign)

Pimelea spicata was targeted in remnants of CPW but no plants were found. The road reserves are typically closely mown preventing shrub regeneration except close to remnant trees and along fence-lines. Potential habitat in other areas is affected by dense woody growth of African Olive. Roads with mature habitat trees and patches of relatively intact native groundcover include Appin Road and Menangle Road. African Love Grass and Kikuyu are dominant invasive species along the roadsides in CPW resulting in loss of native species.

Based on these findings it is reasonable to expect potential habitat to exist along some of the more natural roadsides within the growth areas particularly in more rural environments of the central and southern parts. To realise this potential, however, will require appropriate protection and management. A summary of findings is provided in Table 12.

Table 12. Survey details for Campbelltown LGA roadside habitat survey

Previous studies	**Survey area**	**Effort (flora)**	**Results**
Campbelltown roadside survey T. James (2013)	Cambridge Avenue, Glenfield	Walking along roadsides with targeted search within patches of CPW	Confirm CPW on northern side of road adjoining Glenfield Waste Services site. Weedy. No *Pimelea spicata* recorded but potential habitat.
Campbelltown roadside survey T. James (2013	Canterbury Road Victoria Road Minto Road (Macquarie Fields)	Walking along roadsides with targeted search within patches of CPW	Small patch mapped as CPW is SSTF along Canterbury Rd. No potential PS habitat in this patch. SSTF along Victoria Rd, unlikely habitat. Minimal CPW potential habitat.

Campbelltown roadside survey T. James (2013	Menangle Road (Menangle Park)	Walking along roadsides with targeted search within patches of CPW	Small patches of CPW & derived grasslands, some mown, others with good native groundcover. Potential habitat in these patches south of Glen Alpine.
Campbelltown roadside survey T. James (2013	Appin Road (S. of Rosemeadow)	Walking along roadsides with targeted search within patches of CPW	Mostly CPW/very low sandstone influenced SSTF to just south of Mallaty Creek. Some good sections with larger remnant trees, native groundcovers/sparse shrubs & grasslands. Potential habitat.

4.1.3 Habitat assessments and prior surveys in the Wilton Growth Area

Wilton Junction New Town – Cumberland Ecology/SLR Consulting 2016

Surveys associated with the Wilton Junction/Bingara Gorge covered the eastern side of the WPGA. Comprehensive flora investigations were undertaken in 2013 and 2014 (see details below).

Table 13. Survey details for Wilton

Previous study	Survey area	Effort (flora)	Results
SLR **2013-14**	Wilton Junction /Bingara Gorge	• Walked and driven transects • Target searches for threatened species • 20 m x 20 m flora plots & 50 m transects • 68 *Over-The Fence* surveys	See below
Cumberland Ecology **2014-16**	Wilton Junction /Bingara Gorge	• Collection of biometric data within each plant community • Vegetation mapping	c. 60 ha of CPW identified c. 65 ha of SSTF (low sandstone) c. 8 ha of Derived native Grassland (CPW) No records of *Pimelea spicata*

4.2 Assessment of species presence and justification [BAM 6.5.2.8c, 6.5.2.5]

4.2.1 Greater Macarthur Growth Area

Based on atlas records and the extensive distribution of potential habitat (particularly Cumberland Plain Woodland and Moist Shale Woodland) within the GMGA it is confirmed that *Pimelea spicata* is present and could be present at other sites. The population at Minto Industrial Estate was confirmed in 2013 and is believed to be subject to some level of management. Although no known populations occur within the *biocertification* area, there are extensive areas of potential habitat and a reasonable likelihood that the species is present at other sites either as plants, rootstock or seed. The highest likelihood of occurrence is in central parts of the growth centre in the vicinity of Menangle Sugarloaf coinciding with the largest area of potential habitat in both particularly Cumberland Plain Woodland and Moist Shale Woodland.

4.2.2 Wilton Growth Area

There are no atlas records for *Pimelea spicata* within the Wilton Growth Area. The closest records are just north of Douglas Park on the western side of the Nepean River in similar undulating terrain within Cumberland Plain Woodland and on land largely cleared and used for grazing. In view of these records and presence of similar habitat within the WGA and *biocerification* area, there is a reasonable likelihood of the species being present. A significant proportion of the potential habitat comprises derived grasslands dominated by native species or a mix of native and exotic. It is noted that *Pimelea spicata* has been found in derived grassland dominated by exotics with occasional patches of native grasses and herbs e.g. at Cobham Road, Fairfield.

4.3 Assessment of suitable habitat

Suitable habitat for *Pimelea spicata* has been determined with reference to known sites, flora studies, scientific and personal knowledge. Important habitat attributes used to identify suitable habitat are discussed below.

4.3.1 Key habitat attributes & justification for use in determining suitable habitat

<u>Vegetation communities</u>
Pimelea spicata is primarily associated with *Cumberland Plain Woodland* (PCT's 849 & 850). Dominant canopy species are Narrow-leaved Ironbark *Eucalyptus crebra,* Grey Box *E. moluccana* and Forest Red Gum *E. tereticornis.* In southern parts of the Cumberland Plain, it also occurs in *Moist Shale Woodland* (PCT 830) with the same canopy species. Examples of populations occurring in Moist Shale Woodland include the following Atlas locations:

- Western Sydney Regional Park
- Denham Court (private property)
- Greendale near Wallacia (private property)
- Williamswood Biobank Site, Mount Hunter

The main occurrence of Moist Shale Woodland is at and in the vicinity of the Menangle Sugarloaf within the central zone of the GMPGA. In highly modified remnants it can be difficult to distinguish Moist Shale Woodland from Cumberland Plain Woodland with more resilient drier species replacing the moisture-loving ones until the canopy and understorey is restored.

Shale Sandstone Transition Forest (PCT 1395) may also provide suitable habitat at the shale end of the transition where it is structurally and floristically comparable to Cumberland Plain Woodland. The two communities adjoin each other extensively within the growth areas particularly in southern parts of the GMPGA and through the WPGA. Identification can be difficult particularly in modified remnants typical of these areas. Survey for alleged clearing of native vegetation at Gilead (James 2011) established that vegetation mapped as SSTF was partly Cumberland Plain Woodland. For these reasons some areas of SSTF are included within areas of identified suitable habitat.

Total habitat area of all mapped CPW (PCT's 849 & 850) and derived native grasslands within Wilton/Greater Macarthur priority growth areas is 765 ha.

<u>Physical environment</u>
Pimelea spicata is most often found on slopes in undulating low hilly terrain on Wianamatta Group shales including both Ashfield and Bringelly Shales. Within the GM and Wilton priority growth areas Ashfield Shale is the most widespread. To the south of the study area, particularly around Appin and Wilton it occurs as a capping over sandstone on ridges close to the Nepean and Georges Rivers. *Pimelea spicata* prefers moist soils (clay helps to retain the moisture) and is often found on protected south or east facing slopes close to drainage lines or seepage points. Growth and

flowering appears to be largely dependent on such moist soils with plants often not visible in dry periods and dying back to rootstock or persisting as seed in the soil seed bank.

Such conditions occur through most of the growth areas although protected slopes below ridges could be targeted as preferred habitat. The recent records from the Appin Mine location just west of the Nepean River are associated with such conditions and comparable to terrain within the southern part of the GMPGA and the WPGA.

<u>Habitat condition</u>
Optimal habitat for *Pimelea spicata* is intact woodland with an open, grassy understorey, however, it can survive in disturbed and degraded landscapes (see Section 2.4). Many of the known records are associated with regenerating native vegetation e.g. after a disturbance such as mowing or grazing has ceased. Records from many council reserves have been made in recent years as “no mow” zones have been established. Examples include:

- Faulkland Reserve, Kings Langley (Blacktown LGA)
- Melrose Park, Quakers Hill (Blacktown LGA)
- Power Street Reserve (Fairfield LGA)

Extensive areas of woody weeds such as African Olive occur within the growth areas, for example, at the Menangle Sugarloaf. These areas can still contain potential habitat (see Section 2.4) and are included. Examples of *Pimelea spicata* being recorded after removal of African Olive include a site at Greendale (Penrith LGA) and Mt. Annan.

The condition of habitat, therefore, is not a reliable indicator of species presence and accordingly **all condition states** are considered in determining suitable habitat i.e. intact, thinned, scattered, derived shrubland and grasslands.

4.3.2 Identification of habitat polygons

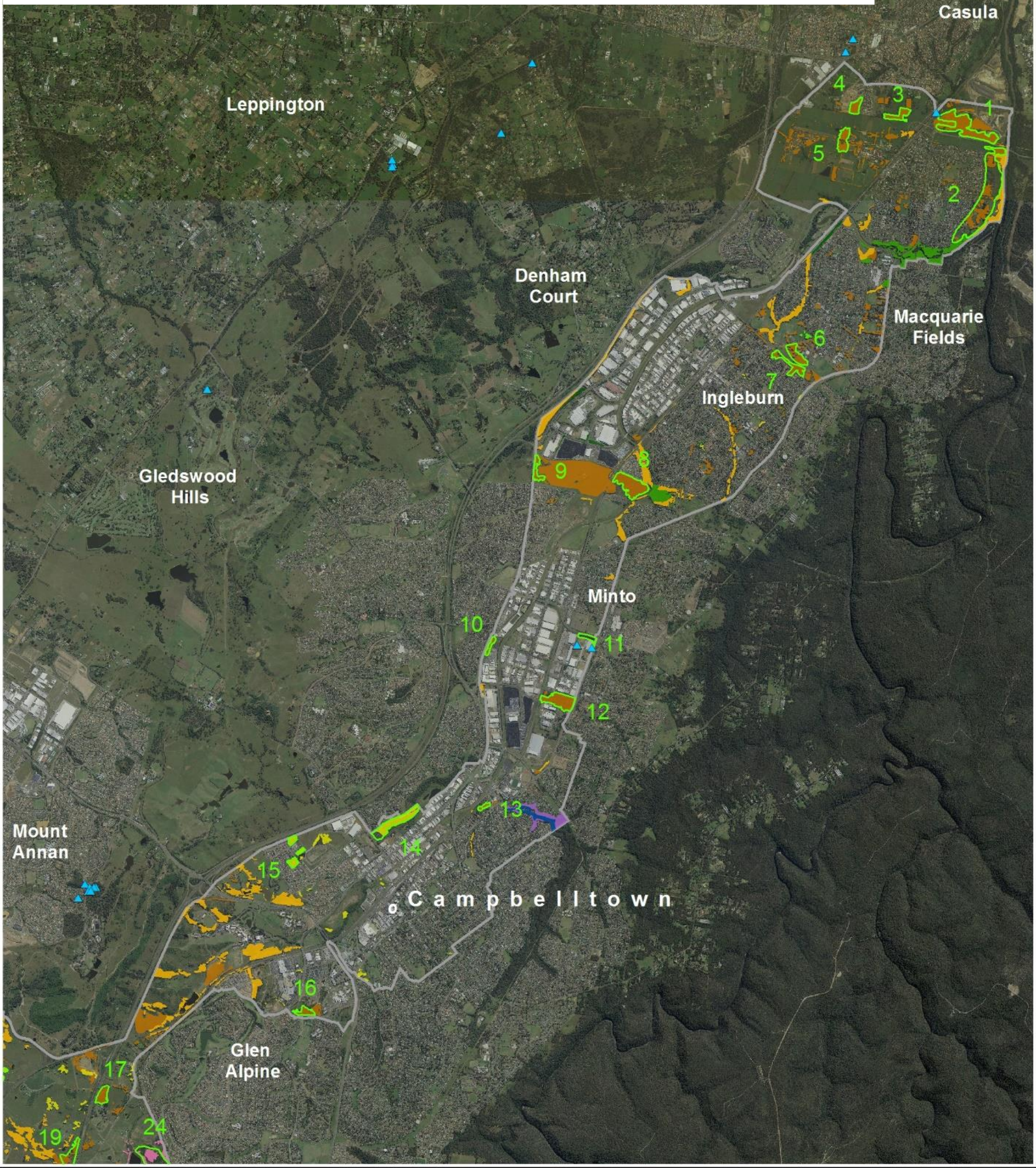
Areas of potential habitat are identified based on the attributes described in Section 4.3.1, landscape context and personal knowledge. Although *Pimelea spicata* is known to occur in degraded sites, very small patches within over-cleared landscapes where the soil is likely to have been modified are excluded.

Forty polygons containing a total of 542 ha of suitable habitat for *Pimelea spicata* are identified within the GMGA and six polygons with 405 ha in the WGA mostly comprising Cumberland Plain Woodland (including derived native grasslands) but also 187 ha of Moist Shale Woodlands and a total of 265 ha of CPW/low sandstone influenced SSTF (see Figures 4 & 5). The relative areas of vegetation communities are provided in Table 14.

Table 14. Areas (ha) of threatened communities identified as potential habitat for *Pimelea spicata* within the Greater Macarthur and Picton Growth Areas

Threatened Community	PCT	Area (ha) in Greater Macarthur	Area (ha) in Wilton
Cumberland Plain Woodland	850	121	0
Cumberland Plain Woodland	849	152	221
Native Grasslands (included in CPW areas)	608, 609	13	162
Moist Shale Woodland	830	187	0
River-flat Eucalypt Forest	835	0.2	0
Shale Sandstone Transition Forest (low sandstone)	1395	81.5	184

Figure 4. Habitat polygons for Greater Macarthur Growth Area Northern Zone



Greater Macarthur Priority Growth Area (Northern Extent)

- Pimelea spicata - Bionet Records
- Pimelea spicata potential habitat
- 1081 - Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1181 - Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion.
- 1292 - Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion
- 1395 - Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion
- 1800 - Swamp Oak
- 830 - Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 835 - Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion
- 849 - Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion
- 850 - Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion
- 877 - Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion
- 883 - Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain, Sydney Basin Bioregion

0 0.75 1.5 3 Km

N W E S

Figure 5. Habitat polygons for Greater Macarthur Growth Area Southern Zone

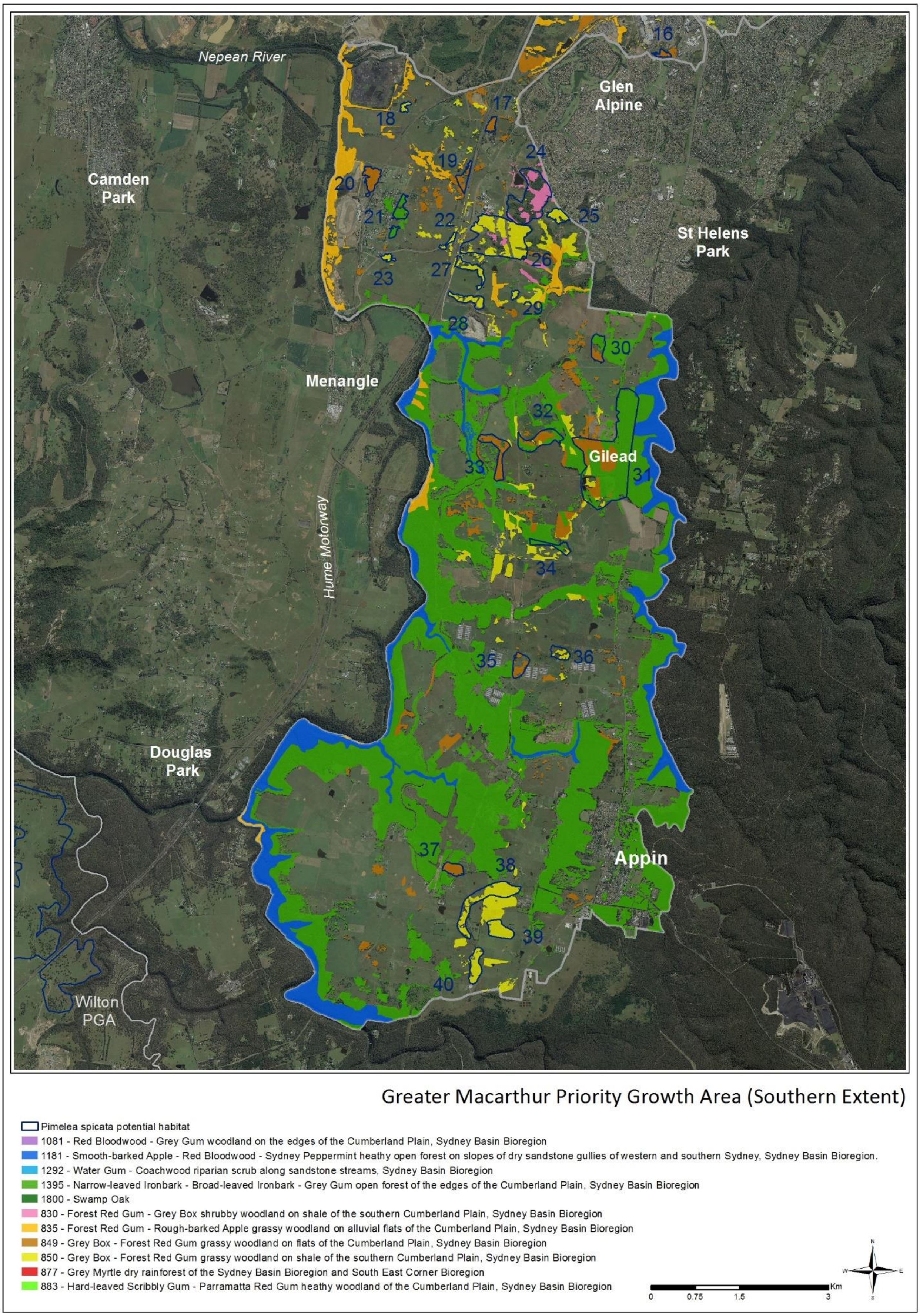


Figure 5a Habitat polygons for Greater Macarthur Growth Area Southern Zone in relation to Derived Native Grassland

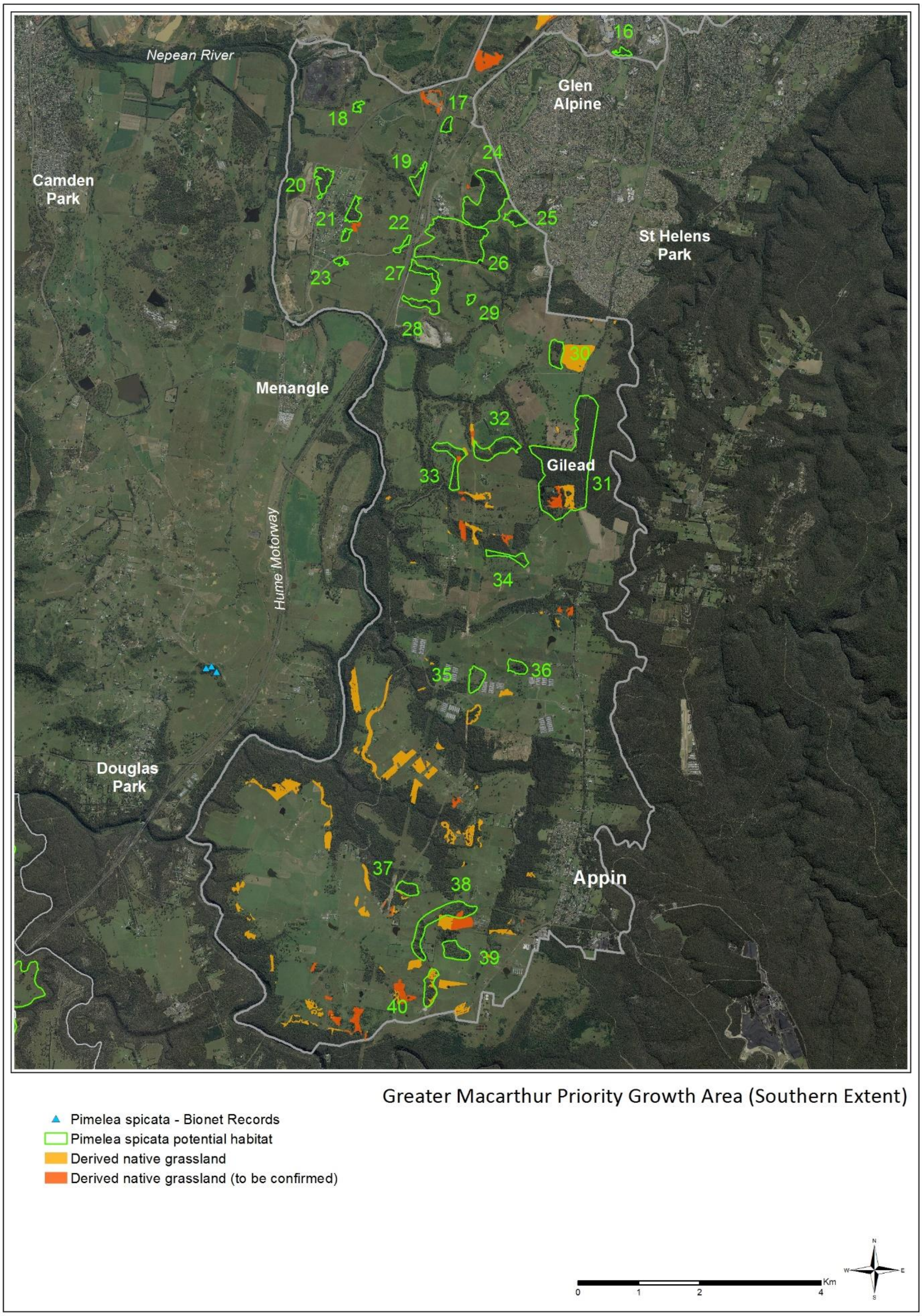


Figure 6. Habitat polygons for Wilton Growth Area

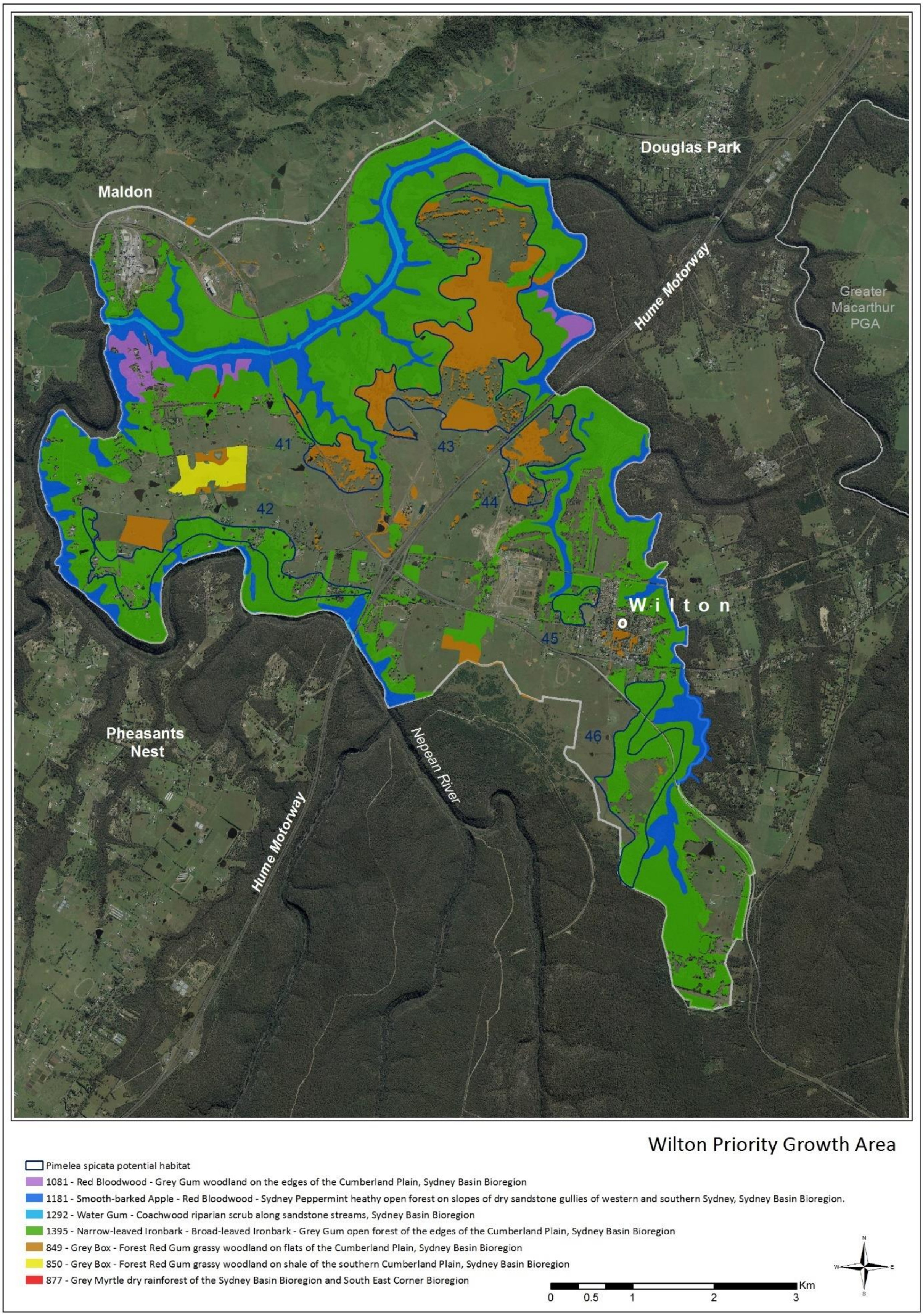
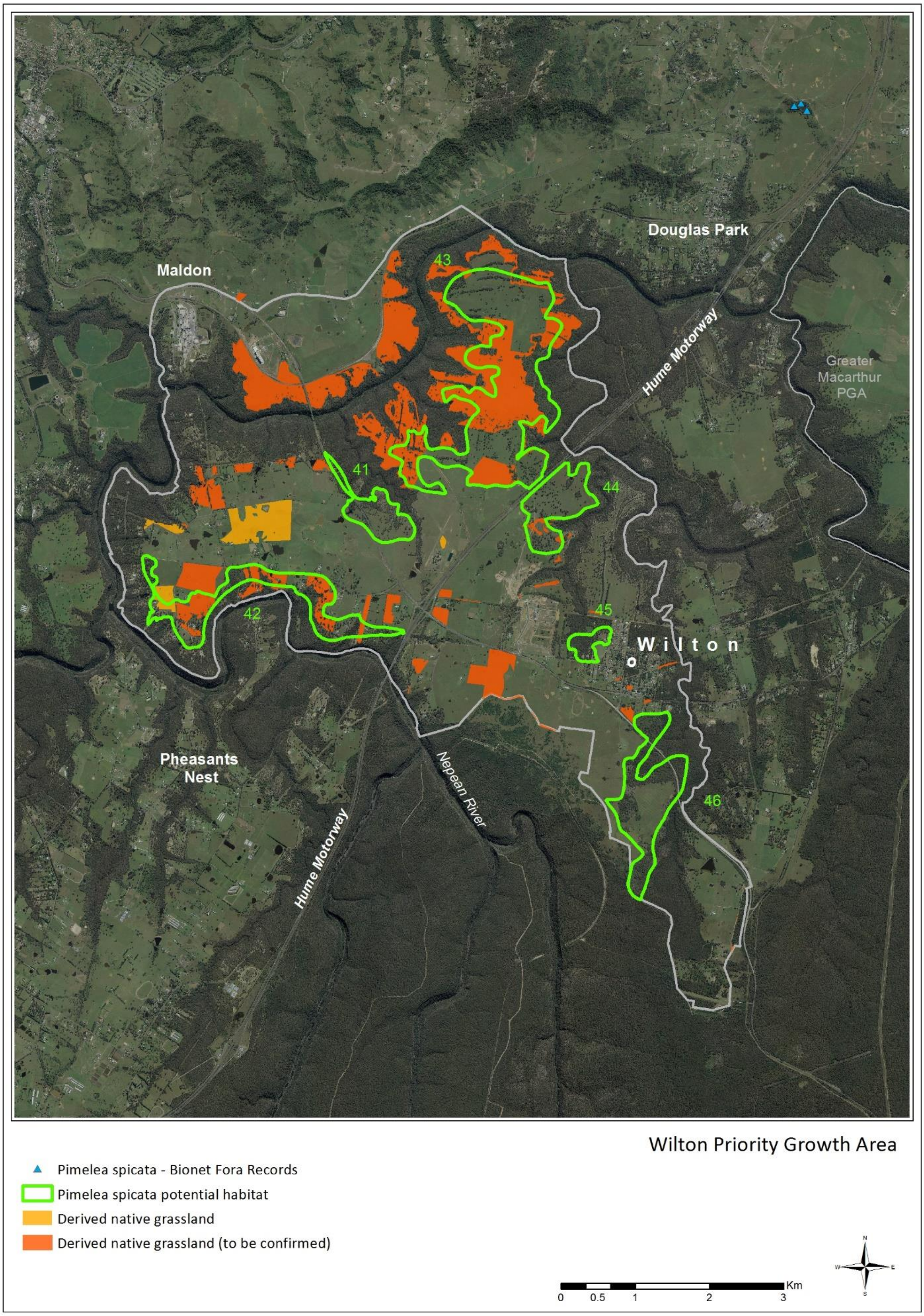
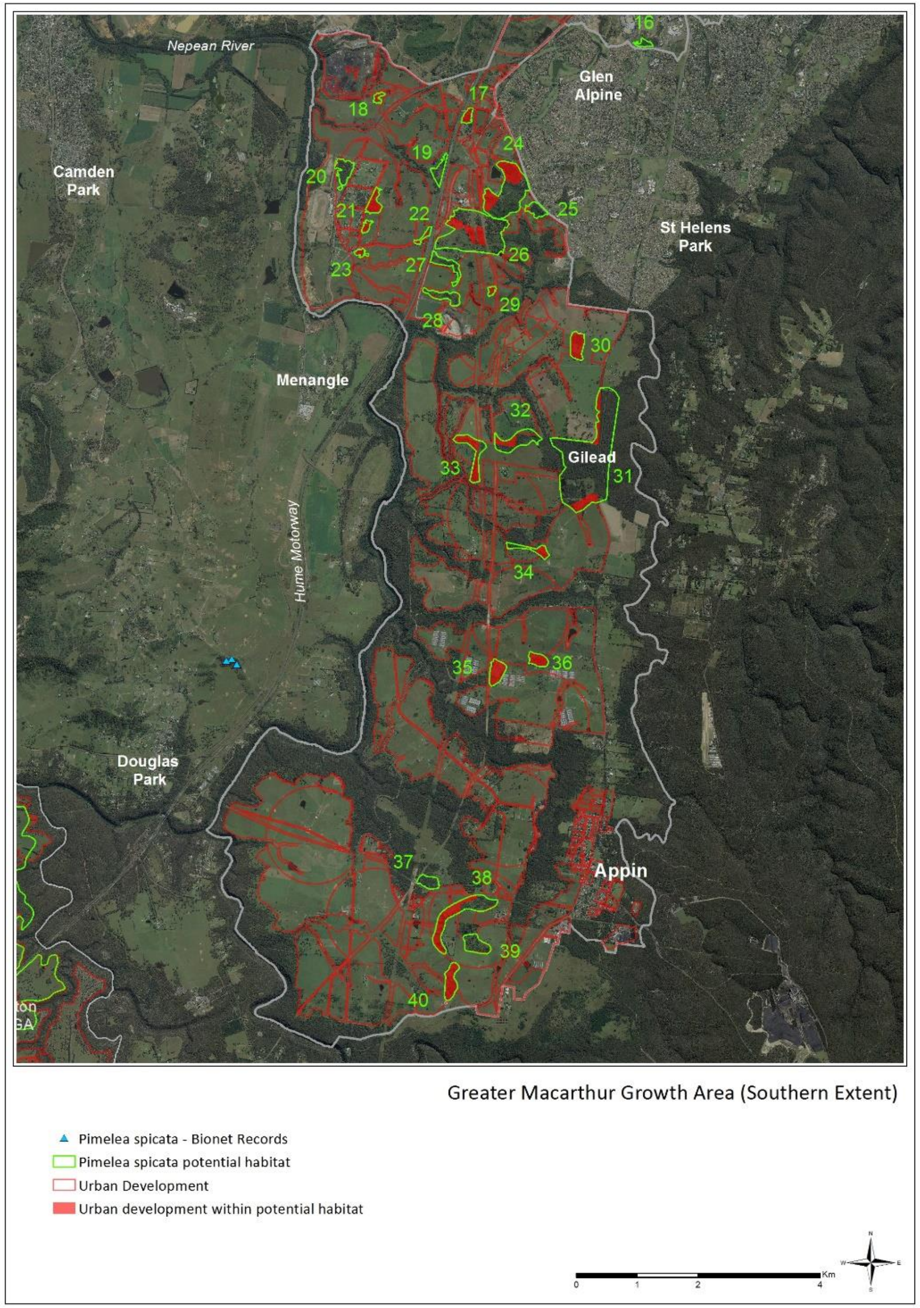
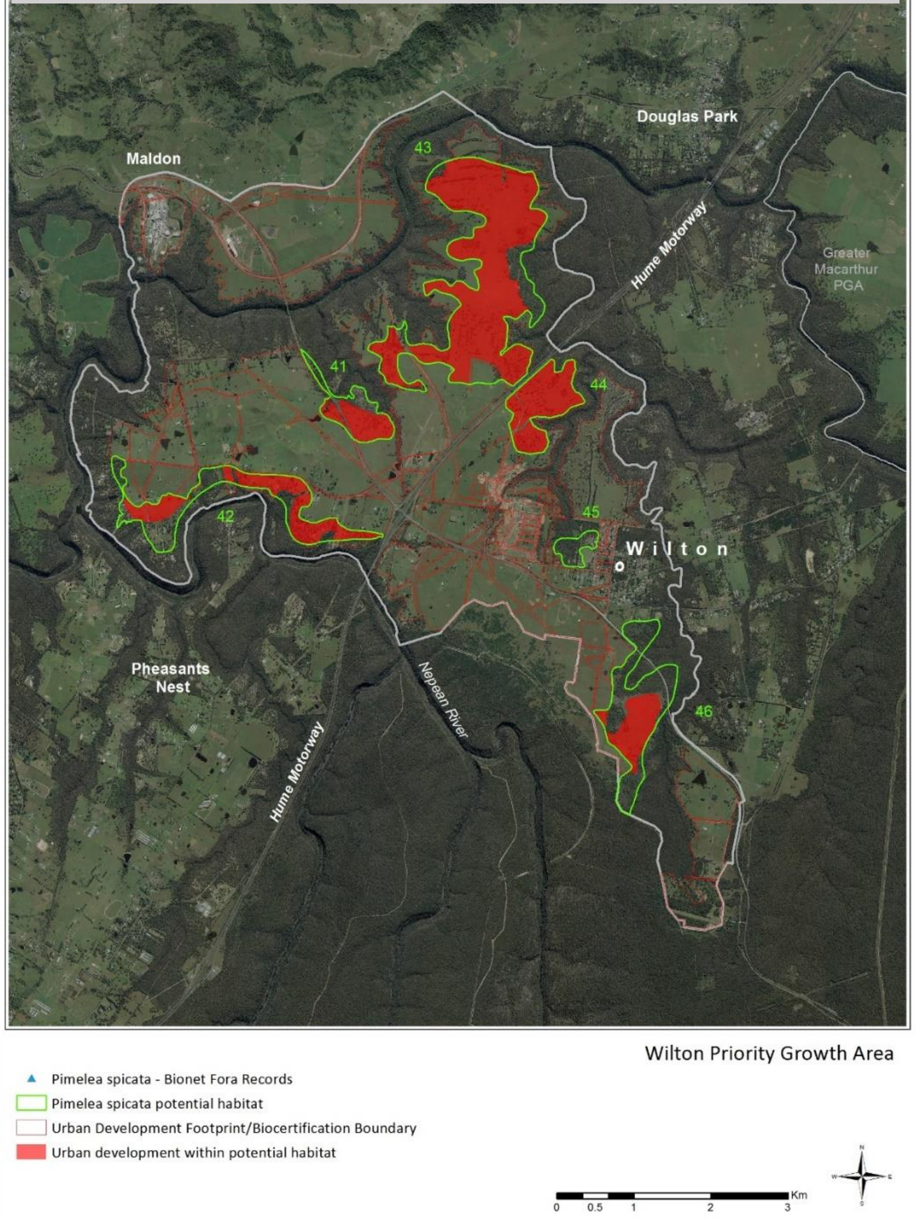


Figure 6a Habitat polygons for Wilton GA in relation to Derived Native Grassland



Figures 7 & 8 . Habitat polygons & overlap with biocertification area for GMGA





Biocertification area

Within the southern zone of the GMGA, the area of suitable habitat that is located within the development footprint is 113 ha or 21%. Within the PGA 468 ha or 82% occurs within the development zone.

4.3.3 Survey effort

Greater Macarthur GA
The nature and level of survey effort undertaken within the habitat polygons as part of the strategic assessment is a factor to consider in identifying potential habitat. Figures 9 - 11 show the overlap of surveys with areas of suitable habitat. This information is summarised in Table 15.

The northern extent of the Greater Macarthur growth area has been well surveyed reflecting the small areas and easy access. Except for polygon 2 where five Ecoplanning plots were sampled the remaining polygons were subject to general flora and fauna survey by Biosis that is reported to have included targeted survey for *Pimelea spicata* (Dayle Green *pers. comm*.). Details of the timing and conditions of surveys, however, are unknown. The spring/summer of 2017/18 was generally hot and dry, not providing suitable conditions for survey of this species (see Section 2). Many of the selected habitats are also currently subject to disturbance such as mowing in council reserves e.g. Georges River Reserve, Kanbyugal Reserve and along Bow Bowing Creek at Minto.

Table 15. Survey effort in suitable habitat polygons for *Pimelea spicata*

Growth area	No. of habitat polygons	No. of habitat polygons unsurveyed	No. of habitat polygons with plot survey	Details
Greater Macarthur (north)	16	2 12.5%	1	1 of the unsurveyed plots (No. 1) Glenfield Waste Services has been surveyed previously including plots – see Section 4.1.2. Except for plots 1 & 2 only general flora survey undertaken (Biosis)
Greater Macarthur (south)	24	12 50%	4	Low level of survey in areas with highest concentration of suitable habitat polygons.
Wilton	6	3 50%	3	Largest polygons with good level of plot survey (Ecoplanning)

The southern extent of the Greater Macarthur Growth Area has been less well surveyed with 50% of habitat polygons surveyed and again mostly through general/targeted survey by Biosis. Habitat occurring on semi-rural/grazing lands around Menangle Sugarloaf and Mount Gilead comprise some of the most potential habitat in Cumberland Plain Woodland and Moist Shale Woodland for *Pimelea spicata* within the growth areas but are among those least surveyed (both general, targeted and plot sampling). Many areas of suitable habitat in the southern extent are also still slashed and grazed or subject to African Olive infestation reducing the likelihood of the species being visible.

Wilton Growth Area
The Wilton GA has been well surveyed and although only 50% of the habitat polygons have been accessed and surveyed they are the largest ones. Reliability of these surveys in detecting *Pimelea,* however, is likely to be low in view of the hot dry conditions experienced during spring-autumn 2017-2018 and the extent of grazing. Figures 9-11 show the overlap of surveys with suitable habitat polygons with the priority growth areas.

Figure 9. Habitat polygons and survey effort for Greater Macarthur GA Northern Zone

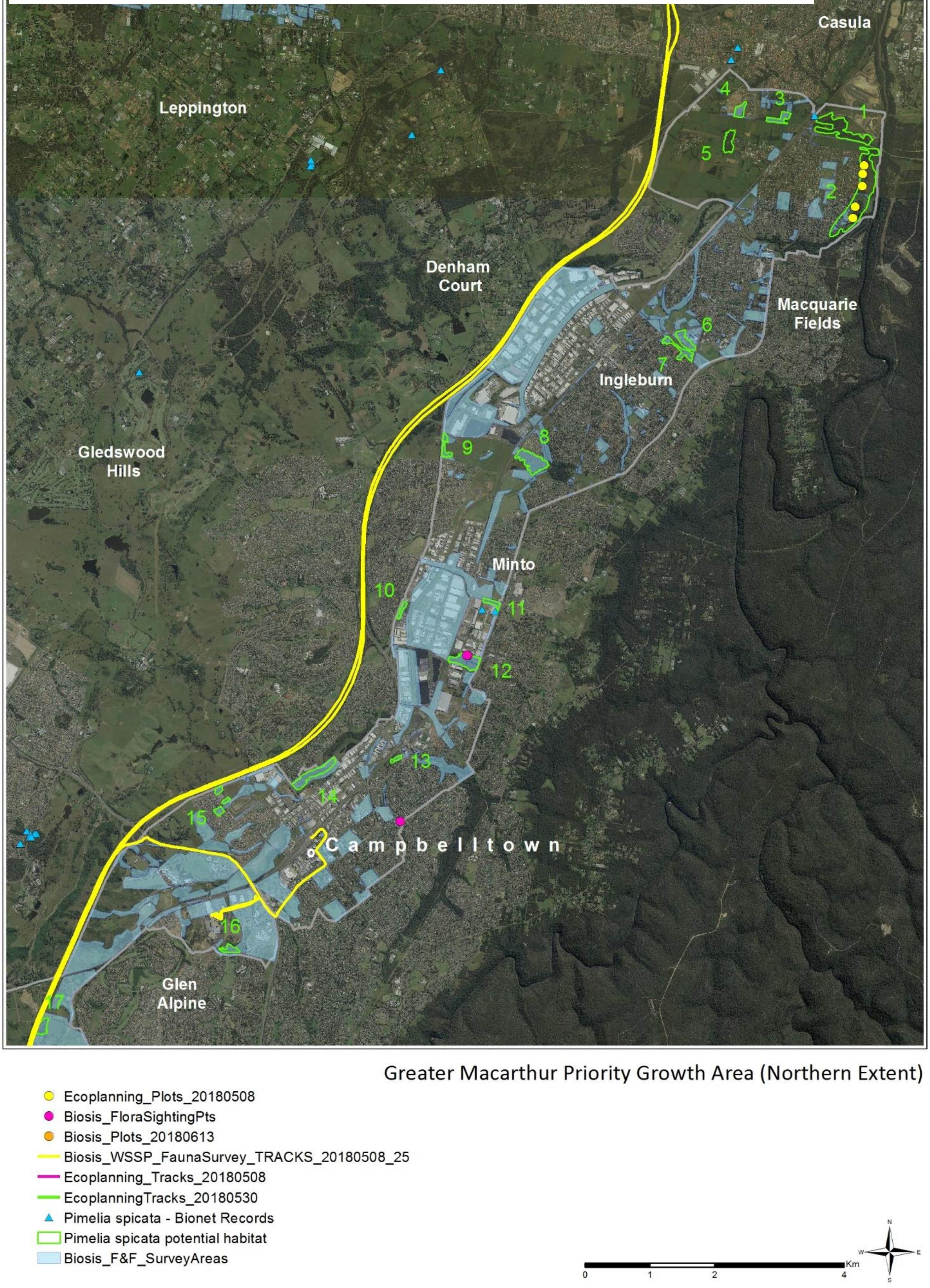


Figure 10. Habitat polygons and survey effort for Greater Macarthur GA Southern Zone

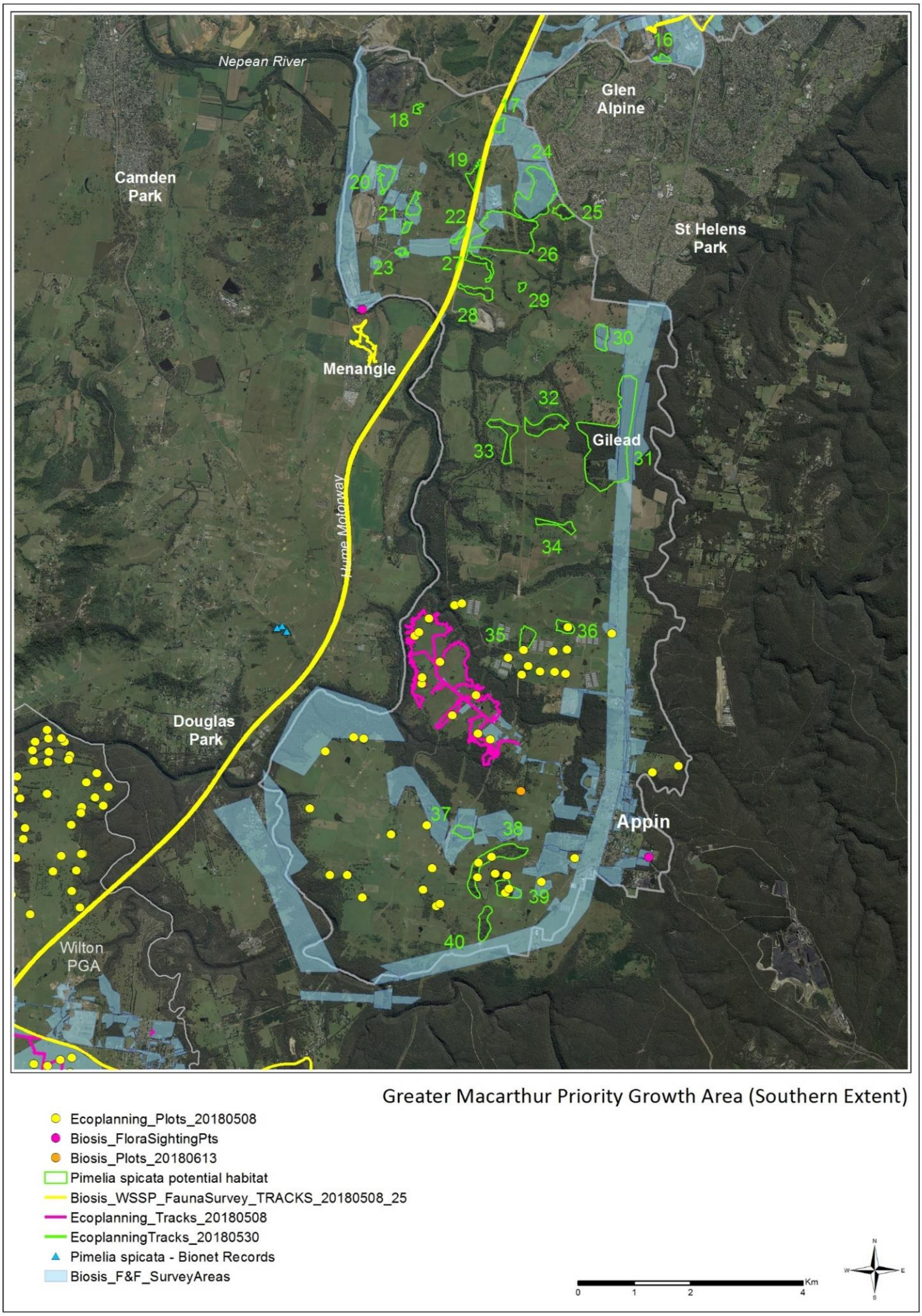
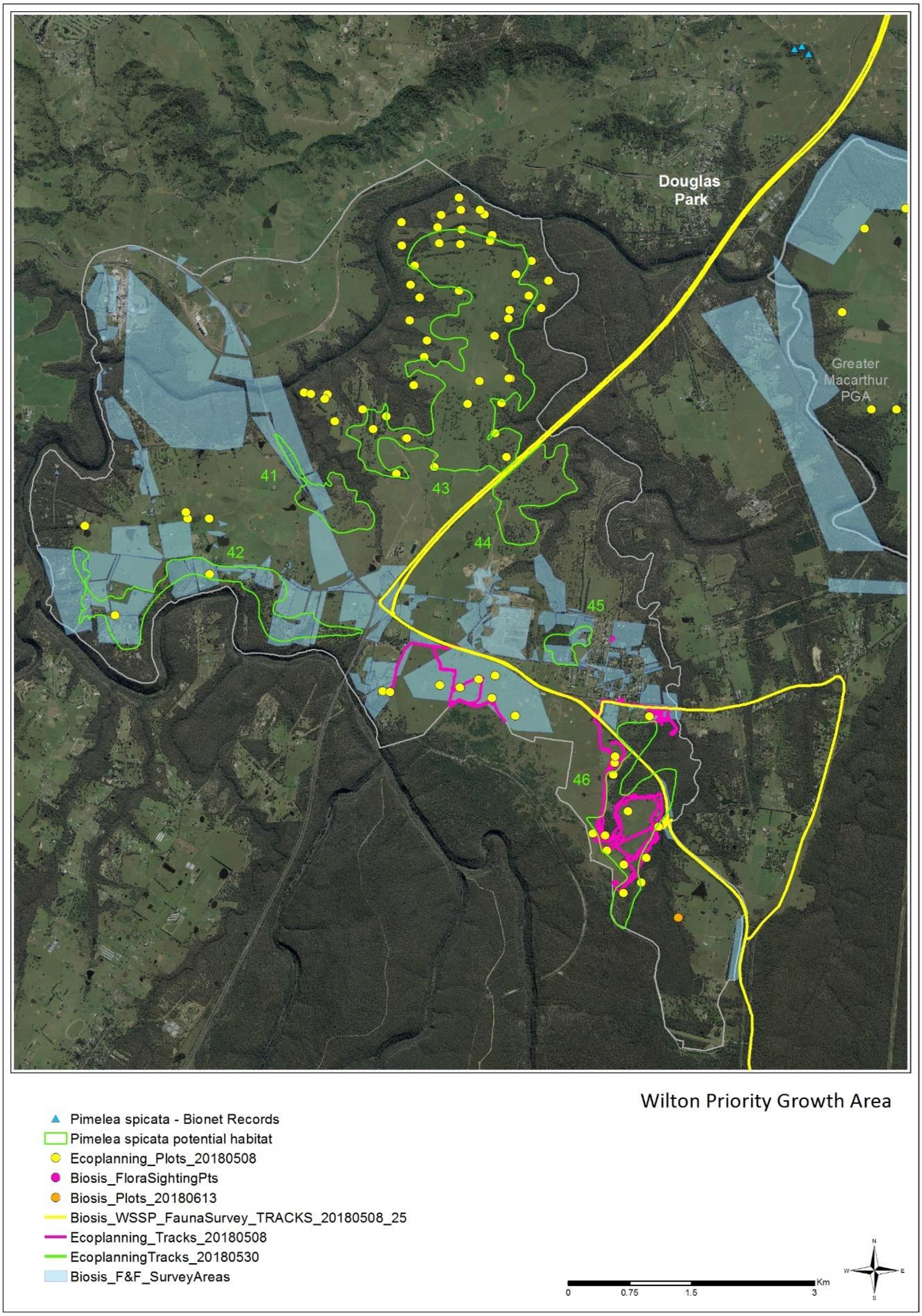


Figure 12. Habitat polygons and survey effort for Wilton GA



5 Summary and conclusion

Pimelea spicata is likely to be present within both the Greater Macarthur and Wilton Priority Growth Areas. Within the northern zone of the Greater Macarthur PGA one atlas record has been confirmed in recent years and has some short-term security. Several populations occur just to the north and west of the study area. The study area is considered important habitat for the species close to the south-eastern limit of its geographical range.

Likelihood of occurrence is based on the:

- Presence of local records;
- Presence of suitable habitat;
- Ability of the species to persist as rootstock and seed for long periods; and
- Ability of the species to easily regenerate when environmental conditions are suitable.

Extensive areas of suitable habitat are identified across the study area but particularly in the more rural lands of the southern extent of Greater Macarthur and the Wilton Growth Areas. A total area of 947 ha is identified within four vegetation communities (TECs) across the two growth areas (542 ha in GMGA & 405 ha in WGA). The condition of habitat is not a reliable indicator of species presence and all condition states were considered in determining suitable habitat.

Survey effort across the study area is variable. Areas with the highest potential for occurrence of *Pimelea spicata* are under-surveyed including Menangle Sugarloaf and Mt. Gilead. Throughout the study area, even where the level of survey is good, the reliability of detecting the species is low due to lack of targeted survey under suitable conditions for growth and flowering.

A high percentage of potential habitat occurs within the biocertification area or proposed development footprint and impacts on *Pimelea spicata* are expected to be high. Within the southern zone of the GMGA, the area of suitable habitat that is located within the development footprint is 113 ha or 21%. Within the WGA 468 ha or 82% occurs within the development zone.

In view of the low reliability of prior/recent surveys it is appropriate to assume the species presence and to reserve areas of suitable habitat across the study area that are protected and managed to protect the species long-term.

6. Information used in the assessment

6.1 NSW Planning & Environment resources

- Bionet sightings & other threatened species data
- Greater Macarthur & Wilton Vegetation Mapping
- Survey effort and land access details

Table 16. Sources for existing vegetation survey data used in the biodiversity assessment

Data collector	Client	Approx. no. plots	Survey year	Growth Area
Cumberland Ecology	Walker Corp	38	2014 - 2016	Wilton
Cumberland Ecology	Brad Corp	66	2014 - 2016	Wilton
Eco Logical Australia	Governors Hill	20	2015 - 2016	Wilton
Eco Logical Australia	Property NSW	None (mapping and assessment of trees only)	2016	Campbelltown

Data collector	Client	Approx. no. plots	Survey year	Growth Area
Eco Logical Australia	Lend Lease	Unknown	Unknown	Mt Gilead
OEH	OEH Koala Habitat Mapping	Around 18 within or bordering GAs (many others west of GAs)		Wilton and Appin

6.2 References

Anne Clements & Associates (2010) Flora study 395 Pembroke Road, Minto

Benson & McDougall (2001) Ecology of Sydney Plants *Cunninghamiana* 7(2)

Cumberland Ecology (2016) Wilton Junction New Town Project – Ecological Issues and Assessment Report

Cumberland Ecology (2017) Wilton Junction – Ecological Summary Report to Walker Corporation

DEC (2006) Approved Recovery Plan for *Pimelea spicata*

Dept. of Environment & Heritage online Spiked Rice-flower *Pimelea spicata* SPRAT profile www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=20834

Dept. of Environment & Heritage (2016) Conservation Advice *Pimelea spicata* Spiked Rice-flower

Eco Logical (2017) Mt Gilead *Biodiversity Certification Assessment & Biocertification Strategy*

Eco Logical (2015) Bingara Gorge Environmental Management Plan for EP & R Lands (Wilton) prepared for Lend Lease

Eco Logical (2017) Mt. Gilead EPS Environmental Property Services

(EPS 2015) Glenfield Ecological Assessment. Report to Glenfield Waste Services.

Harden, G.J. (ed) (1990). *Flora of New South Wales. Volume One*. Kensington, NSW: University of NSW Press

James, T (2009, 2010) Menangle Park Offset Strategy – targeted survey for *Pimelea spicata.* Unpublished report to GHD

James, T. (2011) Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland at a property on Appin Road, Gilead. Report to DEECW

James, T (2012) – targeted survey for *Pimelea spicata* along Denham Court Road for Camden Valley Way Upgrade. Unpublished report

James, T (2013) Campbelltown Roadside Survey – targeted survey for threatened species and EEC verification

Niche Environment & Heritage (2012). Appin Mine Ventilation Shaft No 6 Project. Biodiversity Management Plan

NSW Bionet (OEH) online www.bionet.nsw.gov.au/ including Atlas records

NSW NPWS (1997) Urban Bushland Biodiversity Survey Stage 1 - Western Sydney

NSW NPWS (2004) Environmental Impact Assessment Guidelines

OEH (2016) NSW Guide to Surveying Threatened Plants
OEH (2017) Biodiversity Assessment Method http://www.environment.nsw.gov.au/resources/bcact/biodiversity-assessment-method-170206.pdf

OEH (2017) Spiked Rice-flower Profile http://www.environment.nsw.gov.au/ThreatenedSpeciesApp/profile.aspx?id=10632

Willis *et al.* (2003) Comparative seed ecology of the endangered shrub *Pimelea spicata* and a threatening weed Bridal Creeper. Ecological Management and Restoration Vol 4 Issue 1

7. Appendix 1. Curriculum Vitae for Teresa James

Home & work address: 7/58 Wharf Street, Forster NSW 2428

Mailing address: PO Box 53 Forster NSW 2428

Telephone: Mobile: 04 282 18502.

Email: t.james@optusnet.com.au

Key positions:

- Botanist/ecological consultant specialising in vegetation survey, plant identification, conservation assessment and threatened species.
- Until October 1998 held position of Identifications Botanist, Plant Sciences, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney.

Qualifications:

Bachelor of Science (Combined Honours in Biology and Geography) - University of Exeter, England. 1978.

Accreditation:

Accreditation awarded (2008) as a BioBanking Assessor under the Threatened Species Conservation Act 1995 (NSW); accreditation renewed 2013. Accreditation number 0017.

Current employment (1998-present):

Self- employed flora/ecological consultant (sole trader working as Teresa James Flora Consultant).

- Flora surveys, site/conservation assessments and monitoring projects.
- Preparation of environmental impact assessment reports (e.g. 7-part test, species impact statement & review of environmental factors).
- Biobanking and Biodiversity Offset assessments.
- Preparation of threatened species management plans.
- Expert witness in the Land & Environment Court.
- Botanical training for local councils and community groups.

Previous employment

1978 (3 months)	Technical Assistant, Biological and Chemical Research Institute, Rydalmere (Department of Agriculture).
1978-1998	Employed at the Royal Botanic Gardens, Sydney.
1978-1979	Temporary Herbarium Assistant
1980-1982	Technical Officer, Botanical Information Section
1982-1986	Acting Identifications Botanist, Botanical Information Section
1987-1991	Technical Officer, Botanical Information Section
1991-1994	Acting Identifications Botanist, Botanical Information Section
1994	Secondment 4 days/week to World Heritage Assessment of the Blue Mountains (consultancy for NSW National Parks & Wildlife Service).
1994	Permanent appointment as Identifications Botanist.
1994-	Appointed Botanical Information Section Co-ordinator.
1996-1997	Secondment to NSW National Parks & Wildlife Service as Flora Officer for Urban Bushland Biodiversity Survey. Stage 1: Western Sydney.

1994-1998	Identifications Botanist & Botanical Information Section Co-ordinator.

<u>Selected longer-term projects:</u>

1998-1999	Vegetation sampling for NSW National Parks & Wildlife Service - Western Sydney Vegetation Mapping Project.
1999	Flora consultant to Eastern Gas Pipeline (Duke Australia Operations).
2000	Preparation of Fire Ecology Manual for Rural Fire Service and UWS.
October 2000-2003	Flora consultant to Biosis Research for Penrith City Council – proposed developments & TSC Act issues at Erskine Park.
2001	Field sampling and truthing for vegetation community mapping project - Baulkham Hills LGA. Baulkham Hills Shire Council.
2001-2003	Qualitative and quantitative vegetation surveys (including rare plant species and ecological communities, weeds and other threats, environmental assessment) of Wingecarribee Swamp with Sainty & Associates for the Sydney Catchment Authority.
February 2002-May 2002	Review of wetland boundaries and general vegetation mapping and condition assessment within Baulkham Hills local government area (for Baulkham Hills Shire Council).
2003	Vegetation survey in the Hunter, Nattai & Bargo districts as part of the National Parks & Wildlife Service Vegetation Survey Program.
2002-2007	Flora survey/monitoring at Dr Charles McKay Reserve, Mt. Druitt for Blacktown City Council.
September 2005 –2006	Field validation for Foreshore Vegetation Mapping Project on Sydney Harbour for Botanic Gardens Trust and NSW Maritime Services.
September 2000-2008	Flora consultant to Liverpool City Council – provide review & advice relating to development applications, plans of management & special projects.
February -May 2007	Field survey for Sydney Metropolitan Catchment Management Authority/DECC vegetation mapping. Plot data recorded for 100 sites within SMCMA.
May 2008-2010	Vegetation mapping and assessment of Blue Gum High Forest and Turpentine Ironbark Forest in Ku-ring-gai local government area
August 2008-present	Flora advice to Ku-ring-gai Council - review of development applications, plans of management and mapping/biodiversity projects.
February-August 2012	PAS2 Expert Interviews for NSW threatened species with Office of Environment & Heritage.

*See consultant reports for complete list of projects/surveys.

Special projects:

<u>Assessment of the World Heritage Values of the Blue Mountains and surrounding plateaus</u>

An assessment of the natural and cultural values of the sandstone plateaus of the Blue Mountains and surrounding areas was funded by the Federal and State Governments to determine the potential for world heritage nomination. A team of people worked on the project from the Royal Botanic Gardens, Australian Museum (cultural values) and experts from local universities. I was project co-ordinator for the assessment, wrote much of the text for the natural values sections and was editor of the final report.

This report was used as a basis for the successful Blue Mountains World Heritage nomination (June 1998).

NPWS Urban Bushland Biodiversity Survey. Stage 1: Western Sydney

Documentation of biodiversity and conservation values in Western Sydney was the first priority project undertaken within the State Biodiversity Survey Program. The survey gave emphasis to threatened species, communities and habitats. The region was documented on a local government area basis. I co-ordinated the flora surveys and was principal author for the flora reports.

Particular expertise:

Plant Identification:

- New South Wales plants, native and naturalised (18 years of experience in the Botanical Information Section of the Royal Botanic Gardens, Sydney). Specimens received from all over state. Also cultivated plants.
- Specialist in Sydney flora.
- Prepared taxonomic treatments for various plant families in the publication Flora of New South Wales, volumes 1-4, produced by the Royal Botanic Gardens, Sydney.
- Conduct plant identification workshops both through the RBG and the University of Western Sydney.

Documentation and conservation/ impact assessment: plant communities and species

- Extensive range of sites surveyed with species lists compiled over the last twenty-five years, particularly in Western Sydney, the Blue Mountains and Southern Highlands. Plant specimens collected and incorporated into the National Herbarium of N.S.W. Information used in numerous reports and books e.g. World Heritage Assessment of the Blue Mountains, the NPWS Urban Bushland Biodiversity Survey, Rare Bushland Plants of Western Sydney and various papers.
- Prepare Tests of Significance and Species Impact Statements as required under current legislation (TSC Act, EPBC Act).
- Prepare Statements of Evidence & Affidavits for the Land & Environment Court.
- Provide advice to the community, developers, government agencies and councils concerning the identification of communities and species, impacts of proposed developments, the ecological effects of urbanisation, flood mitigation and management practices such as mowing, burning etc.

Peer review

Assessor services provided to government (all levels), consultancies and NGO's. Including the following:

- DA applications and associated reports e.g. REF's, SIS's, Tests of Significance
- BioBanking/Offset reports
- NSW Land & Environment Court reports

Education & training

- Involvement on committees or in groups providing technical advice and training eg. Greystanes Creek Management Committee, Upper Parramatta River Catchment Trust steering committees, Hawkesbury Rainforest Network.
- Presentations/talks e.g. National Parks Association, Society of Australian Plants, University of NSW, Landcare groups, local councils.
- Conduct plant community and species identification workshops/courses/tours through the Royal Botanic Gardens, the University of Western Sydney and privately.
- Prepared Fire Ecology Manual for Rural Fire Service (2000).

- Training for local government in threatened species, endangered ecological communities and biodiversity conservation.
- Publications e.g. primary author of revised edition of Rare Bushland Plants of Western Sydney (Royal Botanic Gardens 1999*),* contributor to Flora of New South Wales *(*Royal Botanic Gardens).

Courses/workshops & tours provided to local government/catchment management trusts/consultancies:

- Sept. 2004 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers & council staff
- October 2004 – Significant Plant Communities-of Baulkham Hills Shire Council – tour for council staff
- February 2005 – Community workshop in Cumberland Plain Woodland for Holroyd City Council
- July-August 2005 - Biodiversity training for Liverpool City Council – 3 workshops for council officers
- September 2005 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- August 2007 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2007 – Identification of plants in Cumberland Plain Woodland – for Hawkesbury Nepean CMA.
- April 2008 – Basic grass identification course for Baulkham Hills Shire Council (for bushcare volunteers).
- August 2008- Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- November 2008 to April 2009 – Weedy Grass Identification Workshop x 3 for Sydney Metro CMA.
- August 2009- Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2009 – EEC identification field day for Hawkesbury-Nepean CMA
- August 2010 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2010 – Cumberland Plain Woodland identification training for SMEC Australia
- April 2011- – Cumberland Plain Woodland identification training for SMEC Australia
- April 2011 – Field training in identification of communities & plants on the Cumberland Plain for Hawkesbury Nepean CMA.
- June 2011 – Presentation to council staff on threatened flora & fauna and biodiversity conservation within the Hills Shire.
- August 2011- Threatened Species Tour for Hills Shire Council bush care workers
- June 2012 – Eucalypt Identification workshop for Hills Shire Council.
- September 2014 - Threatened Species Tour for Hills Shire Council bush care workers
- September – November 2014 – Series of two-day workshops on threatened ecological communities in western Sydney.
- October 2014 – Plant identification training day held at Dr Charles Mckay Reserve, Mt. Druitt for Blue Tongue Ecosystems.
- March 2015 – Derived Grasslands Workshop (western Sydney) for government and community.
- May 2015 - Threatened Ecological Communities Workshop (western Sydney) for government and community.
- August 2015 – Shale Sandstone Transition Forest Workshop (western Sydney) for government and community.
- September 2015 – Northern Sydney Threatened Communities Workshop for government and community.
- April 2016 - Shale Sandstone Transition Forest Identification Workshop
- April 2016 – Introduction to Identifying Western Sydney Plants
- April 2016 – Grass Identification Workshop

- April 2016 – Cumberland Plain Woodland Workshop for Liverpool Council bushcarers
- August 2016 - Threatened Species Tour for Fairfield City Council.
- August 2016 - Threatened Species Tour for Hills Shire Council.
- April 2017 – Bushcare Training for Penrith Council
- Aug-Sept -Oct 2017 - Community bushland guided walks for Liverpool Council
- August 2017 - Threatened Species Tour for Fairfield City Council.
- August 2017 - Threatened Species Tour for Hills Shire Council.
- September 2017 – Flora workshops at Scheyville and Agnes Banks

Committee & community participation

- Member of NPWS Cumberland Plain Woodland Recovery Team (1998).
- Member of NPWS Acacia pubescens Recovery Team (1998 to 2002).
- Member, Green Corridors Strategy Steering Committee.Upper Parramatta River Catchment Trust. (1997-2000).
- Member, Water Quality Strategy Steering Committee. Upper Parramatta River Catchment Trust (1995-7).
- Member, State of the Environment Report Steering Committee for Holroyd City Council (1995-2002).
- Botanical Advisor for Management Committee, Greystanes Creek Restoration Project (1993-2000).
- Blue Gum High Forest Workshop / Advisory Committee – Ku-ring-gai Council. (2007).

Publications/booklets:

- Stepnell, K. & James, T. A. (1986). *Australia's Native Flowers*. Child & Henry Publishing Pty. Ltd.
- James, T.A. (1988). *Bertya ingramii* (Euphorbiaceae) a new species from New South Wales. *Telopea* 3(2): 285.
- Bedford, D. & James, T. (ed.) (1992). *Collection, Preparation & Preservation of Plant Specimens.* Royal Botanic Gardens, Sydney.
- Powell, J.M. & James, T.A. (1993) *Epacris sparsa* (Epacridaceae) reinstated. *Telopea* 5(2):375-380.
- James, T.A. (1990-1993) in *Flora of New South Wales*. Royal Botanic Gardens, Sydney
- Volume 1: Euphorbiaceae (part), Violaceae.
- Volume 2: Fabaceae (part).
- Volume 3: Celastraceae, Rubiaceae (part).
- Volume 4: Iridaceae (part), Poaceae (part).
- James, T.A. (1994). Observations on the effects of mowing on native species in remnant bushland, Western Sydney. *Cunninghamia* 3(3).
- Kodela, P.G. & James, T.A. & (1994) Aspects of the ecology and conservation status of the rare herb *Gentiana wingecarribiensis*. *Cunninghamia* 3(3).
- James, T.A. (1994) Review of a Key to Australian Grasses by B.K. Simon. *Australian Systematic Botany Society Newsletter* No.78.
- Contributor to Bowen Mountain Bushwalks (1994). Bowen Mountain Association.
- Kodela, P.G, James, T.A & Hind, P. (1996). Vegetation and flora of swamps on the Boyd Plateau, Central Tablelands, New South Wales. *Cunninghamia* 4(3).
- James, T.A. (1996). New combination in *Viola* (Violaceae). *Muelleria* Vol. 9 pp.35-36*.*
- James, T.A. NSW NPWS. (1997). Urban Bushland Biodiversity Survey. Stage 1: Native flora in Western Sydney.
- Hosking, R. J & James, T.A. (1998). An analysis of the native and exotic flora of the North Western Slopes upstream of the junction of the Peel and Namoi Rivers, New South Wales.

- James, T.A., McDougall, L & Benson, D. (1999). Revised edition. *Rare Bushland Plants of Western Sydney.* Royal Botanic Gardens, Sydney.
- James, T.A. (2009) Threatened plant species of Baulkham Hills Shire – unpublished booklet for Baulkham Hills Shire Council.
- James, T.A. (2009) Vegetation communities of Baulkham Hills Shire – unpublished booklet for Baulkham Hills Shire Council.
- James, Teresa (2013) Flora of Cumberland Plain Woodland – an identification guide.
- James, Teresa (2015) Threatened Flora of the Fairfield LGA.
- James, Teresa (2016) Native Flora of Shale Soils of the Cumberland Plain Woodland – An Identification Guide.

Reports

List of unpublished species lists and reports over the last 15 years.

- Kodela, P.G., James, T.A., Coveny, R.G. and Hind, P.D. (1992). Reconaissance survey of the vegetation at Long Swamp, near Penrose, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished report.
- James, T.A. & Kodela, P.G. (1992). Species list for Little Cattai Creek and tributary creeks. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. & Kodela, P.G (1993). Plant species recorded from Butlers Swamp, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. Coveny, R.G., Kodela P.G. and Hind, P.D. (1993). Plant species recorded from a wetland area on the northern side of Fitzroy Falls Reservoir, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A., Hind, P.D., Kodela, P.G. (1993). List of native species recorded for the Vale of Avoca Reserve. Royal Botanic Gardens, Sydney. Unpublished species list.
- Coveny, R.G. and James. T.A. (1993). Plant species recorded from the Dr. Charles McKay Reserve, Mt. Druitt, Western Sydney. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. (1994) Native plant species recorded from Alpha Park Reserve, Greystanes. Unpublished report.
- James, T.A. (1994) Botanical Significance of the Lower Canal, Greystanes. Unpublished report.
- James, T.A. (2004 revised 2009). Rare and threatened plant species of Baulkham Hills Shire for Baulkham Hills Shire Council.
- Allen, CB, Benson, DH, James, T & Kelleway, J (2007). Vegetation map of the Sydney Harbour Foreshore, December 2006. Prepared for NSW Maritime and the Sydney Metropolitan CMA by Royal Botanic Gardens, Sydney.

Consultancies:

- James, T.A. (1992) Vegetation Survey of proposed pipeline and irrigation sites for Goulburn wool scour. Unpublished report for Gunninah Consultants.
- James, T.A. (1992). Survey of Vegetation along New Line Road at Cherrybrook. Unpublished report for Gunninah Consultants.
- James, T.A. (1993). Vegetation survey of the eastern section of the Australian Defence Industries site, St. Marys. Unpublished report for Gunninah Consultants.
- James, T.A. *et al.* (1994) Royal Botanic Gardens Assessment of the World Heritage Values of the Blue Mountains and surrounding plateaus.
- James, T.A & S. Mcune (1998a). Flora assessment for the proposed Highlands Resort development near Picton. Report prepared for DLWC.
- James, T.A. (1998b). Cumberland Plain Woodland Assessment, Claremont Meadows, Penrith. Report prepared for Biosis Research. Subsequent assessment of significance of Cumberland Plain Woodland at the site for Species Impact Statement (Dec. 1998).

- James, T.A. & S. Cook (1998d). Flora Survey of Domain Creek, Parramatta Park.
- Douglas, S.M. & James, T.A. (1998e). Report on the native flora and development potential of Lot72 DP661069 & Lot 75 DP 67236 Sirius Road, Voyager Point. Report to Liverpool City Council.
- James, T.A. (1999a). Species profiles and environmental impact assessment guidelines for the rare species *Epacris sparsa, Kunzea cambagei, Acacia baueri* subsp. *aspera, Euphrasia bowdeniae* and *Zieria covenyi.* Prepared for NSW NPWS.
- James, T.A. (1999b). 8 Part Test- proposed laying of underground electrical conduit at the Crest of Bankstown. Report to Bankstown City Council.
- James, T.A. (1999c). 8 Part Test for drainage works at the Crest of Bankstown. Report to Bankstown City Council.
- James, T.A. (1999d). Overview of vegetation and assessment of conservation significance at proposed Erskine Park Employment Area. Report prepared for Biosis Research.
- James, T.A. (1999e). Vegetation review and survey of Area 3, Chullora Industrial Estate. Report prepared for Mather & Associates and Business Land Group.
- James, T.A. (Sept 1999). Review of management plan for the Highlands Resort, Picton - report for DLWC.
- James, T.A. (Oct 1999). Field survey and 8-part test for *Acacia baueri* subsp. *aspera*. Report for the Illawarra Shooting Association.
- James, T.A. (Nov 1999). Flora assessment - proposed works at Oatlands Golf Course. Report to Oatlands Golf Club.
- James, T.A. (Dec 1999). Flora assessment - Bungarribee Creek, Blacktown. Report to Blacktown City Council.
- James, T.A. (Feb 2000). Norfolk Reserve, Greenacre - Plant Survey and 8 Part Test for proposed walking tracks. Report to Bankstown City Council.
- James, T.A. (March 2000). Flora survey along Clavering Road, Seaforth.
- James, T.A. (May 2000). Flora assessment and 8-part test for proposed high school development along York Road, Kellyville. Report to the Department of Public Works.
- James, T.A. (June 2000). Flora survey and assessment of remnant Cumberland Plain Woodland at Dr. Charles McKay Reserve, Mt. Druitt. Report to Dr. Charles McKay Reserve 271 Park Committee.
- James, T.A. (June 2000). Remnant bushland at Central Gardens, Merrylands - flora survey and assessment of conservation and educational values. Report to Holroyd City Council.
- James, T.A. (July 2000) Powell Park, Kurrajong Hills - flora survey and conservation assessment. Report to Hawkesbury City Council.
- James, T.A. (August 2000) Chullora Industrial Estate - bushland retention area (3) and adjoining lands - flora and fauna assessment and "eight part tests" of significance. Report to Business Land Group.
- James, T.A. (August 2000) Flora report for bushland along Ropes Creek, St. Marys with management guidelines. Report to National Trust.
- James, T.A. & S. Douglas (September 2000). Flora survey & 8-part test for Lower Prospect Canal.. Report to NSW NPWS.
- James, T.A. (November 2000). Flora inspection of proposed driveway across 181 Princes Highway, Sylvania.
- James, T.A. (November 2000) Preliminary flora & fauna survey - Arabella Street, Longueville - proposed subdivsion.. Report to City Plan Services.
- James, T.A. (January 2001) Flora survey and assessment for Dwyer Oval, Cabramatta for Liverpool City Council.
- James, T.A. (January 2001) Flora survey and assessment for Duncan Park, Seven Hills for Friends of Grantham
- James, T.A. & J. Anderson for Oculus Pty Ltd. (Feb-April 2001). Flora and fauna survey of reserves within Mosman Local Government Area for Mosman City Council.

- James, T.A. & J. Anderson (March 2001). Species Impact Statement - Lot 907 Narabang Way, Belrose. Report to Access Industrial Holdings Pty Ltd.
- (April-May 2001). Flora survey of Wingecarribbe Swamp. Field assistance provided to Sainty & Associates Pty. Ltd.
- James T.A. & Anderson, J. (May 2001). Preliminary flora and fauna survey for Public Reserve, Prestons. Report for Liverpool City Council.
- James, T.A. (March 2001). Species Impact Statement for Dendrobium Project (BHP) Woronora Plateau. Assistance provided to Biosis Research.
- James, T. A. (June 2001). Threatened flora assessment & survey – *Grevillea juniperina* subsp. *juniperina, Grevillea parviflora* subsp. *parviflora* and *Pultenaea pedunculata*. Report to NSW National Parks & Wildlife Service.
- James, T.A. & Anderson, J. (June 2001) Preliminary flora and fauna survey for Public Reserve south of Braidwood Avenue, Prestons. Report to Liverpool City Council.
- James, T.A. (July 2001). Flora survey - Scheyville National Park for NSW National Parks & Wildlife Service.
- James, T.A. (August 2001). 8 Part Test for proposed cycle track at Crest Reserve, Bankstown. Report to Bankstown City Council.
- James T.A. & Anderson, J. (August 2001). Preliminary flora & fauna survey of Chullora lands affected by proposed rail upgrade. Report to Rail Infrastructure Corporation.
- James, T.A. (Sept 2001). Inspection and assessment of current mowing/slashing activities at the St Marys ADI site. Report to Compliance and Enforcement Section, Environment Australia
- James, T.A. (Nov 2001). Flora survey for proposed drainage easement at Pleasure Point. Report to Liverpool City Council.
- Kodela, P.G., Bravo, F.J, James, T.A. & Sainty, G.R. (Dec 2001). Quantitative sampling of vegetation in Wingecarribee Swamp. Prepared for Sydney Catchment Authority.
- James, T.A. (March 2002). Moorebank Interchange - Threatened Flora Survey and Assessment. Report to Haliburton KBR and the Roads and Traffic Authority, New South Wales
- *James, T.A. (March 2002). Clearing of native vegetation – Lots 1 & 4 Cowlishaw Street, Redhead. Report to NSWNPWS and Lake Macquarie City Council.*
- James, T.A. (April 2002). Balmoral Road Land Release – Ecological assessment of Cumberland Plain Woodland. Report to Baulkham Hills Shire Council
- Kodela, P.G., Bravo, F.J, James, T.A & Olsen, A. (May 2002). Quantitative sampling for vegetation in Wingecarribee Swamp-Spring 2002 survey. Report for Sydney Catchment Authority.
- James, T.A. (May 2002). Post-fire survey for *Acacia baueri* ssp. *aspera* – proposed shooting range. Report to Illawarra Shooting Association.
- James, T.A. (May 2002). Eight-part test for Chullora siding proposal. Report to Rail Infrastructure Corporation.
- James, T.A. (August 2002). Ecological study of Castle Hill Cemetery. Report to Baulkham Hills Shire Council
- James, T.A. (August 2002). Flora survey and assessment for Precint A1, Judith Street, North Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (September 2002). Flora survey and assessment for Precint C North, Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (November 2002). Flora survey and assessment for proposed roadway and stormwater easement in vicinity of Clavering Road & Gurney Crescent, Seaforth. Report to GHD for NSW Planning & RTA.

- James, T.A. (December 2002). Flora survey and assessment for Lot 38A Boronia Lane, Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (January 2003). Flora survey and assessment (including 8 part-test) for proposed upgrade of Seaforth Oval. Report for Manly Council.
- James, T.A & Anderson, J. (February 2003). Flora and fauna survey and assessment (including 8 part-tests) for Lot 31 Muir Road, Chullora. Report to Landcom.
- James, T.A & Anderson, J. (February 2003). Flora and fauna survey and assessment for proposed re-zoning of creek-line in vicinity of 15-25 First Avenue, Hoxton Park. Report to Liverpool City Council.
- James, T.A. (March 2002). Flora survey of Heath Road Reserve. Report to Baulkham Hills Shire Council.
- James, T.A & Anderson, J. (April 2003). Review of Environmental Factors for proposed hazard reduction burn at the Kings School, North Parramatta.
- James, T.A & Anderson, J. (May 2003). Flora and fauna survey and assessment for Lot 11 Corner Hume Highway and Worth Street, Chullora. Report to Landcom.
- James, T.A. (June 2003). Chullora rail yard upgrade – targeted survey for Tadgell's Bluebell *Wahlenbergia multicaulis*, part of requirement for SIS. Report to Rail Infrastructure Corporation.
- James, T.A. (May-June 2003). Flora survey in Hunter district for NSW National Parks & Wildlife Service.
- James, T.A. (June 2003). Field survey in North West Sydney – for Eco Logical Australia and Planning NSW.
- James, T.A & Anderson, J. (September 2003). Flora and fauna survey of Caroll Park & surrounds, Casula. Report to Liverpool City Council.
- James, T.A. (October 2003). Flora survey in Nattai – Bargo district for NSW National Parks & Wildlife Service.
- James, T.A. (December 2003). Flora survey and assessment for rail corridor at Yagoona. Report to Report to Rail Infrastructure Corporation.
- James, T.A. (December 2003). Review of flora and fauna issues re proposed integrated housing development at Beames Road, Rooty Hill. Report to Dr. Charles McKay Reserve Committee.
- James, T.A. (February 2004). Flora survey and assessment for rail corridor at Birrong. Report to Report to Rail Infrastructure Corporation.
- James, T.A. (May 2004). Summary of flora surveys during 2003-4 in Dr Charles McKay Reserve, Mt. Druitt for Blacktown City Council.
- James, T.A. (May 2004). Conservation assessment of Cumberland Plain Woodland in Balmoral Road Land Release area, Kellyville. Report to Baulkham Hills Shire Council.
- James, T.A. (May-June 2004). Threatened flora assessment for proposed realignment of the Great Western Highway at Lawson. Report to Australian Museum Business Services and Roads & Traffic Authority.
- James, T.A. (July 2004). Yagoona cutting flora review. Report to Rail Infrastructure Corporation.
- James, T.A. & Anderson, J. (September 2004). Flora and fauna survey for proposed residential development at the Kings School, North Rocks. Shale Sandstone Transition Forest and threatened species. Report to the Kings School.
- James, T.A. (September 2004). Flora assessment for proposed construction of sewage effluent pipeline at Megarritys Creek, Warragamba. Report to Australian Museum and Sydney Water.
- James, T.A. (September 2004). Flora survey of Faulkland Crescent Reserve, Kings Park. Report to Blacktown City Council.

- James, T.A. (October 2004). Flora assessment for proposed construction of water quality basins at Henry Street and Waratah Street, Lawson. Report to Australian Museum and Roads & Traffic Authority.
- James, T.A. (October 2004). Clearing of native vegetation at Lot 102 DP 1027438, 238-258 Captain Cook Drive, Kurnell. Report to Dept. of Environment & Conservation.
- James, T.A. (November 2004). Review of flora and fauna assessment for proposed subdivision at Charcoal Road, South Maroota. Report to Baulkham Hills Shire Council.
- James, T.A. (January 2005). Birrong rail cutting - flora review. Report to Rail Infrastructure Corporation.
- James, T.A. (Feb 2005). Proposed construction of electricity transmission line west of Nowra – preliminary flora survey and assessment. Report to Parsons Brinckerhoff Australia Pty Ltd.
- James, T.A. & Anderson Ecological Surveys (March 2005). Amended Species Impact Statement for proposed development at 8 Narabang Way, Austlink Corporate Park, Belrose.
- James, T.A. (March 2005). Review of flora and fauna assessment for proposed subdivision at 48-52 Oratava Avenue, 11 Maralinga Place and 19-25 Timberline Avenue, West Pennant Hills. Blue Gum High Forest. Report to Baulkham Hills Shire Council.
- James, T.A. (May 2005). Flora assessment for proposed extensions at Chatswood High School. Report to NSW Dept. of Commerce (Government Architects Office).
- James, T.A. (September 2005). Review of flora and fauna assessment for proposed hotel complex at 314 Annangrove Road, Rouse Hill. Shale Sandstone Transition Forest. Report to Baulkham Hills Shire Council.
- James, T.A. (October 2005). Flora survey for proposed fire hazard burn at Lawson. Report to GIS Environmental Consultants.
- James, T.A. (November 2005). Flora survey and assessment of shale forest at Helensburgh. Report to J & Z. Erskine.
- James, T.A. (December 2005). Preliminary flora survey at 110 Hebron Road, Lower Portland.. Report to GIS Environmental Consultants.
- James, T.A. (February & March 2006). Flora surveys in BHP exploration areas (Appin district). Surveys undertaken for Biosis Research.
- James, T.A. (March 2006). Flora survey & assessment for proposed reconstruction of 32nd Avenue, Hoxton Park. Report to Liverpool City Council.
- James, T.A. (April 2006). Flora monitoring survey - Hartley Quarry. Survey for Biosis Research.
- James, T.A. (May 2006). Preliminary flora report – proposed Penrith Great River Walk. Report to Australian Museum Business Services for Penrith City Council).
- James, T.A. (May 2006). Autumn surveys in Dr Charles McKay Reserve, Mt. Druitt. Ongoing survey & monitoring for Blacktown City Council.
- James, T.A. (May 2006). Update of Species Impact Statement for proposed development at 8 Narabang Way, Belrose. Report to Access Industrial Holdings Pty Ltd.
- James, T.A. (May 2006). Review of Environmental Management Plan and site inspection for proposed stabilisation works along Birrong rail cutting. Advice to RailCorp.
- James, T.A. (July 2006). Flora investigation of alleged poisoning of vegetation on Lot 42 Warlands Creek via Blandford, Upper Hunter Valley. Report to Department of Environment & Conservation (Legal Branch).
- James, T.A. & Barker, C. H. (June-August 2006). Preliminary flora & fauna survey for Hyland Road Reserve (North), Greystanes. Report to Holroyd City Council.
- James, T.A. (September 2006) Threatened Flora Surveys – western Sydney. Targeted survey for Department of Environment & Conservation.

- James, T.A. (November 2006). Flora survey and assessment for proposed footbridge construction over Cabramatta Creek. Report to Liverpool City Council.
- November 2006. Targeted field survey for *Gentiana wingecarribiensis* at Wingecarribee Swamp, Southern Highlands. Assistance to Parsons Brincherhoff Australia.
- February-May 2007. Field survey of Sydney Metropolitan Catchment Management Authority area. Royal Botanic Gardens Trust and Sydney Metropolitan Catchment Management Authority.
- T.A. James (February 2007). Faulkland Crescent Reserve - flora survey and review. Report to Blacktown City Council.
- James, T.A. (April 2007). Upgrade of Great Western Highway at Wentworth Falls - proposed stockpile, compound and spill basin areas - Flora survey and assessment. Report to Australian Museum Business Services for RTA.
- James, T.A. (May 2007). Upgrade of Great Western Highway at Bullaburra – flora survey and assessment. Report to Australian Museum Business Services for RTA.
- BioBanking Pilot Program (May 2007). Field survey & assessment at three Sydney sites (Wilton, Camden & Cranebrook) to test draft assessment methodology. Undertaken with Australian Museum Business Services for Department of Environment & Conservation.
- James, T.A. (August 2007). Flora review – proposed re-zoning of land along Pacific Highway, Pymble with particular reference to Blue Gum High Forest. Report to Ku-ring-gai Council.
- James, T.A. & C. H. Barker (October 2007). Flora & Fauna Survey and Assessment – Castle Hill Cemetery. Report to Baulkham Hills Shire Council.
- James, T. A. (Nov 2007). Investigation of clearing of native vegetation at Lot 2 DP 559922, 280-282 Captain Cook Drive, Kurnell. Report to NSW Department of Environment & Climate Change (DECC).
- James, T.A. (Nov 2007). Review of flora assessment for proposed residential development at 216-220 New Line Road, Dural. Report to Hornsby Council.
- November 2007. Assistance to SMEC Australia with base-line ecological monitoring in Upper Nepean Special Area for SCA.
- James, T.A (Dec 2007-Feb 2008). Targeted survey for *Hibbertia superans.* Report to Indigenous Business Services.
- November 2007- January 2008. Targeted survey for *Gentiana wingecarribiensis* and *Prasophyllum uroglossum* at Wingecarribee and Hanging Rock Swamps. Report to NSW Department of Environment & Climate Change (DECC).
- March 2008. Flora survey for upgrade of Great Western Highway at Bullaburra. Report to nghenvironmental for RTA.
- James, T.A. (March 2008). Flora survey of Plumpton Park Reserve. Report to Blacktown City Council.
- James, T.A. (April 2008). Review of Water Street DA, Wahroonga. Report to Ku-ring-gai Council.
- James, T.A. (April 2008). Flora survey of Gum Tree Reserve, Guildford and Bolaro Avenue, Greystanes. Report to Holroyd City Council.
- May 2008-June 2009. Assistance to Ku-ring-gai Council to map and assess Blue Gum High Forest and Turpentine Ironbark Forest.
- James, T.A. (August 2008). Flora review of Species Impact Statement prepared for proposed industrial development at 37 Beaumont Road, Mt. Ku-ring-gai. Report to Hornsby Shire Council.
- James, T. A. (May 2009). Preliminary flora report for proposed residential development at 38-40 Grove Avenue, Narwee.
- James, T.A. & Barker, C. (2006-2009). Monitoring of flora and fauna at Hyland Road Reserve. Report to Holroyd City Council.

- James, T. A. (Sept 2009). Ecological issues relating to the Turramurra Deferred Area within Ku-ring-gai LGA. Report to Friends of Turramurra.
- James, T.A. (Sept 2009). Targeted survey for *Pimelea spicata* at Menangle Park. Assistance to GHD Pty Ltd.
- James, T.A. (Sept 2009). Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland - 561 Appin Road, Gilead. Report to Campbelltown City Council.
- James, T.A. (Nov 2009). Peer review of subdivision proposal at Kellyville. Shale Sandstone Transition Forest & threatened species present. Report to Hills Shire Council.
- James, T.A (2010). Field survey and ecological assessment for proposed park at Water Street, Wahroonga. Report to A. Parr.
- James, T.A. (March 2010). Survey of *Pimelea spicata* at Menangle Park for GHD.
- March-April 2010. Advice on threatened species for Growth Centres Strategic Assessment under EPBC Act to EcoLogical Australia.
- Lewis Ecological Surveys & James, T.A. (May –June 2010). Flora and fauna assessment for extension of Kirkwood Road, Tweed Heads. Report to Tweed Heads Shire Council.
- Lewis Ecological Surveys & James, T.A. (May –June 2010). Compensatory habitat assessment for the Kempsey to Eungai pacific highway upgrade.
- Joint project with Australian Museum (October 2010 - March 2011) – Flora & fauna survey for Stage 2 of the Narrabeen Lagoon Multi-use Trail.
- Joint project with Australian Museum (October 2010 - December 2011) – City of Sydney Biodiversity Survey & Strategy.
- James, T.A. (2011). Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland - 561 Appin Road, Gilead. Expert report to DECCW.
- James, T.A. (2011) Flora survey for three reserves in Holroyd LGA to document regeneration following the cessation of mowing. Report to Holroyd City Council.
- James, T.A. (2011) Flora survey of Grey Box Reserve, Greystanes. Report to Holroyd City Council.
- Douglas, S & James, T (2011) Review of listing advice and conservation advice for Shale Sandstone Transition Forest EEC under the EPBC Act – in progress.
- James, T.A. (2011) External Review of White Box – Yellow Box – Blakeley's Red Gum grassy woodlands and derived native grassland ecological community for the Mt. Pleasant Project (EPBC 2011/5795). Report to Dept. of Sustainability, Environment, Water, Population and Communities.
- Ecological advice to SMEC Australia (July-August, 2011). Impact assessment for *Pimelea spicata* – upgrade of Camden Valley Way, western Sydney.
- Ecological advice to SMEC Australia (August-September, 2011). Survey and assessment for Eastern Flame Pea – Trans Grid Dapto substation upgrade.
- Field assistance to SMEC Australia (February 2012) - Targeted survey for *Pimelea spicata* and general survey for RTA Camden Valley Way upgrade.
- PAS2 Expert Interviews for NSW threatened species with Office of Environment & Heritage (February-August 2012).
- Plot survey and ground verification of vegetation mapping within Hills Shire Council (June 2012).
- Threatened species management plans for several species prepared for Hills Shire Council (June 2012) – multi-species plan for Paulls Road (South Maroota), individual plans for *Persoonia hirsuta* and *Epacris purpurascens* at Fred Caterson reserve.
- Joint project with Australian Museum - Narrabeen Lagoon multi-trail (stage 2) Species Impact Statement (June 2012)

- Field assistance to SMEC Australia - Western Sydney Parklands vegetation monitoring project for WSP Trust (July – August 2012).
- Biodiversity/conservation assessment for 12-14 Cabernet Circuit Orchard Hills. Unpublished report to Wayne Olling of CCA (October 2012)
- PAS Reviews for selected NSW threatened species with Office of Environment & Heritage (November 2012).
- Vegetation Peer Review for the Northern Beaches Health Service Project. Report to Health Infrastructure (January 2013).
- Flora survey and assessment on private properties within the Balmoral Release Area, Kellyville (15, 16-20, 24, 26 & 28) for the Hills Shire Council (May-June 2013).
- Preparation of a Threatened Species Plan of Management for *Dillwynia tenuifolia* endangered population along Maquires Road, Maraylya for the Hills Shire Council (May-June 2013).
- Biobanking Assessment Report for the Northern Beaches Hospital Precinct development (a State Significant Development). July 2013. Report to SMEC Australia and Health Infrastructure.
- Threatened species roadside survey and verification of threatened ecological communities for Campbelltown City Council (September-October 2013).
- Peer Review of Species Impact Statement for 34-36 Britton Street, Smithfield for Holroyd City Council (November 2013).
- Flora survey and condition assessment for Pacific Highway Upgrade Woolgoolga to Ballina (Feb - April 2014). Assistance to Ecosure for Roads and Maritime Services.
- Matching of threatened entities occurring in the Greater Sydney Region area to newly mapped vegetation/community types in the Sydney Metro CMA and other parts of the Greater Sydney Region (May-June 2014) for Office of Environment and Heritage (Sydney).
- Parramatta Park baseline flora survey and report for Parramatta Park & Western Sydney Parklands Trust (September 2014).
- Assistance to SMEC with survey and biodiversity report for commonwealth-owned land at Badgerys Creek (Sept-Oct 2014). Report to Department of Infrastructure and Regional Development.
- Identification of Shale Sandstone Transition Forest in the Hills Shire – report to Hills Shire Council (July 2015).
- Assistance with field survey to SMEC Australia at the Holsworthy Training Area for Department of Defence (September 2015).
- Assistance with field survey (base line monitoring) to SMEC Australia at the Kapooka Biodiversity Offset Site near Wagga Wagga for Roads and Maritime Services (Sept-Oct 2015).
- Assistance to SMEC Australia in preparation of a Species Impact Statement for the Mona Vale Road upgrade for RMS (Nov 15-Jan16).
- Assistance to Ecosure in field survey/assessment for Mosman Flora and Fauna Bushland Audit (Jan-Feb 2016).
- Ecological Survey of Sackville Cemetery – report to The Hills Shire Council (May 2016)
- Field survey with 20 m x 20 m plot sampling for OEH Western Cumberland Plain and Bargo Gap Project (targeting transitional areas) – June 2016
- Field survey with 20 m x 20 m plot sampling for OEH Wingecarribee Shire Project – February 2017
- Field survey for vegetation management advice at Greendale property, western Sydney (April 2017)
- Vegetation Benchmark Values Project for the Hills Shire Council (June 2017)

NSW Land & Environment Court cases:

- Grand United Friendly Society v Minister for the Environment - 87A Hammers Road, Toongabbie**.** Land & Environment Court.Proceedings No. 40292 of 1997. Engaged as a consultant by NPWS. Issues relating to Cumberland Plain Woodland and Shale Sandstone Transition Forest.
- Australand v Penrith City Council, Erskine Park (Dec 1999-April 2000). Land & Environment Court Proceedings. Engaged as a consultant by Penrith City Council. Cumberland Plain Woodland and Sydney Coastal River-flat Forest.
- Penrith City Council v Norman Mathie & Others – 392-476 Luddenham Road, Luddenham. Land & Environment Court Proceedings No. 50080-82 of 1999. Engaged as a consultant by Penrith City Council. Issues relating to Cumberland Plain Woodland and Sydney Coastal River-flat Forest.
- Blacktown City Council v Megarry Excavations and Roadworks Pty Ltd. Land & Environment Court Proceedings No 40141 of 2000. Engaged as a consultant by Blacktown Council. Issues relating to Cumberland Plain Woodland and Shale Gravel Transition Forest.
- Mark Topic v Liverpool CityCouncil. North Liverpool Road. Land & Environment Court Proceedings No 0155 of 2000. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland
- Australand v Liverpool City Council. Land & Environment Court Proceedings No 10374, 10375, 10376, 10377 of 2003. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland and Sydney Coastal River-flat Forest
- Development Approval Managers v Liverpool City Council. Land & Environment Court Proceedings No. 10453 (Stage 3), No. 10455 (Stage 4) and No. 10454 (Stage 5) of 2003. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland and Sydney Coastal River-flat Forest
- BGP Properties v Lake Macquarie City Council - Lots 1 & 4 Cowlishaw Street, Redhead. Land & Environment Court Proceedings No 10042 of 2003. Engaged as a consultant by Lake Macquarie City Council. Issues relating to Sydney Freshwater Wetlands and Tetratheca juncea.
- Bentley v Hugh Gordon, Bentley v BGP Properties, Bentley v Whet Investments - Lots 1 & 4 Cowlishaw Street, Redhead. Land & Environment Court Proceedings No 50069-80 of 2003. Engaged as a consultant by NSW National Parks & Wildlife Service. Issues relating to Sydney Freshwater Wetlands and Tetratheca juncea.
- Blue Mountains City Council ats Blaxland Park Pty Ltd**.** - 60 Winnicoopa Road, Blaxland. Land and Environment Court Proceedings No. 10033 of 2004. Court appointed expert. Survey, identification & assessment of *Eucalyptus sclerophylla* Bench Woodland and *Lomandra brevis* in Repsonse to Agreed Questions.
- Providence Projects Pty Ltd v Gosford City Council – Lot 17 Meacham Way, Woy Woy. Land and Environment Court Proceedings No. 11626 of 2004 & 10101 of 2005. Court appointed expert. Review of issues relating to the identification of Umina Coastal Sandplain Woodland.
- Liverpool City Council ats Muslim League of NSW – 264 Wilson Road, Green Valley. . Land & Environment Court Proceedings No 10394 of 2005. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland.
- Liverpool City Council ats AV Jennings – Stage 24 Dalmeny Drive, Prestons. Land & Environment Court Proceedings No 10395 of 2006. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland.
- Director General, Department of Environment & Conservation v Serenity Cove Business Park Pty Ltd – 238-258 Captain Cook Drive, Kurnell. Land & Environment Court Proceedings No 50003-5005 of 2006. Engaged as a consultant by the Department of Environment &

Conservation. Issues relating to Swamp Sclerophyll Forest on Coastal Floodplains (formerly Sydney Coastal Esutary Swamp Forest), Sydney Freshwater Wetlands & Kurnell Dune Forest.

- Sutherland Shire Council ats Rocla Pty Ltd. Land & Environment Court Proceedings No 10447 of 2005. Engaged by Sutherland Shire Council. Issues relating to Swamp Sclerophyll Forest on Coastal Floodplains and Sydney Freshwater Wetlands.
- Wollongong City Council ats Albert David Moulds. Land & Environment Court Proceedings No 10488 & 10563 of 2006. Engaged as Court Appointed Expert. Issues relating to Illawarra Subtropical Rainforest and *Cynanchum elegans.*
- Gerroa Environment Protection Society v Department of Planning and Cleary Bros. Pty Ltd. Land & Environment Court Proceedings No 10801 of 2007. Issues relating to Swamp Sclerophyll Forest, Bangalay Sand Forest and Littoral Rainforest.
- Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 1-9 Buckingham Road, Killara. Issues relating to Blue Gum High Forest.
- Kaligem Pty Ltd v Ku-ring-gai Council. Proceeding No: 10823 of 2008 Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 5-7, Lonsdale Avenue, Pymble. Issues relating to Sydney Turpentine Ironbark Forest.
- Proceedings No: 10496 of 2009 Ecological advice to Warringah Council and Land & Environment Court in relation to proposed development at Beacon Hill. Issues relating to threatened species & general environmental impact. Proceedings No 10973 & 10794 of 2009.
- Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 35 Billyard Avenue, Wahroonga. Issues relating to Blue Gum High Forest. Proceedings 10908 of 2009 (NSWLEC 1222).
- Expert advice to the Environmental Defenders Office and Land & Environment Court in relation to proposed development at Jordan Springs, St. Marys. Proceedings 40873 of 2011.
- Expert advice to the Office of Environment and Heritage and Land & Environment Court in relation to alleged clearing of endangered ecological communities (Cumberland Plain Woodland and Shale Sandstone Transition Forest) at Gilead, western Sydney. Proceedings 50604 of 2011.
- Expert advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at Knox Grammar School, Warrawee. Issues relating to Blue Gum High Forest. Proceedings 10762 of 2011.
- Expert advice to The Hills Shire and NSW Land & Environment Court re proposed subdivision at 186-186A Cattai Ridge Rd Maraylya (Case No. 11216 of 2015).
- Expert advice to Cumberland Council and Land & Environment Court in relation to deemed refusal of DA (Fife Capital Pty Ltd) - Land and Environment Court Proceedings No. 2016/00310627
- Expert advice to Northern Beaches Council and Land & Environment Court in relation to deemed refusal of DA - Land and Environment Court Proceedings No. 53907 of 2017. Issues **- i**mpacts on *Swamp Sclerophyll Forest on Coastal Floodplains*, Warriewood.

Strategic Assessment for Cumberland Plain Conservation Plan

Greater Penrith to Eastern Creek and Western Sydney Aerotropolis Growth Areas

Expert Report for *Pimelea spicata* Spiked Rice-flower

Prepared for NSW Department of Planning & Environment

Teresa James April 2019

Contents

*GIS mapping prepared for report by Anthea Whitlam

Executive summary

Pimelea spicata is known to be present within the Greater Penrith to Eastern Creek Growth Area (9 records) and is likely to be present within the Western Sydney Aerotropolis Growth Area with one unsubstantiated record, >500 ha of potential habitat and a large population recently discovered just to the east. The study area is considered important habitat for the species at the western limit of its known extent on the Cumberland Plain.

Potential habitat is based on the:

- Presence of local records;
- Presence of suitable habitat;
- Ability of the species to persist as rootstock and seed for long periods; and
- Ability of the species to easily regenerate when environmental conditions are suitable.

Extensive areas of suitable habitat are identified across the study area. A total area of 2714 ha is identified within four vegetation communities, all threatened ecological communities (TEC's), across the two growth areas (2168 ha in the GPECGA & 564 ha in the WSAGA). The condition of habitat is not a reliable indicator of species presence and all condition states were considered in determining potential (suitable) habitat.

Survey effort within potential habitat across the study area is very low particularly for favoured Cumberland Plain Woodland habitat (only 5% and 7% for PCT 849 within the GPEC and WSA growth areas). More rural areas in western zones of the growth areas (particularly in the south) have been poorly surveyed largely reflecting private ownership and access restrictions. Where targeted survey has been undertaken, the reliability of detecting the species is considered low due to unsuitable conditions for growth and flowering with the best climatic conditions (particularly successive good rain events) occurring post-survey in late 2018 and much of the habitat being grazed and/or slashed. In view of the low reliability of surveys it is considered appropriate to assume a greater presence within the growth areas and reserve suitable habitat across its known range to protect the species long-term.

Within the Greater Penrith to Eastern Creek growth area 133 ha or 6% of potential (i.e. suitable) habitat is found within the certified zone, 178 ha (8%) is zoned for conservation and 1857 ha (86%) occurs in the non-certified zoning. The latter includes larger areas within Wianamatta Regional Park and the Orchard Hills Defence Establishment that has long been recognised for its conservation values. Small council reserves in the far north-west associated with a north to south ridge-line above the Hawkesbury-Nepean River floodplain are particularly important for known and potential *Pimelea spicata* habitat, only two of which currently have conservation zoning. With records of *Pimelea spicata* just outside of the GPECGA at Mulgoa the protection of suitable habitat adjacent and to the south of Mulgoa Nature Reserve is desirable.

In the Western Sydney Aerotropolis growth area just over 53% occurs within the certified or development zone with 43% zoned for conservation predominantly associated with the South Creek corridor (around Kemps Creek) and the upper catchment of Duncan's Creek in the vicinity of Willowdene Avenue, south of Luddenham. The latter area is close to the recently discovered population west of the Northern Road and includes similar habitat.

1. Introduction

1.1 Purpose of the expert report

An expert report may be prepared under section 6.5 of the Biodiversity Assessment Method (OEH 2017) in place of undertaking a threatened species survey. Use of an expert report may be beneficial where it is highly unlikely that a species may occur within the study area, survey effort is inadequate and/or the reliability of detecting the species through survey is low. In respect of *Pimelea spicata*, low survey effort and unreliability of survey are the primary reasons for preparing an expert report.

The purpose of this report is to provide scientific assessment of the current status and conservation needs of *Pimelea spicata* within the Western Sydney Aerotropolis and Greater Penrith to Eastern Creek growth areas of western Sydney. Specifically, the report is to determine whether:

- The species is unlikely to be present and in this case no further assessment is required, or
- The species is likely to be present and in this case the expert report must provide estimates of habitat area both within the growth and biocertified or development footprint areas.

1.2 Project context

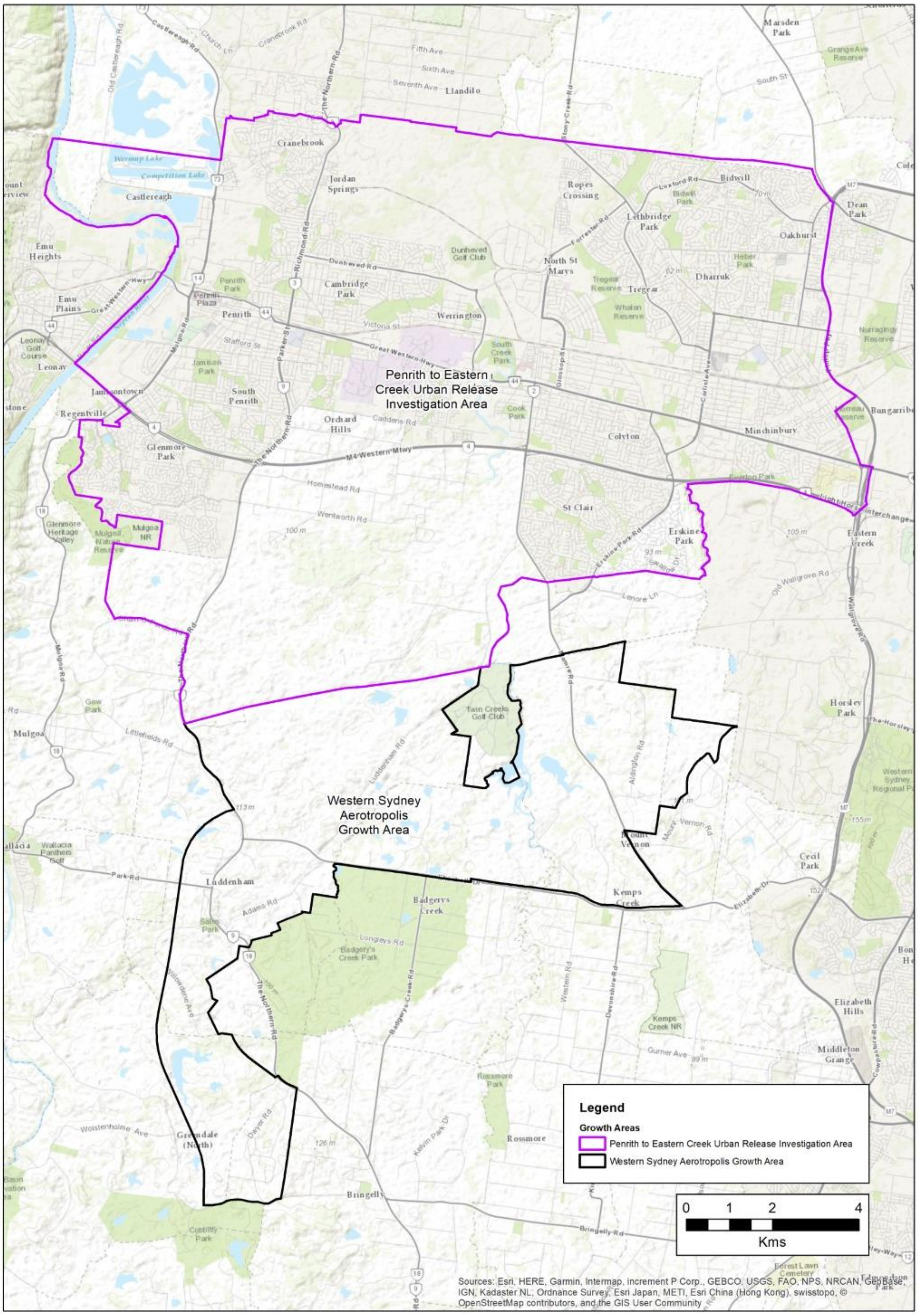
The NSW Government is identifying areas for future urban development and associated infrastructure in western Sydney. There are four priority growth areas: Wilton, Greater Macarthur (Campbelltown and Appin), Western Sydney Airport, and Greater Penrith to Eastern Creek. These new growth areas are all located within the Cumberland Interim Biogeographic Regionalisation for Australia (IBRA) sub-region.

As part of the planning for the priority growth areas, the Department of Planning and Environment (DPE) will prepare the Cumberland Plain Conservation Plan to identify development and conservation outcomes for the growth areas. A strategic assessment of this plan is underway and this expert report will assist the biodiversity assessment to assess the conservation benefits and development impacts of the Plan in respect of *Pimelea spicata*. This report is consistent with the Scope of Works for expert reports provided by DPE and dated November 2018.

1.3 The study area

The study area for this report comprises the growth areas of Western Sydney Aerotropolis and Greater Penrith to Eastern Creek (see Figure 1) and includes parts of the Penrith, Blacktown and Liverpool LGA's in far western to south-western parts of the Cumberland Plain, western Sydney. It adjoins the Western Sydney Airport in the south. The study area is located within the Cumberland subregion on Triassic Wianamatta Group sediments. The study area is within the Hawkesbury-Nepean River catchment and is dissected north to south by South Creek (and its tributaries). It is associated with low-lying to gently undulating land (<100 m a.s.l.) with clay soils (Blacktown and Luddenham soil landscapes) and recent alluvium on floodplains with soils of the Richmond, Freeman's Reach and South Creek soil landscapes.

Figure 1. Western Sydney Aerotropolis and Greater Penrith to Eastern Creek Priority Growth Areas



1.4 Reasons for use of an expert report

An expert report for *Pimelea spicata* is required as part of the threatened species assessment for the Cumberland Plain Conservation Plan for the following reasons:

1. The survey effort for this species did not meet the recommendations in the OEH threatened species guidelines (OEH 2016) for targeted surveys largely due to limitations imposed by land access. Around 3.7 % of total potential habitat for *Pimelea spicata* has been accessed for survey within the Greater Penrith to Eastern Creek Growth Area and 6% in the Western Sydney Aerotropolis Growth Area.
2. Poor survey timing. *Pimelea spicata* is difficult to detect particularly when not in flower. Flowering is unpredictable and considered dependant on good rains (Environmental Impact Assessment Guidelines NPWS 2004, and personal knowledge). During dry periods the species is often invisible above ground but may persist in the soil as rootstock and seed. Dry, hot spring/summers have been a particular feature of the western Sydney environment in the last few years and survey has not been timed to coincide with suitable conditions following good rain events.
3. The cryptic nature of the species and extent of disturbance across the growth areas significantly reduces the likelihood of detecting the species. Many populations have only been recorded once the disturbance factor e.g. mowing, grazing or weed infestation has been removed. Many of the sites surveyed are heavily grazed or mown/slashed.

Survey for *Pimelea spicata* has been insufficient to reliably determine the presence and extent of the species within the growth centres. An expert report is necessary to provide a more comprehensive and reliable level of scientific assessment appropriate for an endangered species.

1.5 Credentials of expert

I am a botanist/ecologist with over forty years of experience in vegetation survey, plant identification, conservation assessment and threatened species, particularly in western Sydney. I have worked within the NSW government (National Herbarium of NSW, NSW National Parks & Wildlife Service) and for the last twenty years as a consultant (sole trader). A summary of my credentials as required under the Biodiversity Assessment Methodology (2014, 2016) is provided in Table 1. Under 6.5.2.4 of the BAM I am recognized as a biodiversity expert for *Pimelea spicata*.

Table 1. Credentials of Teresa James

BAM section	BAM requirement	Details
BAM s 6.5.2.8 (g)	Name of expert	Teresa James
BAM s 6.5.2.4	Biodiversity expert	*Pimelea spicata*
BAM s 6.5.2.3 (a)	The expert's qualifications	Bachelor of Science (Honours), University of Exeter 1978 Accredited BioBanking Assessor (awarded 2008, renewed 2013)
BAM s 6.5.2.3 (b)	History of experience in ecological research and survey method, for the relevant species	Field surveys and other relevant studies: • Populations of *Pimelea spicata* across western Sydney e.g. Denham Court Road, Campbelltown (1999, 2012), Alpha Road Park, & Grey Box Reserve, Holroyd (2011), Cobham Road Reserve & Power Street Reserve, Fairfield (2016-17), Greendale (near Wallacia), private property (2016-7), Cranebrook Reserve, Penrith (2017). • Threatened community and threatened species (including *Pimelea spicata*) roadside surveys through Campbelltown

		LGA for Campbelltown City Council (2013) • Targeted survey for *Pimelea spicata* along Denham Court Road, near Camden Valley Way for SMEC (2012) • Expert report to DECCW: Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland at a property on Appin Road, Gilead (2011). • Targeted survey for *Pimelea spicata* at Menangle Park Offset Strategy for GHD (2009, 2010) • Biobanking Pilot Project at Wilton (2007). • Survey & monitoring of Cumberland Plain Woodland and *Pimelea spicata* at Faulkland Crescent Reserve, Blacktown (2004, 2007) for Blacktown City Council.
BAM s 6.5.2.3 (c)	A resume detailing projects pertaining to the survey of the relevant species	Resume attached at Appendix 1. Relevant field surveys listed above.
BAM s 6.5.2.3 (d)	Their employer's name and period of employment (where relevant)	Self-employed ecological consultant Teresa James Flora Consultant 1998 to present
BAM s 6.5.2.3 (f)	Evidence that the person is a well-known authority on the relevant species to which the survey relates	1. Author of several botanical guides to the flora of Western Sydney: • James, T.A., McDougall, L & Benson, D. (1999). Revised edition. *Rare Bushland Plants of Western Sydney.* Royal Botanic Gardens, Sydney. • James, Teresa (2013) Flora of Cumberland Plain Woodland – an identification guide. • James, Teresa (2015) Threatened Flora of the Fairfield LGA. • James, Teresa (2016) Native Flora of Shale Soils of the Cumberland Plain Woodland – An Identification Guide. 2. Author of flora component of Urban Bushland Biodiversity Survey of Western Sydney (1997). Included compilation of information on *Pimelea spicata* and its habitat across western Sydney local government areas. 3. Contributed information to the *Pimelea spicata* Approved Recovery Plan (2006). 4. Has acted as Expert witness in NSW Land and Environment Court in relation to threatened communities in western Sydney including: • Expert advice to OEH and Land & Environment Court in relation to alleged clearing of endangered ecological communities (Cumberland Plain Woodland and Shale Sandstone Transition Forest) at Gilead, western Sydney. Proceedings 50604 of 2011. • Expert advice to Liverpool City Council ats Muslim League of NSW – 264 Wilson Road, Green Valley. Land & Environment Court Proceedings No 10394 of 2005. Issues relating to Cumberland Plain Woodland. • Expert advice to Liverpool City Council ats AV Jennings – Stage 24 Dalmeny Drive, Prestons. Land & Environment Court Proceedings No 10395 of 2006. Issues relating to Cumberland Plain Woodland.

		5. PAS2 Expert Interviews for several NSW threatened species with OEH (February-August 2012) including a range of Cumberland Plain species 6. Member of SOS Project Panel (2018) – Cumberland Plain Woodland, Western Sydney Dry Rainforest, Moist Shale Woodland, River-flat Eucalypt Forest, Agnes Banks Woodland and Castlereagh Ironbark Forest 7. Member of NPWS Cumberland Plain Recovery Team (1998) 8. Author of expert report for *Pimelea spicata* in Greater Macarthur and Wilton growth areas (2018)

Through this experience I have developed a good knowledge and understanding of the life history and habitat requirements of *Pimelea spicata* and associated habitats within the growth areas.

2. Species Information

2.1 Species description

A small, slender to spreading shrub or sub-shrub to c. 50 cm high; stems 1-several, glabrous. Older stems are often seen intertwining with grasses and herbs. *Pimelea spicata* has an underground carrot-like tap root recorded up to 18 cm in length that gives plants the ability to re-sprout after defoliation and periods of drought stress (NSW NPWS 1997). The leaves are mostly opposite, narrow-elliptic to elliptic in shape, to 20 mm long and 8 mm wide, spreading, soft and often bluish-green. Inflorescence is a raceme, dense when young, elongated and interrupted at maturity, bracts absent. Flowers tubular, white to pink tinged, 7-10 mm long with four spreading lobes. Fruit is a narrow-ovoid nut, c. 3 mm long, 1-seeded, mostly green.

Pimelea spicata leaves (left); flowers & fruit (above)

2.2 Life cycle

Pimelea spicata is incapable of effective vegetative spread (Benson and McDougall 2001) although more recent observations suggest that mature individuals can spread over short distances through underground rhizomes (OEH 2017) giving rise to “clumps” of plants. Seed production, however, is the primary means of recruitment. Flowering is sporadic throughout the year and is likely in response to climatic conditions, particularly rainfall (DEC 2006). Flowering and fruiting has been observed in plants 1.5-2 years old (NPWS 1997); flowers continue to be produced as fruits mature. Native bees are known pollinators and moths may also contribute to pollination (DEC 2006). The species may also be capable of spontaneous self-pollination (DEC 2006). Fruiting is highly variable depending on environmental conditions. Seed viability has been recorded as relatively high ranging from 83% - 86% (Nash & Matthes 1995, Willis et al. 2003 cited in DEC 2006). Seed dispersal is highly localised with the majority of seedlings observed within 30 cm of adult plants following fire (Hogbin pers. obs. cited in DEC 2006). *Pimelea spicata* maintains a long-lived soil-stored seed bank resulting in potential for considerable recruitment following disturbance. The soil seed bank can survive under infestations of invasive weeds (Willis et al. cited in DEC 2006).

Seed germination can be triggered by disturbance including fire, slashing/mowing, grazing and soil disturbance (NPWS 1997, Willis et al. 2003 cited in DEC 2006). Monitoring of seedlings following fire revealed 80% survival in the first year (NPWS 1997 cited in DEC 2006). Ex-situ trials found that smoke application increased seed germination (Tozer & Robertson 1998), however, Willis et al. (2003) cited in DEC (2006) found only a 20-30% germination rate for seed in any trial.

Re-sprouting from the taproot occurs following defoliation caused by fire, drought or physical damage (NPWS 1997). The species can survive periods of drought stress or weed infestation by dying back to the tap root and re-sprouting when favourable conditions return. It is unknown at what age the tap root has to be of a sufficient size to facilitate re-sprouting.

2.3 Distribution and abundance

Pimelea spicata occurs in two disjunct regions of the Sydney Basin IBRA bioregion, the Cumberland subregion in western Sydney and the coastal region of the Illawarra, south of Sydney.

<u>Cumberland subregion</u>
In the Cumberland subregion *Pimelea spicata* is found on clay soils derived from Wianamatta Group Shales. The current known distribution extends from Freeman’s Reach in the north to Douglas Park in the south and west from Penrith to Georges Hall in the east. *Pimelea spicata* has been recorded in the following vegetation communities:

PCT 849 – Grey Box – Forest Red Gum grassy woodlands on flats of the Cumberland Plain
PCT 850 - Grey Box – Forest Red Gum grassy woodlands on shale of the southern Cumberland Plain
PCT 830 – Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain
PCT 835 – Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain (most commonly when intergrading with CPW)

These communities are equivalent to the Cumberland Plain Woodland, Moist Shale Woodland and River-flat Eucalypt Forest threatened ecological communities and include derived grasslands.

The recovery plan for *Pimelea spicata* (DEC 2006) identified 25 populations on the Cumberland Plain. Currently there are approx. 70 sites (Bionet Atlas records, June 2018). The main concentration of sites is found in the Blacktown, Prospect, Bankstown and Narrellan districts. More recent records (post 2014) are from near Wallacia, Horsley Park - Cecil Park and Greendale. Populations in the Penrith LGA are at the western limit of the specie’s geographical range.

<u>Coastal Illawarra</u>
In the Illawarra *Pimelea spicata* is associated with coastal headlands and hill tops from Mount Warrigal south to just north of Kiama. The recovery plan for *Pimelea spicata* (DEC 2006) identified 5 populations in the Illawarra.

In 2006, the total population of *Pimelea spicata* across 30 known populations was estimated to be around 4300. Populations varied from a few individuals to >500 plants although larger populations were rare with over half with <50 individuals and small habitat areas of less than 0.5 ha (DEC 2006, Dept. Environment & Heritage 2016*)*. Since 2006 several populations are likely to have been lost to development or habitat modification. At several sites survey has failed to re-locate plants including at Menangle and along Denham Court Road, Camden Valley Way and Jamisontown (James 2009, 2010, 2012, 2019). Prolonged periods of drought, increased weed invasion, heavy grazing/slashing or soil disturbance are likely to be the main causes. Counterbalancing losses are several new records within Fairfield, Liverpool, Penrith and Liverpool LGAs (mostly <50 individuals). A new site south-west of Luddenham within the Western Sydney Airport impact zone is by far the largest known population with >4000 plants recorded in 2017, however, is likely to be cleared. Increased population sizes are noted at Narellan and Prospect although numbers at any site at any one time will depend on the timing of rainfall and other environmental factors. Ongoing monitoring of the new population near Luddenham noted a decline from more than 4000 above-ground plants (after good summer and autumn rains in early 2017 together with exclusion of grazing and slashing) to around 400 by December 2017 (GHD 2018). Area of known habitat is likely to be a more accurate measure of population size than number of above-ground plants.

2.4 Habitat requirements

Pimelea spicata is found in grassy woodlands or at grassland sites on the Cumberland Plain and in the Illawarra.

Cumberland subegion
In the Cumberland subregion *Pimelea spicata* occurs in Cumberland Plain Woodland (CPW), intergrading zones between CPW and River-flat Eucalypt Forest, Moist Shale Woodland and associated derived grasslands. Associated canopy trees are Grey Box *Eucalyptus moluccana*, Forest Red Gum *E. tereticornis,* Narrow-leaved Ironbark *E. crebra* and Spotted Gum *Corymbia maculata*. The mid-storey typically contains *Acacia parramattensis, A. decurrens, Bursaria spinosa*, *Acacia implexa, A. falcata, Dillwynia sieberi* and *Indigofera australis*. Common groundcover grasses and herbs associated with most occurrences include Kangaroo Grass *Themeda triandra,* Weeping Grass *Microlaena stipoides,* Kidney Weed *Dichondra repens*, Woodruff *Asperula conferta* and Blue Trumpet Flower *Brunoniella australis*.

Pimelea spicata prefers moist soil and typically occurs on gentle lower slopes where groundwater seepage maintains higher soil moisture levels for longer (*T. James pers. obs.*). The more resilient sites appear to be those in protected gullies close to drainage lines e.g. Mountain View Reserve, Cranebrook. A relatively open grassy groundcover maintained by occasional disturbance e.g. fire or infrequent/low intensity grazing/slashing provides favourable habitat. Although the species can survive (and flower) among taller grasses and perennial weeds (e.g. at Cobham Street Road, Horsley Park) it is likely to disappear above ground under extended weed infestations. A population along Denham Court Road (around 2003), for example, was estimated to be hundreds yet in 2011 no plants were found (*T. James pers. obs.)*. The road reserve had become increasingly degraded with weed infestation in both the mid-storey layer (African Olive, Box Thorn and Lantana) and the ground-layer (Bridal Creeper, Prickly Pear, Blackberry & Mother-of Millions). The species was likely still present, however, in the soil seed-bank.

Frequent or intensive grazing, slashing or mowing will restrict the growth of plants with re-sprouting controlled by the frequency of disturbance and environmental conditions. Frequent cutting creates open, dry and hot conditions at the soil surface resulting in die-back of plants above ground. The species can persist for many years under such a regime as a tap root and seed in the soil. There are many examples of regeneration following cessation of mowing and slashing in council reserves e.g. Faulkland Crescent Reserve and Melrose Park in Blacktown and Power Street Reserve in Fairfield.

Habitat of *Pimelea spicata* along unformed road reserve (Cobham Road, Horsley Park)

Illawarra
In coastal habitat of the Illawarra *Pimelea spicata* occurs in a wider range of geologies and soils derived from the Permian Shoalhaven Group sediments (sandier than the clay soils of western Sydney). The favoured sites are on grassy headlands and hilltops with Kangaroo Grass *Themeda triandra*, Mat-grass *Lomandra longifolia* and Blady Grass *Imperata cylindrica*, often with Coast Banksia *Banksia integrifolia*. Woodland is also often dominated by Forest Red Gum *Eucalyptus tereticornis* and Thin-leaved Stringybark *E. eugenioides* above Kangaroo Grass, species also occurring in *Pimelea* habitat in western Sydney. Habitat in the Illawarra includes the endangered ecological community *Themeda Grasslands on Seacliffs and Coastal Headlands* (PCT 898).

3. Description of the study area

3.1 Land use history

Greater Penrith to Eastern Creek Growth Area (GPECGA)
An area of approx. 18, 619 ha extending east from the Nepean River to Wallgrove Road and from the former ADI site in the north to the Warragamba to Prospect Water Pipe-line in the south. The area is highly urbanised in northern and central parts and includes the city of Penrith and suburbs of St. Mary's Mt. Druitt, St. Clair, Glenmore Park and Jordan Springs. The Great Western Highway, the western railway line and the M4 Motorway all dissect the area east to west and act as a stimulus to further residential and industrial development. In contrast, a rural landscape predominates south of the Western Motorway although close proximity to the new airport has recently increased development activity.

Western Sydney Aerotropolis Growth Area (WSAGA)
The Western Sydney Aerotropolis Growth Area comprises a smaller area of approx. 6232 ha immediately to the north and east of the Western Sydney Airport site within the Penrith and Liverpool LGA's. It extends south from the Warragamba to Prospect Water Pipe-line to Greendale and includes the Northern Gateway, North Luddenham and Luddenham to Greendale zones. The western boundary is along the Northern Road. It has a predominantly rural landscape and has been extensively cleared in the past for farming. Close proximity to the new airport has significantly stimulated new development activity for infrastructure, housing and industry.

3.2 Landscape context

Greater Penrith to Eastern Creek Growth Area (GPECGA)
Reference to the 1:100,000 Geological Series Sheet for Penrith, indicates that most of the growth area is underlain by Triassic rocks (Bringelly Shale) and unconsolidated Quaternary sediments (alluvial gravel, sand, silt and clay). Small areas of older Tertiary alluvium occur particularly in the north-east associated with Ropes Creek. The Soil Landscape Series Sheet 9030 (Bannerman & Hazelton 1990) maps six soil landscape groups in the study area:

- Luddenham and Blacktown on shale
- Richmond, Freeman's Reach and South Creek on recent alluvium

- Berkshire Park on older (Tertiary) alluvium

The topography is low-lying to gently undulating land (<100 m a.s.l.). It is dissected north to south by the South Creek floodplain and includes the tributaries of Ropes Creek and Blaxland Creek. A small ridge-line up to 50 -60 m above sea level runs north to south extending up from the Nepean floodplain in the north-west of the GA (just north of the Penrith CBD) at Mount Pleasant and Kingswood Park on the hillier Luddenham soil landscape.

Native vegetation has been extensively cleared in the north for urban development and farming in the south. Open space corridors (including bushland) are centred along the creeks, particularly South Creek and Ropes Creek. Larger bushland remnants occur within Wianamatta Regional Park (237 ha) (formerly the ADI site) in the north and the Orchards Hills Defence Establishment (c. 260 ha) in the south. Higher concentrations of smaller remnants occur in the north-west (suburbs of Cranebrook to Kingswood Park) and the east (suburbs of Mt. Druitt, Plumpton).

Western Sydney Aerotropolis Growth Area (WSAGA)
Reference to the 1:100,000 Geological Series Sheet for Penrith, indicates that most of the growth area is underlain by Triassic rocks (Bringelly Shale) and unconsolidated Quaternary sediments (alluvial gravel, sand, silt and clay). The Soil Landscape Series Sheet 9030 (Bannerman & Hazelton 1990) maps three soil landscape groups in the study area, Luddenham, Blacktown and South Creek. The northern part of the area is low-lying and dissected by four creek-lines Badgerys Creek, South Creek, Cosgrove's Creek and Kemps Creek. A hilly ridge system up to 100-120 m above sea level is found in south-western parts extending south from Orchard Hills through Luddenham associated with the Luddenham Dyke comprising olivine basalt intruded into the Bringelly shale.

Native vegetation is patchy and occurs predominantly along Cosgrove's Creek (with a larger remnant west of Twin Creeks Golf Course), in the east between Erskine Creek and Kemps Creek and in the south-west south of Luddenham.

3.3 Native Vegetation

Greater Penrith to Eastern Creek Growth Area (GPECGA)
The predominant ecological communities are Cumberland Plain Woodland (CPW) and River-flat Eucalypt Forest (RFEF), both threatened ecological communities. Cumberland Plain Woodland is listed as critically endangered at both state (*Biodiversity Conservation Act, 2016*) and national (*EPBC Act, 1999*) levels. A summary of plant community types based on mapping provided by NSW Planning & Environment is found in Table 2.

Table 2. Plant community types (PCT's) within the Greater Penrith to Eastern Creek growth area

PCT No	PCT Name	TEC / Non-TEC	Area (ha)	Distribution & notes
724	Broad-leaved Ironbark – Grey Box – Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin.	Shale Gravel Transition Forest	138.3	Main occurrence within Wianamatta Regional Park in far north. Small patches identified at Minchinbury, Claremont Meadows, St. Clair.
725	Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion	Cooks River Castlereagh Ironbark Forest	127.5	Main occurrence within Wianamatta Regional Park in far north. Small patches identified at Mount Druitt, Claremont Meadows.

PCT No	PCT Name	TEC / Non-TEC	Area (ha)	Distribution & notes
781	Coastal freshwater lagoons of the Sydney Basin Bioregion	Freshwater Wetlands on coastal floodplains	65.4	On Nepean floodplain in north-west. Small dams in southern area.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Moist Shale Woodland (MSW)	2.8	Small area identified at edge of Mulgoa Regional Park.
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	River-flat Eucalypt Forest (RFEF)	826.3	Along all creeks with largest patches within Wianamatta Regional Park and along South Creek corridor.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CPW)	1794	Larger remnants within Wianamatta Regional Park & Orchard Hills; medium size patches at north Luddenham, Plumpton; small patches through GA.
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Cumberland Plain Woodland (CPW)	80.8	More common within western parts e.g. Mulgoa NR on more hilly terrain.
806	Derived grasslands on shale hills of the Cumberland Plain	Cumberland Plain Woodland (CPW)	6.99	Only small areas mapped not representative of actual extent. Other areas included within 849 & 850 or unmapped.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Castlereagh Scribbly Gum Woodland Castlereagh Swamp Woodland	6.5	Small linear remnants associated with watercourses in Wianamatta Regional Park, along Rope's Creek, Glenmore Park. More likely to be Castlereagh Swamp Woodland.
1395	Narrow-leaved Ironbark - Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain	Shale Sandstone Transition Forest (SSTF)	2	Small patch near Mulgoa, not ground-truthed.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain	River-flat Eucalypt Forest	118.4	Small patches with creek corridors mostly along South Creek, Rope's Creek & Cosgrove's Creek.

Western Sydney Aerotropolis Growth Area (WSAGA)
The predominant ecological vegetation communities within the WSAGA are Cumberland Plain Woodland (CPW) and River-flat Eucalypt Forest (RFEF), both threatened ecological communities. Cumberland Plain Woodland is listed as critically endangered at both state (*Biodiversity Conservation Act, 2016*) and national (*EPBC Act, 1999*) levels. A summary of mapped plant community types based on maps provided by NSW Planning & Environment and Cumberland Ecology (2018) is found in Table 3.

Table 3. Plant community types (PCT's) within the Western Sydney Aerotropolis growth area

PCT No	PCT Name	TEC / Non-TEC	Area (ha)	Distribution & notes
724	Broad-leaved Ironbark – Grey Box – Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin.	Shale Gravel Transition Forest	52.9	Localised at Kemps Creek north of Elizabeth Drive between creek-lines.
725	Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion	Cooks River Castlereagh Ironbark Forest	39.9	Localised at Kemps Creek north of Elizabeth Drive between creek-lines.
781	Coastal freshwater lagoons of the Sydney Basin Bioregion	Freshwater Wetlands on coastal floodplains	3.5	Very small areas associated with Badgery's & South Creek but probably more common.
830	Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain	Moist Shale Woodland (MSW)		None mapped but potential to occur in far south-west associated with the Luddenham dyke.
835	Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain	River-flat Eucalypt Forest (RFEF)	162.9	Along all creek lines in association with 1800. Largest patch within South Creek corridor north of Elizabeth Drive.
849	Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain	Cumberland Plain Woodland (CPW)	550.1	Across the GA with largest remnant south of Erskine Park and south from Luddenham on rural properties (patchy less intact remnants).
850	Grey Box – Forest Red Gum grassy woodland on shale of the Southern Cumberland Plain	Cumberland Plain Woodland (CPW)	7.7	Small area mapped but more extensive in south western parts in vicinity of The Northern Road.
806	Derived grasslands on shale hills of the Cumberland Plain	Cumberland Plain Woodland (CPW)	53.35	Other areas included within 849 & 850 or unmapped.
883	Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain	Castlereagh Scribbly Gum Woodland Castlereagh Swamp Woodland	6.5	Very small area associated with Castlereagh Woodlands at Kemps Creek.
1800	Swamp Oak open forest on river-flats of the Cumberland Plain	River-flat Eucalypt Forest	110.1	Riparian forest along creek-lines in association with 835.

4. Assessment of species presence and habitat

4.1 Existing records and surveys

Existing records used in this report have been sourced primarily from the NSW Bionet Atlas. Two records were not in the Atlas but were identified in Appendix 2 of the *Pimelea spicata* Recovery Plan (DEC 2004). Penrith City Council and Local Land Services were also contacted for any additional records. In total there are ten records relating to eight sites for the Greater Penrith to

Eastern Creek Growth Area (GPEC) and just one for the Western Sydney Aerotropolis Growth Area (WSA) that is unsubstantiated (see tables 4 & 5).

The western ADI sites are located within the Jordan Springs development area but the northern ones are within Wianamatta Regional Park. The sites are typically associated with lower slopes and drainage lines. Population size is small with <10 plants recorded at most sites. Two of the sites (PS5 & PS6) have been confirmed by the author for this study (and Penrith City Council 2018) and are in council-managed reserves although PS6 (Grey Gums Reserve) is currently zoned uncertified rather than conservation. One of the records (PS9) at Badgerys Creek may be within or very close to certified land.

Table 4: *Pimelea spicata* records from Greater Penrith to Eastern Creek Growth Area

Record Id	Location	Date of record	No. of individuals	Map unit	Notes
PS1	ADI Site, St. Mary's	30/07/2004	4	835/849	Northern bank of drainage channel. Not observed in Biosis survey 2017.
PS2	ADI Site, St. Mary's	30/07/2004	5 - 20	835/849	Weedy area. In small gully with south western facing slope. Not observed in Biosis survey 2017.
PS3 & 4	Western part of ADI Site, St. Mary's	04/09/2003	3 (2 close sites)	849	Area now or soon to be developed, Jordan Springs
PS5	South of Nepean Street, Cranebrook (Mountain View Reserve)	02/08/07	c.80	849	Bottom of south-western facing slope; habitat area of 700 sq. m adjacent to drainage line. Monitored 2017-19 (TJ).
PS6	Grey Gums Reserve, Cranebrook (2 locations)	22/10/2010	30	849	Threatened by weeds and edge effects. Development & roads nearby. Confirmed in 2018 (PCC) & 2019 (James)
PS7	Kanangra Reserve, Glebe Place, Kingswood	2003 Appendix 2 of Recovery Plan 11/10/18	7 plants 1 plant	849	Council managed CPW adjacent to water reservoir. South-facing slope. Only 1 plant in poor health located in 2018 (PCC), no plants observed in Feb 19.
PS8	St. John Jamison Catholic Cemetery, Lilac Place, Jamisontown	2003 Appendix 2 of Recovery Plan	2 plants	849	Mostly mown/slashed grassland with some remnant trees. Native species persist around trees, over abandoned burial sites. Not seen 2019.
PS9	Badgerys Creek Lot 1 DP 111726	31/05/1999	1 small group of plants	835/849	Western side of bank, just before joins South Creek. Base of steep slope with SE aspect in small patch of thinned *Eucalyptus tereticornis*, mostly cleared around.
PS10	Kingswood Park Hickeys Lane (2 locations)	13/07/2018	10+	849	Two locations close to southern edge of reserve, one within APZ
	Mulgoa Nature Reserve		Few	LLS	On lee of dam

	Outside but close to Growth Area			**Source**	
	Just west of Chain O' Ponds Road Mulgoa	01/06/2005	30-60	Atlas of Australian Plants.	In grounds of 2 private properties. Similar habitat occurs just to the north within the GA. Current status unknown
	Gow Park, Mulgoa	03/10/18	5	PCC	West of car park in council reserve
	Blacktown and Liverpool LGA's	Various	Medium to larger populations	849, 850 & derived grassland	

*PCC = Penrith City Council LLS = Local Land Services

Records close to the growth areas

To the east of the growth areas there is a comparatively high density of sites in the Prospect, Quakers Hill and Western Sydney Regional Park districts (see Figure 2). Population size in these areas is typically moderate to large e.g. 150+ plants at Faukland Road Reserve (Kings Langley), several hundred's/thousands within Prospect Nature Reserve and 400 at Cobham Road Reserve (Horsley Park). This more central Cumberland Plain location is considered to comprise core habitat for the species.

Table 5 : *Pimelea spicata* records from the WSAGA or within 5 km

Record Id	Location	Date of record	No. of individuals	Notes
PS11	Just west of Aldington Road, east of Mamre Road, Kemps Creek	?	?	Sourced from (Biosis_FloraSightingPts, 2018) but not substantiated by Biosis or EcoPlanning for this report
	Outside of Growth Area			
	Private property along Greendale Road. Steep slope above tributary of Duncan's Creek.	April 2017	25-50	Recorded by the author (TJ). In regenerating CPW/MSW on steep, southeast-facing slope (after removal of African Olive).
	West of the Northern Road, south of Luddenham.	Mar-April 2017	4000+	In remnant modified CPW on rural grazing property. Habitat area of 2.94 ha. Likely to be cleared for construction of WSA.
	Twin Creeks Resort, Luddenham Road, Orchard Hills	Extant in 2003	?	Referenced in recovery plan but needed to be confirmed. Private tenure, likely now developed.

There are three records just to the west at Greendale and Mulgoa (details in Tables 4 & 5). The closest known records in the south of the Western Sydney Aerotropolis growth area do not appear in the Bionet data but are documented in biodiversity assessments for a transmission line realignment (GHD 2017) and the Western Sydney Airport Offset Strategy (DPIRDC 2018). Some 4000+ plants were recorded in 2017 from an area of 2.94 ha just west of the Northern Road (south-west of Luddenham) and c. 1 km east of the growth area.

Several of these populations are likely to be developed in the near future e.g. Cobham Road Reserve (road upgrade within Horsley Park Urban Plan) and south-west of Luddenham for the Western Sydney Airport.

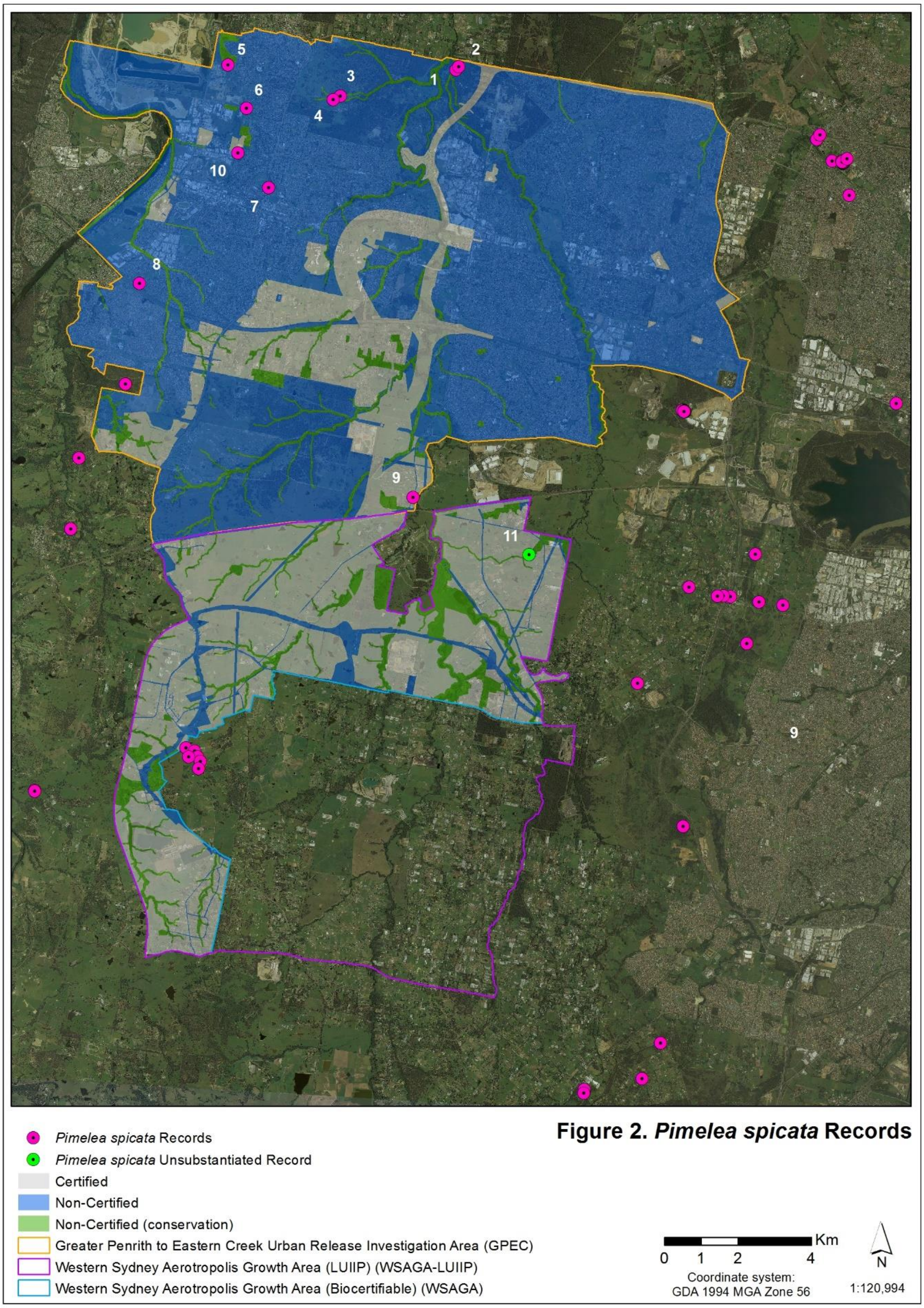


Figure 2. *Pimelea spicata* Records

4.2 Surveys completed for the biocertification

To assess the impacts of development within the growth areas new biometric data has been considered together with general and targeted survey. Field sampling and community/habitat verification has been undertaken by EcoPlanning and Biosis with assessment based on vegetation zones within Plant Community Types (PCT's) consistent with the Biodiversity Assessment Methodology (BAM 2017). No data from previous investigations within the growth areas was used. It is noted that the urban zone is being revised as the studies progress and accordingly the comparison of survey effort in relation to this zone is indicative only (DPE background information). The urban zone includes land zoned for future urban development plus transport corridors *within* the growth areas but not outside.

Survey and assessment was based on the following vegetation zones: Intact, Grasslands, Scattered Trees and Thinned. Survey effort has included the following:

- Field verification of vegetation type and condition mapping
- BAM plot sampling (all new)
- Flora and fauna habitat survey
- Targeted survey for threatened species using transects and random meanders

The location of survey areas, tracks and plots are shown in Figures 3 & 4. Quantitative plot data was collected to sample variability within each vegetation zone (EcoPlanning, Biosis 2017-18). The exact position of each plot within the vegetation patch was randomly located. Within the GPECGA a total of 10 BAM plots were sampled and within the WSAGA 56 plots.

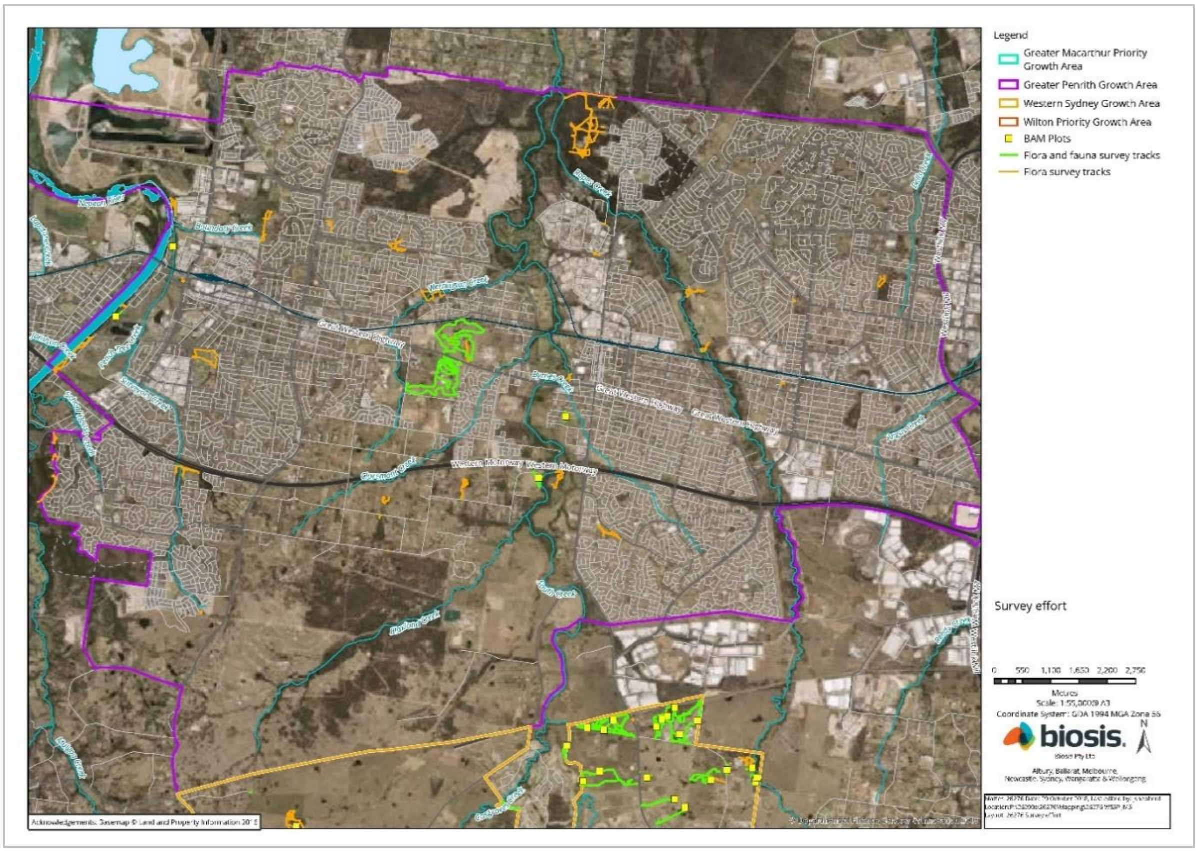
Targeted survey for threatened species, including *Pimelea spicata*, was conducted on accessible lands proposed for certification (and immediately adjacent) with particular attention to areas of lower disturbance and known topographic/habitat preferences. Survey comprised targeted random meanders (Figures 3 & 4) by Ecoplanning (orange tracks) and Biosis (green tracks). Biosis also surveyed for "fauna habitat" at the same time.

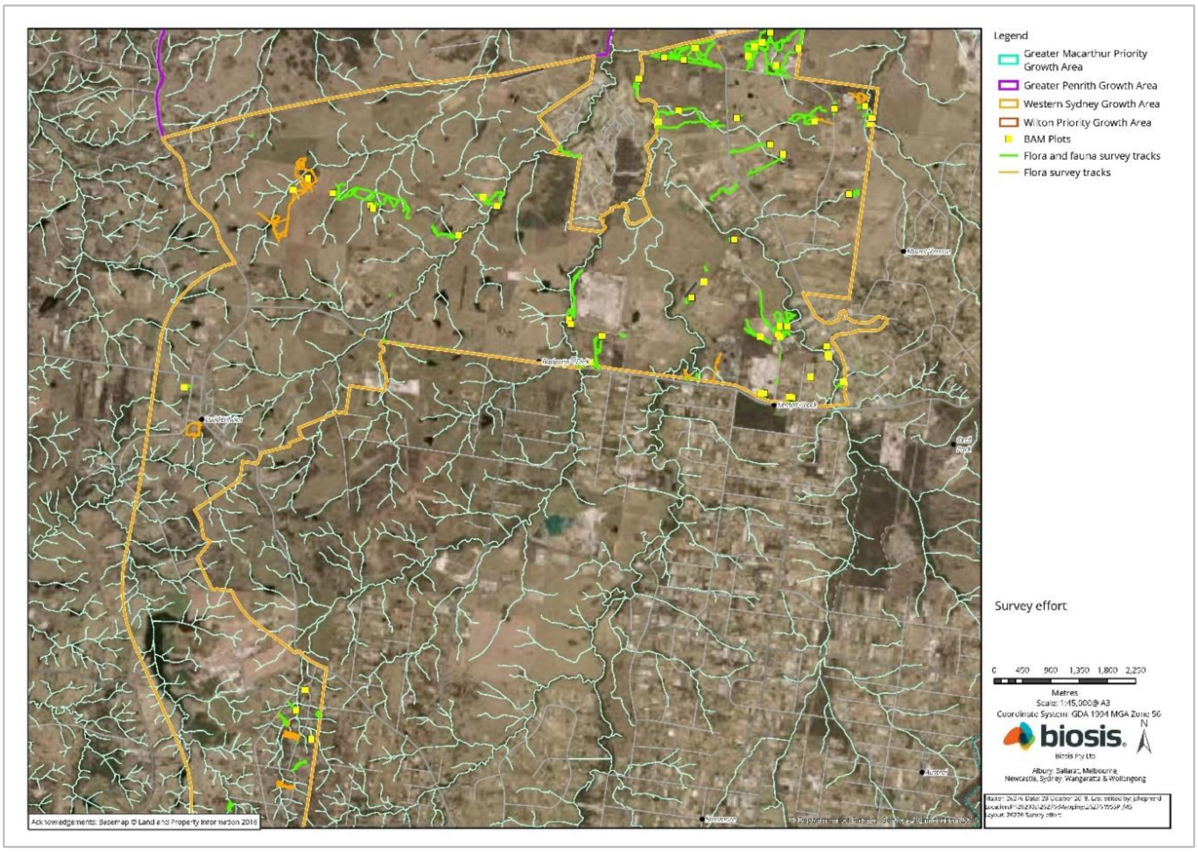
Land access
Within the GPECGA letters sent in 2017 and 2018 have led to 177 landholders providing access and an additional three landowners provided permission via door knocking with a 12% response rate. In addition access to 64 lots owned by Council was provided. Only properties with vegetation of particular interest were accessed.

A total of 432 letters were sent to landholders across the WSAGA between Nov 2017 and August 2018 with 84 granting access and a further seven properties accessed after doorknocking giving a response rate of 21%.

Survey timing
Surveys for *Pimelea spicata* should be undertaken when flowering due to its cryptic nature. Flowering is sporadic throughout the year and is likely to be in response to climatic conditions, particularly rainfall (DEC 2006). At other times plants are difficult to see or may only be present as rootstock or seed. Surveys have been undertaken mostly during 2017 and 2018 and no confirmed sighting of this species recorded within the growth areas. Periods of hot and/or dry conditions were experienced through this period although reasonable rain events occurred in February, November and December of 2018 (www.bom.gov.au/climate). Timing of surveys subsequent to such rain events is likely to be crucial in detecting the species.

Figures 3 & 4: Survey effort within GPEC (top) and WSA (bottom) growth areas





Survey effort

Threatened species survey effort within the GPEC (3.7%) and WSA (6%) growth areas is significantly lower than that completed for the Greater Macarthur and Wilton growth areas. Sites surveyed within or close to the certified zone include part of Hickeys Lane, Cranebrook (where *Pimelea spicata* was subsequently recorded by PCC), Claremont Meadows, South Creek in vicinity of Samuel Marsden Reserve, Kemps Creek (e.g. Aldington Road, South Creek), North Orchard Hills, Luddenham and Greendale North.

Most importantly survey effort for *Pimelea spicata* within preferred habitat across the growth areas is very low. For PCT 849 just 5% has been surveyed in the GPECGA and 7% in the WSAGA (see Table 6). There were no recorded sightings of *Pimelea spicata* during the surveys.

Table 6. Survey effort (20 m buffer from survey tracks) for threatened plant species (including *Pimelea spicata*) for relevant PCT's and growth area (data provided by DPE)

Growth Area	Vegetation Type (PCT)	Total area (ha) in GA	Survey area (ha)	% surveyed Within GA
Greater Penrith-Eastern Creek	849	1794	89	5
	850	81	0	0
	830	3	0	0
	835	826	13	2
Western Sydney Aerotropolis	849	550	37	7
	850	164	4	2
	835	163	12	7

A summary of plots sampled within the PCT's with potential habitat for *Pimelea spicata* is provided in the table below.

Table 7: Number of BAM plots undertaken by Growth Area, PCT & Vegetation Zone

	PCT 608	PCT 609	PCT 830	PCT 835	PCT 849	PCT 850	PCT 1395
GPEC							
Intact				2			
Grassland				2	1		
Scattered trees				1			
Thinned				4			
Total	0	0	0	9	1	0	0
WSA							
Intact				1	3	10	
Grassland				2	7	8	
Scattered trees				4	4	5	
Thinned				3	6	3	
Total	0	0	0	10	20	26	0

The level of plot sampling undertaken within potential *Pimelea spicata* habitat is very low for the GPECGA with no plots sampled within intact Cumberland Plain Woodland (PCT's 849 & 850) and just one plot sampled in modified CPW that being non-offsetable grassland (i.e. very low condition). Nine plots were sampled within River-flat Eucalypt Forest (PCT 835), however, this is not preferred habitat. No plots were sampled in Moist Shale Woodland (PCT 830) although only 2.8 ha of this community is currently mapped.

The level of survey undertaken within potential *Pimelea spicata* habitat within the WSAGA is higher with 20 plots surveyed across all vegetation zones for PCT 849 (Cumberland Plain Woodland) and 26 in PCT 850 which becomes more common on hilly terrain in the south-west. There is good coverage for River-flat Eucalypt Forest (PCT 835), however, this is not preferred habitat.

The more intensive and focused survey methodology of plot sampling is likely more reliable in detecting the species than meandering transects that often target more than one species.

4.3 Surveys completed for this assessment

Limited survey was undertaken in January and February 2019 by Teresa James and Anthea Whitlam. Survey was considered timely based on good rain events in late 2018 (www.bom.gov.au/climate) and regular storms in January and February 2019. By the mid-February, however, high temperatures and drier conditions resulted in rapid drying of soils with groundcovers, including plants of *Pimelea spicata*, showing marked signs of heat stress. Survey during December – January would have been more conducive to detection.

Confirmation of existing records
A known population at Mountain View Reserve, Cranebrook was checked in the field (January 2019) to confirm suitability of timing for survey. Other records were subsequently checked to determine presence and population status.

<u>Greater Penrith to Eastern Creek Growth Area</u>

Mountain View Reserve, Cranebrook
Moderate size population (80+), locally frequent adjacent to a small watercourse (habitat area c. 20 m x 5 m) at southern end of reserve, steep slope above to ridge-line. In Cumberland Plain Woodland dominated by Grey Box, *Eucalyptus moluccana*. Flowering and fruiting well in January 2019. By end of February flowering had ceased and leaves were shrivelling. This was used as a reference site.

Grey Gums Reserve, Cranebrook
A 2010 record was confirmed in the southern bushland area of the reserve close to the intersection of Andrews Road and Laycock Road. It is located on the lower slope below a footpath and above a drainage channel and road in Cumberland Plain Woodland dominated by Grey Box, *Eucalyptus moluccana*. Population size apparently smaller than previously with 5 clumps within an area of c. 5 m x 5 m but flowering and fruiting well. Weed invasion is reducing available habitat. A few plants were also recorded in late 2018 by PCC just above the footpath.

Kanangra Reserve, Glebe Place, Kingswood
A Council managed reserve containing Cumberland Plain Woodland adjacent to water reservoir. Seven (7) plants were recorded in 2003 (Appendix 2 of Recovery Plan), however, no details were provided relating to exact location and habitat. Search was undertaken on 28th February, 2019 for one hour and fifteen minutes focussing on intact habitat to the south and west of the reservoir. Conditions were warm and dry with native groundcovers showing signs of heat stress. The site is managed (weeding evident). Good potential habitat was observed to the south on a protected south-facing slope with a native grassy groundcover. No plants of *Pimelea spicata* were observed. Several small plants (re-sprouting from underground roots) of *Marsdenia viridiflora* subsp. *viridiflora*, however, were observed. To the west of the reservoir the groundcover is less intact in parts where scouring is evident on slopes from overwater flows and weed invasion more significant along ephemeral water courses.

Hickeys Lane Reserve, Kingswood Park (lower most disturbed part within certified area)
This reserve is south of the confirmed Cranebrook sites (see 4.3.1) on the same north-south running ridge-line. Similar habitat in Cumberland Plain Woodland exists on lower and mid parts of the slope

with high soil moisture associated with ephemeral watercourses, depressions and a wetland at the northern end. Lower slopes are dominated by Forest Red Gum *Eucalytus tereticornis* and higher slopes by Grey Box, *Eucalyptus moluccana*. Lower parts, in particular, are very weedy with dense exotic perennial grasses including Rhodes Grass, Paspalum and African Lovegrass. Condition of the vegetation improves upslope with active restoration occurring.

Survey was undertaken in January and February 2019 totalling 3 hours. Suitable habitat was observed, similar to known habitat within Grey Gums Reserve (plants at latter site were visible and flowering, although heat-stressed on the day of this survey) on slopes above the wetland in the north of the reserve. Good potential habitat also occurs on south and south-eastern slopes in the south of the reserve although unstable slopes and weeds are likely to restrict suitable sites/visibility. Subsequent to this inspection confirmation from Penrith City Council was received re a small population at two locations seen in late 2018. The lower part of this site (apparently adjacent to Hickeys Lane) was also surveyed by Biosis and EcoPlanning in mid-2018.

St. John Jamison Catholic Cemetery, Lilac Place, Jamisontown
At the time of inspection the grass had been recently mown, however, it was evident that native species persist on slopes and towards the back of the property away from the main central burial area. A range of native species were observed through the grassland, around the base of remnant trees and over old burial sites. No plants of *Pimelea spicata* were observed, however, some suitable habitat persists at the site.

<u>Western Sydney Aerotropolis Growth Area</u>

In vicinity of Aldington Road, Kemps Creek
An obscure record (included in a Biosis 2018 flora sightings file) from 99-111 Aldington Road with no date, habitat or population details. A patch of regenerating Cumberland Plain Woodland associated with a small gully off a ridge-top was searched on 06/02/19. The remainder of the property had been largely cleared except at the western end. The woodland was in moderate condition with past clearing and weed invasion (e.g. Blackberry and perennial exotic grasses). There was suitable habitat identified on protected south to south-west facing slopes of the gully but no plants were found. The far western section of the property was not accessed. Conditions were suitable for flowering with several other moisture sensitive species observed growing well and flowering.

This site and close vicinity was surveyed by Biosis/EcoPlanning in mid-2017.

Survey in potential habitat

<u>Greater Penrith to Eastern Creek Growth Area</u>

Peppermint Reserve, Kingswood
A council reserve with Cumberland Plain Woodland on gentle south-eastern and eastern facing slopes. Marginal habitat was observed (February 2019) with suitability constrained by lack of water availability in dry periods and weeds.

Werrington Creek, Kingswood
Good potential habitat was observed upslope from Werrington Creek within and south of the Western Sydney University Campus (February 2019), latter area in early stages of regeneration.

Glenmore Park (South) *Surveyor's Creek*
Drainage reserve east of Mulgoa Nature Reserve is mapped as Cumberland Plain Woodland, however, field inspection indicates it is River-flat Eucalypt Forest enhanced by plantings and landscaping and is not considered to provide potential habitat for *Pimelea spicata*. The mapping has been altered accordingly for this report.

Western Sydney Aerotropolis

Samuel Marsden Reserve, South Creek, Orchard Hills (within certified area)
Some existing records for *Pimelea spicata* are located close to creek lines in intergrading Cumberland Plain Woodland and River-flat Forest e.g. within the northern section of the former ADI site and at Badgerys Creek close to the confluence with South Creek. Similar habitat was searched on 6/02/19 along the creek at Samuel Marsden Reserve. Some flora survey was previously undertaken in spring 2018 at and in the vicinity of this site by Biosis/EcoPlanning but focussed on the eastern side of the creek and not after good rains.

The vegetation was regenerating and dominated by Forest Red Gum *Eucalytus tereticornis* (river-flat dominance) with an open, grassy groundcover. No plants of *Pimelea spicata* were observed although suitable habitat noted although limited.

West of Aldington Road, Kemps Creek
Good condition, mostly intact/regenerating Cumberland Plain Woodland on slopes above an ephemeral watercourse (mostly south-east facing) was searched on a property (53 Aldington Road) adjacent to the Aldington Road site described above in early February 2018. Despite good suitable habitat on protected lower slopes with Grey Box and Forest Red Gum no plants of *Pimelea spicata* were observed.

Greendale North/Bringelly
Small rural residential properties with modified Cumberland Plain Woodland and River-flat Forest associated with Badgerys Creek. At the time of inspection the understorey was highly modified through slashing, mowing and horse grazing. Although potential habitat for *Pimelea spicata* persists in this area, the vegetation condition and dryness at time of survey (and previous surveys) significantly limited the likelihood of plants being visible and no properties were accessed.

4.4 Assessment of species presence [BAM 6.5.2.8c]

Likelihood of species presence
Based on existing records (see Tables 4 & 5) and the extensive distribution of potential habitat (particularly Cumberland Plain Woodland including derived grasslands) it is confirmed that *Pimelea spicata* is present within the GPECGA and is likely to occur at other sites potentially within the proposed urban footprint (certified areas). There are no substantiated records for *Pimelea spicata* within the WSAGA, however, there are recent records within 1-5 km and extensive suitable or potential habitat.

Greater Penrith to Eastern Creek Growth Area (GPECGA)
Populations confirmed in this study or likely to still be present (based on habitat persistence) are summarised in Table 8. Two of the atlas records (PS 3 & 4) are no longer relevant for this report being within the Jordan Springs development footprint.

All sites, except PS7, are located in a regional park or council reserves and are assumed to have at least a moderate level of protection although it is noted that Grey Gums Reserve (PS6) is not currently zoned for conservation within the context of this report and known *Pimelea* habitat is mostly disturbed and weedy. The Badgerys Creek site appears to be in the vicinity of land zoned for conservation although the level of past and current protection and management, if any, is unknown. It is an older record (1999) with few plants recorded and the likelihood of the species persisting at the site is considered low.

There are no existing records located within the certified area although PS7 appears to be very close.

Table 8: Populations of *Pimelea spicata* confirmed or likely to persist in the GPECGA

Record Id	Location	Zoning	Protection level	Status
PS1	ADI Site, St. Mary's	Within regional park	Moderate – assumed active management	Presumed extant although not recorded in recent EcoPlanning survey
PS2	ADI Site, St. Mary's	Within regional park	Moderate – assumed active management	As above
PS5	North of Nepean Street, Cranebrook (now Mountain View Reserve)	Within council managed reserve, zoned conservation	Good – assumed active management	Confirmed 2018 (PCC), 2019 (James)
PS6	Grey Gums Reserve, Cranebrook (2 locations)	Within council reserve, zoned not certified	Low without management as in wetter more disturbed zone	Confirmed 2018 (PCC), 2019 (James)
PS9	Badgery's Creek	Probably just above riparian zone	Probably low	Unlikely but possible
PS10	Kingswood Park Hickeys Lane (2 locations)	Within council reserve	Low-moderate. In disturbed lower parts, one in APZ but council has ceased mowing at present	2018 (PCC)

Western Sydney Aerotropolis Growth Area
There are no confirmed or substantiated records for *Pimelea spicata* within the WSAGA. There is one vague record for *Pimelea spicata* west of Adlington Road, Kemps Creek (sourced from (*Biosis_FloraSightingPts*, 2018) located within the certified area, however, this record remains unsubstantiated. The site was inspected in early February 2019 but no plants were seen, however, suitable habitat was noted on this property and the adjoining one (53 Adlington Road). A very large population has been recently recorded within the adjoining airport zone less than a 1 km from the growth area boundary (see Figure 2). The plants were located on a rural grazing property in modified Cumberland Plain Woodland including derived grasslands. A summary of information on *Pimelea spicata* habitat at the airport site is provided below sourced from GHD (2017):

- Majority of plants were found in derived native grassland formerly supporting PCT 849.
- Grassland was in good condition with moderate species richness, high native grass and herb cover and low exotic plant cover.
- Clumps of plants were separated by tracks, building pads, dumped fill and dense African Olive infestations.

In view of this record, presence of similar habitat within the WSA and certified area and records to the west at Mulgoa and Greendale, there is a good likelihood of the species being present at additional sites within the growth area. A significant proportion of the potential habitat comprises derived grasslands dominated by native species or a mix of native and exotic.

Justification for determining presence

The association between known sites of *Pimelea spicata* both within and outside of the growth areas with Cumberland Plain Woodland and Moist Shale Woodland, and to a lesser extent River-flat Eucalypt Forest and Shale Sandstone Transition Forest is well documented in sections 4.3 and 4.5 of this report. Preferred habitats within these communities are described below.

<u>Physical environment</u>
Pimelea spicata is most often found on slopes in undulating low hilly terrain on Wianamatta Group shales including both Ashfield and Bringelly shales. Within the Greater Penrith and Sydney Airport growth areas Bringelly shales are the most widespread. *Pimelea spicata* prefers moist soils (clay helps to retain the moisture) and is often found on protected south or east facing slopes close to drainage lines or seepage points. Growth and flowering appears to be largely dependent on such moist soils with plants often not visible in dry periods and dying back to rootstock or persisting as seed in the soil seed bank. Such conditions occur extensively through the growth areas.

<u>Habitat condition</u>
Optimal habitat for *Pimelea spicata* is intact woodland with an open, grassy understorey, however, it can survive in disturbed and degraded landscapes e.g. recently discovered airport population south of Luddenham. Areas affected by localised woody weed infestations e.g. African Olive can also contain potential habitat. *Pimelea spicata* has been recorded after removal of African Olive at sites at Greendale (Penrith LGA) and Mt. Annan.
Many of the known records are associated with regenerating native vegetation e.g. after a disturbance such as mowing or grazing has ceased. Records from several council reserves have been made in recent years as “no mow” zones have been established. Examples include:

- Faulkland Reserve, Kings Langley (Blacktown LGA)
- Melrose Park, Quakers Hill (Blacktown LGA)
- Power Street Reserve (Fairfield LGA)

Woody weed infestations (e.g. African Olive) occur within the growth area, particularly in southern parts. These areas can still contain potential habitat (see Section 2.4) and are included.

The condition of habitat is not considered to be a reliable indicator of species presence and accordingly **all condition states** are considered in determining suitable habitat i.e. intact, thinned, scattered, derived shrubland and grasslands.

4.5 Assessment of suitable habitat [6.5.2.5]

Suitable habitat within the growth areas

Pimelea spicata is known to occur in the following vegetation communities:

PCT 849 – *Grey Box – Forest Red Gum grassy woodlands on flats of the Cumberland Plain*
PCT 850 - *Grey Box – Forest Red Gum grassy woodlands on shale of the southern Cumberland Plain*
PCT 806 & 807 – *Derived grasslands on shale hills and shale plains of the Cumberland Plain*
PCT 830 – *Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain*
PCT 835 - *Forest Red Gum – Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain* (particularly intergrading zone with PCT 849) where floodplain is not well defined
PCT 1395 - *Narrow-leaved Ironbark – Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain.* Low sandstone forms (at the shale end of the transition) of Shale Sandstone Transition Forest, which is structurally and floristically very similar to Cumberland Plain Woodland at the shale end of the transition.

The communities identified above are equivalent to the Cumberland Plain Woodland, Moist Shale Woodland, River-flat Eucalypt Forest and Shale Sandstone Transition Forest threatened ecological communities (see Tables 9 & 10). Degraded and disturbed examples of these communities (i.e.

reduced canopy and/or mid-layer cover or weedy areas) including road reserves can provide habitat for the species due to its long-term persistence as woody rootstock (tap root) and in the soil seed bank. Cumberland Plain Woodland and Moist Shale Woodland, including derived grasslands, are the most favoured habitat for *Pimelea spicata* occurring on mid to lower slopes or close to watercourses where soil moisture is retained for longer periods. Populations in such habitat appear to be more resilient to drought and other disturbances.

Within the growth areas there is extensive potential habitat for *Pimelea spicata* based on existing known sites, flora studies, scientific and personal knowledge. Important habitat attributes used to identify suitable habitat are discussed in section 4.3.

Greater Penrith to Eastern Creek Growth Area
Cumberland Plain Woodland comprises >57% of remnant vegetation in the *Greater Penrith to Eastern Creek Growth Area* with just 2.8 ha of Moist Shale Woodland. Only small patches of derived grasslands are mapped e.g. within the Orchard Hills RAAF site due to lack of targeted survey and are likely to be reasonably extensive. The 826 ha of land mapped as PCT 835 (part of River-flat Eucalypt Forest) is likely to include intergrading zones with Cumberland Plain Woodland that can provide suitable habitat for *Pimelea spicata.*

Table 9. Suitable habitat in the Greater Penrith to Eastern Creek Growth Area

Vegetation community	Distribution	Habitat value
Cumberland Plain Woodland (all conditions including mowed or slashed as long as meet final determination)	Across the GA with largest remnants within Wianamatta Regional Park & Orchard Hills RAAF base	High (primary habitat) but typically on mid to lower slopes or close to watercourses where soil moisture retained for longer periods.
Moist Shale Woodland	Restricted to small area at edge of Mulgoa Regional Park.	High: moist conditions and hilly terrain favour the species
Derived Native Grasslands (including mowed, slashed or grazed)	Throughout comprising grazing lands, roadsides & council reserves	Moderate to high: several records from over-cleared CPW or derived native grasslands
Cumberland Plain Woodland intergrading with Alluvial Woodland (RFEF) or more rarely Shale Gravel Transition Forest	Along creek corridors	Moderate to marginal depending on floodplain characteristics, again probably associated with higher moisture levels
Shale Sandstone Transition Forest	Only a small area (not confirmed in field) is mapped east of Mulgoa Nature Reserve	Moderate to high as expect very low sandstone influence & population known within the reserve (but in CPW).

The larger known populations in the north-west of the growth area are associated with a low ridge-line above the Nepean floodplain that is dissected by several ephemeral watercourses (PS 5 & 6). A relatively large patch of regenerating CPW associated with this ridge-line (south of PS 5 & 6) in Hickeys Lane Reserve provides good potential habitat and is currently not certified or zoned for conservation.

Sydney Aerotropolis Growth Area
The Sydney Aerotropolis Growth Area comprises predominantly a rural landscape with major creek corridors. Although it has been extensively cleared, patches of native vegetation, remnant trees and derived grasslands occur across the area. The dominant vegetation communities are Cumberland Plain Woodland (including derived grasslands) and River-flat Eucalypt Forest with extensive potential habitat for *Pimelea spicata*.

Table 10. Suitable habitat in the *Sydney Airport Aerotropolis* Growth Area

Vegetation community	Distribution	Habitat value
Cumberland Plain Woodland (all condition states)	Mostly in northern parts.	High, most records from CPW both Shale Plains and Shale Hills
Derived Native Grasslands (including mown, slashed or grazed)	Mostly northern areas comprising grazing lands, roadsides & council reserves	Moderate to high. Several records from over-cleared CPW or derived grasslands with varying levels of native species
Cumberland Plain Woodland intergrading with alluvial woodland part of River-flat Eucalypt Forest	Along creek corridor throughout growth area	Moderate to high, again probably driven by higher moisture levels

The large population recently discovered within the adjoining Airport zone less than a 1 km from the growth area boundary (GHD 2017) on a highly modified rural grazing property (including derived grasslands) suggests that similar habitat within the certified North Greendale district contains suitable habitat. Populations to the west of the growth area at Greendale and Mulgoa in similar habitat also supports this position.

Identification of habitat polygons

Extensive areas of potential habitat occur across the two growth areas. Potential habitat is identified based on the attributes described in Sections 4.3 of this report, existing populations, landscape context and personal knowledge. Although *Pimelea spicata* is known to occur in degraded sites, very small patches within over-cleared landscapes where the soil is likely to have been modified are excluded. Figures 5 & 6 show species polygons for the GPEC and WSA growth areas respectively.

<u>Estimate of area of habitat</u>

Ninety three (93) polygons containing a total of 2068 ha of suitable habitat within Cumberland Plain Woodland (PCT's 849 & 850) for *Pimelea spicata* are identified within the GPECGA. Small additional areas within Shale Gravel Transition Forest (PCT 724) and River-flat Eucalypt Forest (PCT 835) comprise marginal habitat. Seventy (70) polygons with 546 ha of suitable habitat are identified within the WSAGA mostly within Cumberland Plain Woodland (inclusive of derived grasslands). Small areas within Shale Gravel Transition Forest (PCT 724) and River-flat Eucalypt Forest (PCT 835) comprise marginal potential habitat in view of sandier soils and potentially denser tree canopy. The relative areas of vegetation communities are provided in Table 11..

Table 11. Areas (ha) of threatened communities identified as potential habitat for *Pimelea spicata*

Threatened Community	PCT	Habitat value	Area (ha) in GPEC including WRP	Area (ha) in GPEC excluding WRP	Area (ha) in WSAGA
Cumberland Plain Woodland (including derived grasslands)	850	High	59	59	3
Cumberland Plain Woodland (including derived grasslands)	849	High	2009	1511	483
River-flat Eucalypt Forest	835	Marginal	77	62	60
Shale Gravel Transition Forest	724	Marginal	18	9	0
Shale Sandstone Transition Forest (low sandstone)	1395	Marginal	2		

WRP = Wianamatta Regional Park

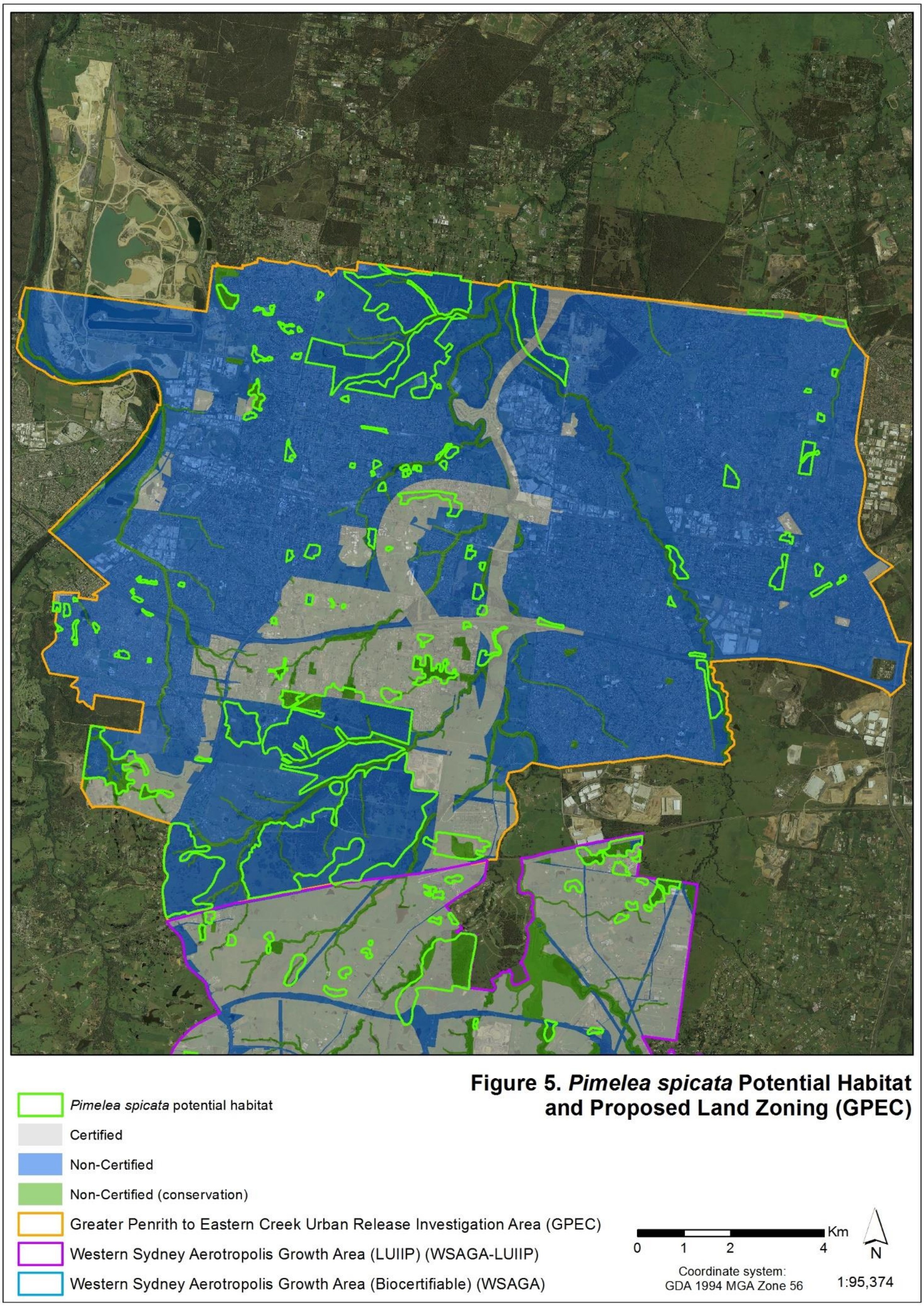


Figure 5. *Pimelea spicata* Potential Habitat and Proposed Land Zoning (GPEC)

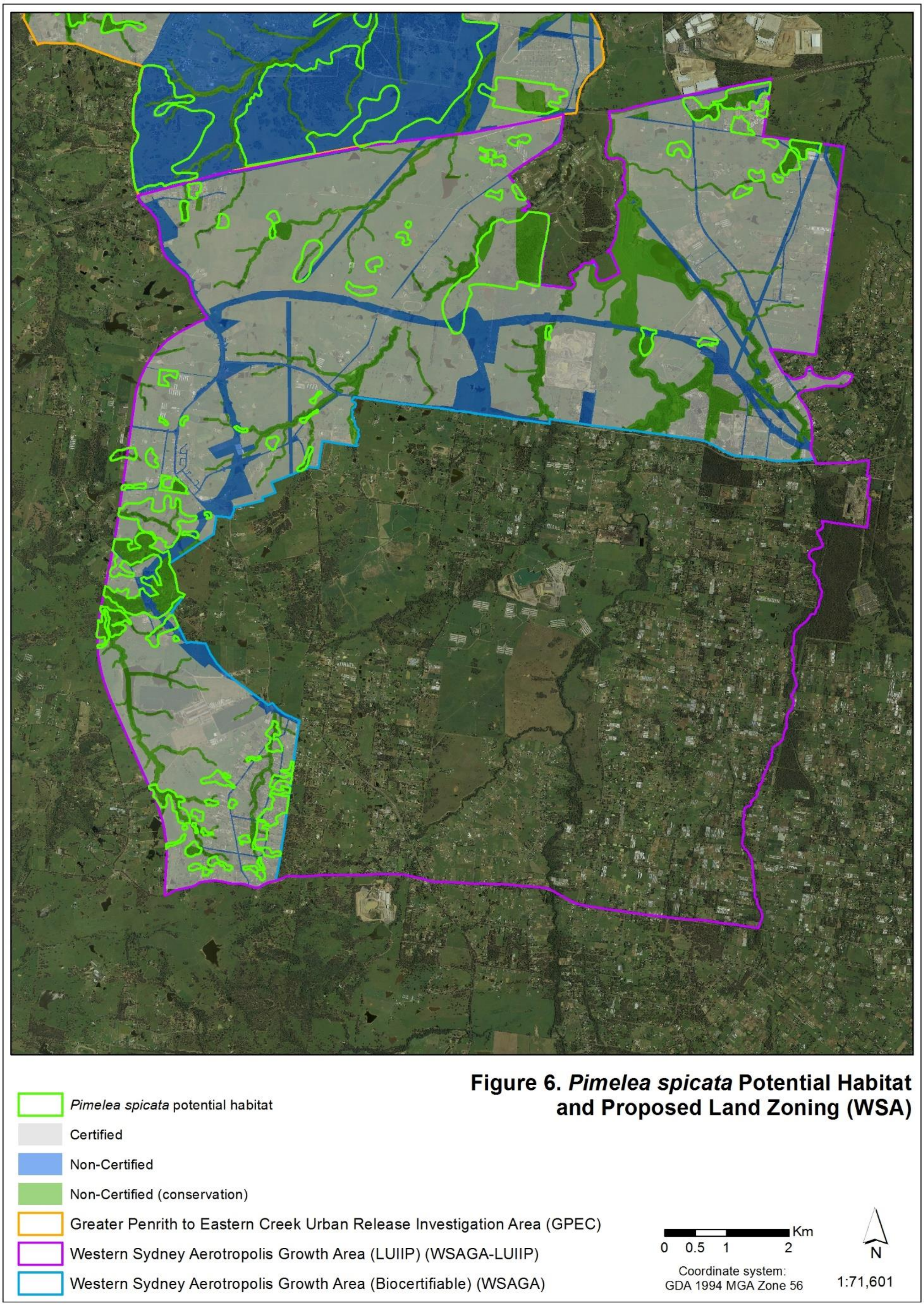


Figure 6. *Pimelea spicata* Potential Habitat and Proposed Land Zoning (WSA)

A significant proportion of the Cumberland Plain Woodland identified as potential habitat comprises native/mixed grasslands with scattered remnant trees and localised shrub regrowth. Such habitat is best represented at Orchard Hills (GPECGA) and between Luddenham and North Greendale in the WSAGA.

<u>Estimate of potential habitat relative to zoning (see Table 12)</u>

Within the Greater Penrith to Eastern Creek growth area 133 ha or 6% of potential habitat is found within the certified zone, 178 ha (8%) is zoned for conservation and 1857 ha (86%) occurs in the non-certified zoning. The latter includes larger areas within Wianamatta Regional Park [presumably with reasonable conservation prospects] and the Orchard Hills Defence Establishment that has long been recognised for its conservation values) and has been considered as an offset site for the Sydney Airport development (Dept. of Infrastructure, Regional Development & Cities, 2018).

Small council reserves in the far north-west associated with a north to south ridge-line above the Hawkesbury-Nepean River floodplain are particularly important for known and potential *Pimelea spicata* habitat, only two of which currently have conservation zoning. With records of *Pimelea spicata* (1) within and to the south of Mulgoa Nature Reserve, protection of potential habitat identified adjacent to the reserve also represents a good conservation opportunity for the species.

In the Western Sydney Aerotropolis growth area just over 53% occurs within the certified or development zone although 43% is zoned conservation predominantly associated with the South Creek corridor (around Kemps Creek) and the upper catchment of Duncan's Creek in the vicinity of Willowdene Avenue, south of Luddenham. The latter area is close to the recently discovered population west of the Northern Road and includes similar habitat. Potential habitat to the south around Greendale North is less intact and currently suppressed by a high level of grazing, however, may provide some conservation opportunities.

Table 12: Potential habitat relative to zoning

Growth Area	**Greater Penrith-Eastern Creek (GPEC)**	**Western Sydney Aerotropolis (WSA)**
Certified	133 ha	290 ha
Non-Certified	1857 ha	30 ha
Conservation	178 ha	237 ha

5. Information used in the assessment

5.1 NSW Planning & Environment and OEH resources

- Bionet sightings & other threatened species data from Atlas of Living Australia, *Pimelea spicata* Recovery Plan, Penrith City Council & LLS
- Greater Penrith to Eastern Creek and Western Sydney Airport Growth Areas Vegetation Mapping (see Table 13)
- Survey data, effort and land access details (see Table 13)

Unlike for the Wilton and Greater Macarthur growth areas all plots sampled were new i.e. surveyed for this project. Much of this information was available via the project's spatial viewer.

Table 13. Sources for existing vegetation survey data used in the biodiversity assessment

Data collector	Approx. no. plots	Survey year	Growth Area
Biosis & EcoPlanning	26	2017- 2018	Greater Penrith to Eastern Creek
Biosis & EcoPlanning	53	2017 - 2018	Western Sydney Airport

6. References

Benson & McDougall (2001) Ecology of Sydney Plants *Cunninghamiana* 7(2)

DEC (2006) Approved Recovery Plan for *Pimelea spicata*

Dept. of Environment & Heritage online Spiked Rice-flower *Pimelea spicata* SPRAT profile www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=20834

Dept. of Environment & Heritage (2016) Conservation Advice *Pimelea spicata* Spiked Rice-flower

Dept. of Infrastructure, Regional Development & Cities (2018) Western Sydney Airport Biodiversity Offset Delivery Plan

GHD (2018) TransGrid Re-location Appendix E Environmental assessment

Harden, G.J. (ed) (1990). *Flora of New South Wales. Volume One*. Kensington, NSW: University of NSW Press

NSW Bionet (OEH) online www.bionet.nsw.gov.au/ including Atlas records

NSW NPWS (1997) Urban Bushland Biodiversity Survey Stage 1 - Western Sydney

NSW NPWS (2004) Environmental Impact Assessment Guidelines

OEH (2016) NSW Guide to Surveying Threatened Plants

OEH (2017) Biodiversity Assessment Method http://www.environment.nsw.gov.au/resources/bcact/biodiversity-assessment-method-170206.pdf

OEH (2017) Spiked Rice-flower Profile http://www.environment.nsw.gov.au/ThreatenedSpeciesApp/profile.aspx?id=10632

Willis *et al.* (2003) Comparative seed ecology of the endangered shrub *Pimelea spicata* and a threatening weed Bridal Creeper. Ecological Management and Restoration Vol 4 Issue 1

Appendix 1. Curriculum Vitae for Teresa James

Home & work address: 1 Sharland Avenue, Chatswood NSW 2067

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Telephone: Mobile: 04 282 18502.

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Key positions:

- Botanist/ecological consultant specialising in vegetation survey, plant identification, conservation assessment and threatened species.
- Until October 1998 held position of Identifications Botanist, Plant Sciences, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney.

Qualifications:

Bachelor of Science (Combined Honours in Biology and Geography) - University of Exeter, England. 1978.

Accreditation:

Accreditation awarded (2008) as a BioBanking Assessor under the Threatened Species Conservation Act 1995 (NSW); accreditation renewed 2013. Accreditation number 0017.

Current employment (1998-present):

Self- employed flora/ecological consultant (sole trader working as Teresa James Flora Consultant).

- Flora surveys, site/conservation assessments and monitoring projects.
- Preparation of environmental impact assessment reports (e.g. 7-part test, species impact statement & review of environmental factors).
- Biobanking and Biodiversity Offset assessments.
- Preparation of threatened species management plans.
- Expert witness in the Land & Environment Court.
- Botanical training for local councils and community groups.

Previous employment

1978 (3 months)	Technical Assistant, Biological and Chemical Research Institute, Rydalmere (Department of Agriculture).
1978-1998	Employed at the Royal Botanic Gardens, Sydney.
1978-1979	Temporary Herbarium Assistant
1980-1982	Technical Officer, Botanical Information Section
1982-1986	Acting Identifications Botanist, Botanical Information Section
1987-1991	Technical Officer, Botanical Information Section
1991-1994	Acting Identifications Botanist, Botanical Information Section
1994	Secondment 4 days/week to World Heritage Assessment of the Blue Mountains (consultancy for NSW National Parks & Wildlife Service).
1994	Permanent appointment as Identifications Botanist.
1994-	Appointed Botanical Information Section Co-ordinator.
1996-1997	Secondment to NSW National Parks & Wildlife Service as Flora Officer for Urban Bushland Biodiversity Survey. Stage 1: Western Sydney.
1994-1998	Identifications Botanist & Botanical Information Section Co-ordinator.

<u>Selected longer-term projects:</u>

1998-1999	Vegetation sampling for NSW National Parks & Wildlife Service - Western Sydney Vegetation Mapping Project.

1999	Flora consultant to Eastern Gas Pipeline (Duke Australia Operations).
2000	Preparation of Fire Ecology Manual for Rural Fire Service and UWS.
October 2000-2003	Flora consultant to Biosis Research for Penrith City Council – proposed developments & TSC Act issues at Erskine Park.
2001	Field sampling and truthing for vegetation community mapping project - Baulkham Hills LGA. Baulkham Hills Shire Council.
2001-2003	Qualitative and quantitative vegetation surveys (including rare plant species and ecological communities, weeds and other threats, environmental assessment) of Wingecarribee Swamp with Sainty & Associates for the Sydney Catchment Authority.
February 2002-May 2002	Review of wetland boundaries and general vegetation mapping and condition assessment within Baulkham Hills local government area (for Baulkham Hills Shire Council).
2003	Vegetation survey in the Hunter, Nattai & Bargo districts as part of the National Parks & Wildlife Service Vegetation Survey Program.
2002-2007	Flora survey/monitoring at Dr Charles McKay Reserve, Mt. Druitt for Blacktown City Council.
September 2005 –2006	Field validation for Foreshore Vegetation Mapping Project on Sydney Harbour for Botanic Gardens Trust and NSW Maritime Services.
September 2000-2008	Flora consultant to Liverpool City Council – provide review & advice relating to development applications, plans of management & special projects.
February -May 2007	Field survey for Sydney Metropolitan Catchment Management Authority/DECC vegetation mapping. Plot data recorded for 100 sites within SMCMA.
May 2008-2010	Vegetation mapping and assessment of Blue Gum High Forest and Turpentine Ironbark Forest in Ku-ring-gai local government area
August 2008-present	Flora advice to Ku-ring-gai Council - review of development applications, plans of management and mapping/biodiversity projects.
February-August 2012	PAS2 Expert Interviews for NSW threatened species with Office of Environment & Heritage.

*See consultant reports for complete list of projects/surveys.

Special projects:

Assessment of the World Heritage Values of the Blue Mountains and surrounding plateaus

An assessment of the natural and cultural values of the sandstone plateaus of the Blue Mountains and surrounding areas was funded by the Federal and State Governments to determine the potential for world heritage nomination. A team of people worked on the project from the Royal Botanic Gardens, Australian Museum (cultural values) and experts from local universities. I was project co-ordinator for the assessment, wrote much of the text for the natural values sections and was editor of the final report. This report was used as a basis for the successful Blue Mountains World Heritage nomination (June 1998).

NPWS Urban Bushland Biodiversity Survey. Stage 1: Western Sydney

Documentation of biodiversity and conservation values in Western Sydney was the first priority project undertaken within the State Biodiversity Survey Program. The survey gave emphasis to threatened species, communities and habitats. The region was documented on a local government area basis. I co-ordinated the flora surveys and was principal author for the flora reports.

Particular expertise:

Plant Identification:

- New South Wales plants, native and naturalised (18 years of experience in the Botanical Information Section of the Royal Botanic Gardens, Sydney). Specimens received from all over state. Also cultivated plants.
- Specialist in Sydney flora.
- Prepared taxonomic treatments for various plant families in the publication Flora of New South Wales, volumes 1-4, produced by the Royal Botanic Gardens, Sydney.
- Conduct plant identification workshops both through the RBG and the University of Western Sydney.

Documentation and conservation/ impact assessment: plant communities and species

- Extensive range of sites surveyed with species lists compiled over the last twenty-five years, particularly in Western Sydney, the Blue Mountains and Southern Highlands. Plant specimens collected and incorporated into the National Herbarium of N.S.W. Information used in numerous reports and books e.g. World Heritage Assessment of the Blue Mountains, the NPWS Urban Bushland Biodiversity Survey, Rare Bushland Plants of Western Sydney and various papers.
- Prepare Tests of Significance and Species Impact Statements as required under current legislation (TSC Act, EPBC Act).
- Prepare Statements of Evidence & Affidavits for the Land & Environment Court.
- Provide advice to the community, developers, government agencies and councils concerning the identification of communities and species, impacts of proposed developments, the ecological effects of urbanisation, flood mitigation and management practices such as mowing, burning etc.

Peer review

Assessor services provided to government (all levels), consultancies and NGO's. Including the following:

- DA applications and associated reports e.g. REF's, SIS's, Tests of Significance
- BioBanking/Offset reports
- NSW Land & Environment Court reports

Education & training

- Involvement on committees or in groups providing technical advice and training eg. Greystanes Creek Management Committee, Upper Parramatta River Catchment Trust steering committees, Hawkesbury Rainforest Network.
- Presentations/talks e.g. National Parks Association, Society of Australian Plants, University of NSW, Landcare groups, local councils.
- Conduct plant community and species identification workshops/courses/tours through the Royal Botanic Gardens, the University of Western Sydney and privately.
- Prepared Fire Ecology Manual for Rural Fire Service (2000).
- Training for local government in threatened species, endangered ecological communities and biodiversity conservation.
- Publications e.g. primary author of revised edition of Rare Bushland Plants of Western Sydney (Royal Botanic Gardens 1999*),* contributor to Flora of New South Wales *(*Royal Botanic Gardens).

Courses/workshops & tours provided to local government/catchment management trusts/consultancies:

- Sept. 2004 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers & council staff
- October 2004 – Significant Plant Communities-of Baulkham Hills Shire Council – tour for council staff
- February 2005 – Community workshop in Cumberland Plain Woodland for Holroyd City Council
- July-August 2005 - Biodiversity training for Liverpool City Council – 3 workshops for council officers
- September 2005 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers

- August 2007 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2007 – Identification of plants in Cumberland Plain Woodland – for Hawkesbury Nepean CMA.
- April 2008 – Basic grass identification course for Baulkham Hills Shire Council (for bushcare volunteers).
- August 2008- Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- November 2008 to April 2009 – Weedy Grass Identification Workshop x 3 for Sydney Metro CMA.
- August 2009- Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2009 – EEC identification field day for Hawkesbury-Nepean CMA
- August 2010 - Threatened Species Tour for Baulkham Hills Shire Council bush care workers
- October 2010 – Cumberland Plain Woodland identification training for SMEC Australia
- April 2011- – Cumberland Plain Woodland identification training for SMEC Australia
- April 2011 – Field training in identification of communities & plants on the Cumberland Plain for Hawkesbury Nepean CMA.
- June 2011 – Presentation to council staff on threatened flora & fauna and biodiversity conservation within the Hills Shire.
- August 2011- Threatened Species Tour for Hills Shire Council bush care workers
- June 2012 – Eucalypt Identification workshop for Hills Shire Council.
- September 2014 - Threatened Species Tour for Hills Shire Council bush care workers
- September – November 2014 – Series of two-day workshops on threatened ecological communities in western Sydney.
- October 2014 – Plant identification training day held at Dr Charles Mckay Reserve, Mt. Druitt for Blue Tongue Ecosystems.
- March 2015 – Derived Grasslands Workshop (western Sydney) for government and community.
- May 2015 - Threatened Ecological Communities Workshop (western Sydney) for government and community.
- August 2015 – Shale Sandstone Transition Forest Workshop (western Sydney) for government and community.
- September 2015 – Northern Sydney Threatened Communities Workshop for government and community.
- April 2016 - Shale Sandstone Transition Forest Identification Workshop
- April 2016 – Introduction to Identifying Western Sydney Plants
- April 2016 – Grass Identification Workshop
- April 2016 – Cumberland Plain Woodland Workshop for Liverpool Council bushcarers
- August 2016 - Threatened Species Tour for Fairfield City Council.
- August 2016 - Threatened Species Tour for Hills Shire Council.
- April 2017 – Bushcare Training for Penrith Council
- Aug-Sept -Oct 2017 - Community bushland guided walks for Liverpool Council
- August 2017 - Threatened Species Tour for Fairfield City Council.
- August 2017 - Threatened Species Tour for Hills Shire Council.
- September 2017 – Flora workshops at Scheyville and Agnes Banks

Committee & community participation

- Member of NPWS Cumberland Plain Woodland Recovery Team (1998).
- Member of NPWS Acacia pubescens Recovery Team (1998 to 2002).
- Member, Green Corridors Strategy Steering Committee.Upper Parramatta River Catchment Trust. (1997-2000).
- Member, Water Quality Strategy Steering Committee. Upper Parramatta River Catchment Trust (1995-7).
- Member, State of the Environment Report Steering Committee for Holroyd City Council (1995-2002).
- Botanical Advisor for Management Committee, Greystanes Creek Restoration Project (1993-2000).
- Blue Gum High Forest Workshop / Advisory Committee – Ku-ring-gai Council. (2007).

Publications/booklets:

- Stepnell, K. & James, T. A. (1986). *Australia's Native Flowers*. Child & Henry Publishing Pty. Ltd.
- James, T.A. (1988). *Bertya ingramii* (Euphorbiaceae) a new species from New South Wales. *Telopea* 3(2): 285.
- Bedford, D. & James, T. (ed.) (1992). *Collection, Preparation & Preservation of Plant Specimens.* Royal Botanic Gardens, Sydney.
- Powell, J.M. & James, T.A. (1993) *Epacris sparsa* (Epacridaceae) reinstated. *Telopea* 5(2):375-380.
- James, T.A. (1990-1993) in *Flora of New South Wales*. Royal Botanic Gardens, Sydney
- Volume 1: Euphorbiaceae (part), Violaceae.
- Volume 2: Fabaceae (part).
- Volume 3: Celastraceae, Rubiaceae (part).
- Volume 4: Iridaceae (part), Poaceae (part).
- James, T.A. (1994). Observations on the effects of mowing on native species in remnant bushland, Western Sydney. *Cunninghamia* 3(3).
- Kodela, P.G. & James, T.A. & (1994) Aspects of the ecology and conservation status of the rare herb *Gentiana wingecarribiensis*. *Cunninghamia* 3(3).
- James, T.A. (1994) Review of a Key to Australian Grasses by B.K. Simon. *Australian Systematic Botany Society Newsletter* No.78.
- Contributor to Bowen Mountain Bushwalks (1994). Bowen Mountain Association.
- Kodela, P.G, James, T.A & Hind, P. (1996). Vegetation and flora of swamps on the Boyd Plateau, Central Tablelands, New South Wales. *Cunninghamia* 4(3).
- James, T.A. (1996). New combination in *Viola* (Violaceae). *Muelleria* Vol. 9 pp.35-36*.*
- James, T.A. NSW NPWS. (1997). Urban Bushland Biodiversity Survey. Stage 1: Native flora in Western Sydney.
- Hosking, R. J & James, T.A. (1998). An analysis of the native and exotic flora of the North Western Slopes upstream of the junction of the Peel and Namoi Rivers, New South Wales.
- James, T.A., McDougall, L & Benson, D. (1999). Revised edition. *Rare Bushland Plants of Western Sydney.* Royal Botanic Gardens, Sydney.
- James, T.A. (2009) Threatened plant species of Baulkham Hills Shire – unpublished booklet for Baulkham Hills Shire Council.
- James, T.A. (2009) Vegetation communities of Baulkham Hills Shire – unpublished booklet for Baulkham Hills Shire Council.
- James, Teresa (2013) Flora of Cumberland Plain Woodland – an identification guide.
- James, Teresa (2015) Threatened Flora of the Fairfield LGA.
- James, Teresa (2016) Native Flora of Shale Soils of the Cumberland Plain Woodland – An Identification Guide.

Reports

List of unpublished species lists and reports over the last 15 years.

- Kodela, P.G., James, T.A., Coveny, R.G. and Hind, P.D. (1992). Reconaissance survey of the vegetation at Long Swamp, near Penrose, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished report.
- James, T.A. & Kodela, P.G. (1992). Species list for Little Cattai Creek and tributary creeks. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. & Kodela, P.G. (1993). Plant species recorded from Butlers Swamp, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. Coveny, R.G., Kodela P.G. and Hind, P.D. (1993). Plant species recorded from a wetland area on the northern side of Fitzroy Falls Reservoir, Central Tablelands, N.S.W. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A., Hind, P.D., Kodela, P.G. (1993). List of native species recorded for the Vale of Avoca Reserve. Royal Botanic Gardens, Sydney. Unpublished species list.
- Coveny, R.G. and James. T.A. (1993). Plant species recorded from the Dr. Charles McKay Reserve, Mt. Druitt, Western Sydney. Royal Botanic Gardens, Sydney. Unpublished species list.
- James, T.A. (1994) Native plant species recorded from Alpha Park Reserve, Greystanes. Unpublished report.

- James, T.A. (1994) Botanical Significance of the Lower Canal, Greystanes. Unpublished report.
- James, T.A. (2004 revised 2009). Rare and threatened plant species of Baulkham Hills Shire for Baulkham Hills Shire Council.
- Allen, CB, Benson, DH, James, T & Kelleway, J (2007). Vegetation map of the Sydney Harbour Foreshore, December 2006. Prepared for NSW Maritime and the Sydney Metropolitan CMA by Royal Botanic Gardens, Sydney.

Consultancies:

- James, T.A. (1992) Vegetation Survey of proposed pipeline and irrigation sites for Goulburn wool scour. Unpublished report for Gunninah Consultants.
- James, T.A. (1992). Survey of Vegetation along New Line Road at Cherrybrook. Unpublished report for Gunninah Consultants.
- James, T.A. (1993). Vegetation survey of the eastern section of the Australian Defence Industries site, St. Marys. Unpublished report for Gunninah Consultants.
- James, T.A. *et al.* (1994) Royal Botanic Gardens Assessment of the World Heritage Values of the Blue Mountains and surrounding plateaus.
- James, T.A & S. Mcune (1998a). Flora assessment for the proposed Highlands Resort development near Picton. Report prepared for DLWC.
- James, T.A. (1998b). Cumberland Plain Woodland Assessment, Claremont Meadows, Penrith. Report prepared for Biosis Research. Subsequent assessment of significance of Cumberland Plain Woodland at the site for Species Impact Statement (Dec. 1998).
- James, T.A. & S. Cook (1998d). Flora Survey of Domain Creek, Parramatta Park.
- Douglas, S.M. & James, T.A. (1998e). Report on the native flora and development potential of Lot72 DP661069 & Lot 75 DP 67236 Sirius Road, Voyager Point. Report to Liverpool City Council.
- James, T.A. (1999a). Species profiles and environmental impact assessment guidelines for the rare species *Epacris sparsa, Kunzea cambagei, Acacia baueri* subsp. *aspera, Euphrasia bowdeniae* and *Zieria covenyi.* Prepared for NSW NPWS.
- James, T.A. (1999b). 8 Part Test- proposed laying of underground electrical conduit at the Crest of Bankstown. Report to Bankstown City Council.
- James, T.A. (1999c). 8 Part Test for drainage works at the Crest of Bankstown. Report to Bankstown City Council.
- James, T.A. (1999d). Overview of vegetation and assessment of conservation significance at proposed Erskine Park Employment Area. Report prepared for Biosis Research.
- James, T.A. (1999e). Vegetation review and survey of Area 3, Chullora Industrial Estate. Report prepared for Mather & Associates and Business Land Group.
- James, T.A. (Sept 1999). Review of management plan for the Highlands Resort, Picton - report for DLWC.
- James, T.A. (Oct 1999). Field survey and 8-part test for *Acacia baueri* subsp. *aspera*. Report for the Illawarra Shooting Association.
- James, T.A. (Nov 1999). Flora assessment - proposed works at Oatlands Golf Course. Report to Oatlands Golf Club.
- James, T.A. (Dec 1999). Flora assessment - Bungarribee Creek, Blacktown. Report to Blacktown City Council.
- James, T.A. (Feb 2000). Norfolk Reserve, Greenacre - Plant Survey and 8 Part Test for proposed walking tracks. Report to Bankstown City Council.
- James, T.A. (March 2000). Flora survey along Clavering Road, Seaforth.
- James, T.A. (May 2000). Flora assessment and 8-part test for proposed high school development along York Road, Kellyville. Report to the Department of Public Works.
- James, T.A. (June 2000). Flora survey and assessment of remnant Cumberland Plain Woodland at Dr. Charles McKay Reserve, Mt. Druitt. Report to Dr. Charles McKay Reserve 271 Park Committee.
- James, T.A. (June 2000). Remnant bushland at Central Gardens, Merrylands - flora survey and assessment of conservation and educational values. Report to Holroyd City Council.
- James, T.A. (July 2000) Powell Park, Kurrajong Hills - flora survey and conservation assessment. Report to Hawkesbury City Council.
- James, T.A. (August 2000) Chullora Industrial Estate - bushland retention area (3) and adjoining lands - flora and fauna assessment and “eight part tests” of significance. Report to Business Land Group.

- James, T.A. (August 2000) Flora report for bushland along Ropes Creek, St. Marys with management guidelines. Report to National Trust.
- James, T.A. & S. Douglas (September 2000). Flora survey & 8-part test for Lower Prospect Canal.. Report to NSW NPWS.
- James, T.A. (November 2000). Flora inspection of proposed driveway across 181 Princes Highway, Sylvania.
- James, T.A. (November 2000) Preliminary flora & fauna survey - Arabella Street, Longueville - proposed subdivsion.. Report to City Plan Services.
- James, T.A. (January 2001) Flora survey and assessment for Dwyer Oval, Cabramatta for Liverpool City Council.
- James, T.A. (January 2001) Flora survey and assessment for Duncan Park, Seven Hills for Friends of Grantham
- James, T.A. & J. Anderson for Oculus Pty Ltd. (Feb-April 2001). Flora and fauna survey of reserves within Mosman Local Government Area for Mosman City Council.
- James, T.A. & J. Anderson (March 2001). Species Impact Statement - Lot 907 Narabang Way, Belrose. Report to Access Industrial Holdings Pty Ltd.
- (April-May 2001). Flora survey of Wingecarribbe Swamp. Field assistance provided to Sainty & Associates Pty. Ltd.
- James T.A. & Anderson, J. (May 2001). Preliminary flora and fauna survey for Public Reserve, Prestons. Report for Liverpool City Council.
- James, T.A. (March 2001). Species Impact Statement for Dendrobium Project (BHP) Woronora Plateau. Assistance provided to Biosis Research.
- James, T. A. (June 2001). Threatened flora assessment & survey – *Grevillea juniperina* subsp. *juniperina, Grevillea parviflora* subsp. *parviflora* and *Pultenaea pedunculata*. Report to NSW National Parks & Wildlife Service.
- James, T.A. & Anderson, J. (June 2001) Preliminary flora and fauna survey for Public Reserve south of Braidwood Avenue, Prestons. Report to Liverpool City Council.
- James, T.A. (July 2001). Flora survey - Scheyville National Park for NSW National Parks & Wildlife Service.
- James, T.A. (August 2001). 8 Part Test for proposed cycle track at Crest Reserve, Bankstown. Report to Bankstown City Council.
- James T.A. & Anderson, J. (August 2001). Preliminary flora & fauna survey of Chullora lands affected by proposed rail upgrade. Report to Rail Infrastructure Corporation.
- James, T.A. (Sept 2001). Inspection and assessment of current mowing/slashing activities at the St Marys ADI site. Report to Compliance and Enforcement Section, Environment Australia
- James, T.A. (Nov 2001). Flora survey for proposed drainage easement at Pleasure Point. Report to Liverpool City Council.
- Kodela, P.G., Bravo, F.J, James, T.A. & Sainty, G.R. (Dec 2001). Quantitative sampling of vegetation in Wingecarribee Swamp. Prepared for Sydney Catchment Authority.
- James, T.A. (March 2002). Moorebank Interchange - Threatened Flora Survey and Assessment. Report to Haliburton KBR and the Roads and Traffic Authority, New South Wales
- *James, T.A. (March 2002). Clearing of native vegetation – Lots 1 & 4 Cowlishaw Street, Redhead. Report to NSWNPWS and Lake Macquarie City Council.*
- James, T.A. (April 2002). Balmoral Road Land Release – Ecological assessment of Cumberland Plain Woodland. Report to Baulkham Hills Shire Council
- Kodela, P.G., Bravo, F.J, James, T.A & Olsen, A. (May 2002). Quantitative sampling for vegetation in Wingecarribee Swamp-Spring 2002 survey. Report for Sydney Catchment Authority.
- James, T.A. (May 2002). Post-fire survey for *Acacia baueri* ssp. *aspera* – proposed shooting range. Report to Illawarra Shooting Association.
- James, T.A. (May 2002). Eight-part test for Chullora siding proposal. Report to Rail Infrastructure Corporation.
- James, T.A. (August 2002). Ecological study of Castle Hill Cemetery. Report to Baulkham Hills Shire Council
- James, T.A. (August 2002). Flora survey and assessment for Precint A1, Judith Street, North Seaforth. Report to GHD for NSW Planning & RTA.

- James, T.A. (September 2002). Flora survey and assessment for Precint C North, Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (November 2002). Flora survey and assessment for proposed roadway and stormwater easement in vicinity of Clavering Road & Gurney Crescent, Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (December 2002). Flora survey and assessment for Lot 38A Boronia Lane, Seaforth. Report to GHD for NSW Planning & RTA.
- James, T.A. (January 2003). Flora survey and assessment (including 8 part-test) for proposed upgrade of Seaforth Oval. Report for Manly Council.
- James, T.A & Anderson, J. (February 2003). Flora and fauna survey and assessment (including 8 part-tests) for Lot 31 Muir Road, Chullora. Report to Landcom.
- James, T.A & Anderson, J. (February 2003). Flora and fauna survey and assessment for proposed re-zoning of creek-line in vicinity of 15-25 First Avenue, Hoxton Park. Report to Liverpool City Council.
- James, T.A. (March 2002). Flora survey of Heath Road Reserve. Report to Baulkham Hills Shire Council.
- James, T.A & Anderson, J. (April 2003). Review of Environmental Factors for proposed hazard reduction burn at the Kings School, North Parramatta.
- James, T.A & Anderson, J. (May 2003). Flora and fauna survey and assessment for Lot 11 Corner Hume Highway and Worth Street, Chullora. Report to Landcom.
- James, T.A. (June 2003). Chullora rail yard upgrade – targeted survey for Tadgell's Bluebell *Wahlenbergia multicaulis*, part of requirement for SIS. Report to Rail Infrastructure Corporation.
- James, T.A. (May-June 2003). Flora survey in Hunter district for NSW National Parks & Wildlife Service.
- James, T.A. (June 2003). Field survey in North West Sydney – for Eco Logical Australia and Planning NSW.
- James, T.A & Anderson, J. (September 2003). Flora and fauna survey of Caroll Park & surrounds, Casula. Report to Liverpool City Council.
- James, T.A. (October 2003). Flora survey in Nattai – Bargo district for NSW National Parks & Wildlife Service.
- James, T.A. (December 2003). Flora survey and assessment for rail corridor at Yagoona. Report to Report to Rail Infrastructure Corporation.
- James, T.A. (December 2003). Review of flora and fauna issues re proposed integrated housing development at Beames Road, Rooty Hill. Report to Dr. Charles McKay Reserve Committee.
- James, T.A. (February 2004). Flora survey and assessment for rail corridor at Birrong. Report to Report to Rail Infrastructure Corporation.
- James, T.A. (May 2004). Summary of flora surveys during 2003-4 in Dr Charles McKay Reserve, Mt. Druitt for Blacktown City Council.
- James, T.A. (May 2004). Conservation assessment of Cumberland Plain Woodland in Balmoral Road Land Release area, Kellyville. Report to Baulkham Hills Shire Council.
- James, T.A. (May-June 2004). Threatened flora assessment for proposed realignment of the Great Western Highway at Lawson. Report to Australian Museum Business Services and Roads & Traffic Authority.
- James, T.A. (July 2004). Yagoona cutting flora review. Report to Rail Infrastructure Corporation.
- James, T.A. & Anderson, J. (September 2004). Flora and fauna survey for proposed residential development at the Kings School, North Rocks. Shale Sandstone Transition Forest and threatened species. Report to the Kings School.
- James, T.A. (September 2004). Flora assessment for proposed construction of sewage effluent pipeline at Megarritys Creek, Warragamba. Report to Australian Museum and Sydney Water.
- James, T.A. (September 2004). Flora survey of Faulkland Crescent Reserve, Kings Park. Report to Blacktown City Council.
- James, T.A. (October 2004). Flora assessment for proposed construction of water quality basins at Henry Street and Waratah Street, Lawson. Report to Australian Museum and Roads & Traffic Authority.
- James, T.A. (October 2004). Clearing of native vegetation at Lot 102 DP 1027438, 238-258 Captain Cook Drive, Kurnell. Report to Dept. of Environment & Conservation.

- James, T.A. (November 2004). Review of flora and fauna assessment for proposed subdivision at Charcoal Road, South Maroota. Report to Baulkham Hills Shire Council.
- James, T.A. (January 2005). Birrong rail cutting - flora review. Report to Rail Infrastructure Corporation.
- James, T.A. (Feb 2005). Proposed construction of electricity transmission line west of Nowra – preliminary flora survey and assessment. Report to Parsons Brinckerhoff Australia Pty Ltd.
- James, T.A. & Anderson Ecological Surveys (March 2005). Amended Species Impact Statement for proposed development at 8 Narabang Way, Austlink Corporate Park, Belrose.
- James, T.A. (March 2005). Review of flora and fauna assessment for proposed subdivision at 48-52 Oratava Avenue, 11 Maralinga Place and 19-25 Timberline Avenue, West Pennant Hills. Blue Gum High Forest. Report to Baulkham Hills Shire Council.
- James, T.A. (May 2005). Flora assessment for proposed extensions at Chatswood High School. Report to NSW Dept. of Commerce (Government Architects Office).
- James, T.A. (September 2005). Review of flora and fauna assessment for proposed hotel complex at 314 Annangrove Road, Rouse Hill. Shale Sandstone Transition Forest. Report to Baulkham Hills Shire Council.
- James, T.A. (October 2005). Flora survey for proposed fire hazard burn at Lawson. Report to GIS Environmental Consultants.
- James, T.A. (November 2005). Flora survey and assessment of shale forest at Helensburgh. Report to J & Z. Erskine.
- James, T.A. (December 2005). Preliminary flora survey at 110 Hebron Road, Lower Portland.. Report to GIS Environmental Consultants.
- James, T.A. (February & March 2006). Flora surveys in BHP exploration areas (Appin district). Surveys undertaken for Biosis Research.
- James, T.A. (March 2006). Flora survey & assessment for proposed reconstruction of 32nd Avenue, Hoxton Park. Report to Liverpool City Council.
- James, T.A. (April 2006). Flora monitoring survey - Hartley Quarry. Survey for Biosis Research.
- James, T.A. (May 2006). Preliminary flora report – proposed Penrith Great River Walk. Report to Australian Museum Business Services for Penrith City Council).
- James, T.A. (May 2006). Autumn surveys in Dr Charles McKay Reserve, Mt. Druitt. Ongoing survey & monitoring for Blacktown City Council.
- James, T.A. (May 2006). Update of Species Impact Statement for proposed development at 8 Narabang Way, Belrose. Report to Access Industrial Holdings Pty Ltd.
- James, T.A. (May 2006). Review of Environmental Management Plan and site inspection for proposed stabilisation works along Birrong rail cutting. Advice to RailCorp.
- James, T.A. (July 2006). Flora investigation of alleged poisoning of vegetation on Lot 42 Warlands Creek via Blandford, Upper Hunter Valley. Report to Department of Environment & Conservation (Legal Branch).
- James, T.A. & Barker, C. H. (June-August 2006). Preliminary flora & fauna survey for Hyland Road Reserve (North), Greystanes. Report to Holroyd City Council.
- James, T.A. (September 2006) Threatened Flora Surveys – western Sydney. Targeted survey for Department of Environment & Conservation.
- James, T.A. (November 2006). Flora survey and assessment for proposed footbridge construction over Cabramatta Creek. Report to Liverpool City Council.
- November 2006. Targeted field survey for *Gentiana wingecarribiensis* at Wingecarribee Swamp, Southern Highlands. Assistance to Parsons Brincherhoff Australia.
- February-May 2007. Field survey of Sydney Metropolitan Catchment Management Authority area. Royal Botanic Gardens Trust and Sydney Metropolitan Catchment Management Authority.
- T.A. James (February 2007). Faulkland Crescent Reserve - flora survey and review. Report to Blacktown City Council.
- James, T.A. (April 2007). Upgrade of Great Western Highway at Wentworth Falls - proposed stockpile, compound and spill basin areas - Flora survey and assessment. Report to Australian Museum Business Services for RTA.
- James, T.A. (May 2007). Upgrade of Great Western Highway at Bullaburra – flora survey and assessment. Report to Australian Museum Business Services for RTA.

- BioBanking Pilot Program (May 2007). Field survey & assessment at three Sydney sites (Wilton, Camden & Cranebrook) to test draft assessment methodology. Undertaken with Australian Museum Business Services for Department of Environment & Conservation.
- James, T.A. (August 2007). Flora review – proposed re-zoning of land along Pacific Highway, Pymble with particular reference to Blue Gum High Forest. Report to Ku-ring-gai Council.
- James, T.A. & C. H. Barker (October 2007). Flora & Fauna Survey and Assessment – Castle Hill Cemetery. Report to Baulkham Hills Shire Council.
- James, T. A. (Nov 2007). Investigation of clearing of native vegetation at Lot 2 DP 559922, 280-282 Captain Cook Drive, Kurnell. Report to NSW Department of Environment & Climate Change (DECC).
- James, T.A. (Nov 2007). Review of flora assessment for proposed residential development at 216-220 New Line Road, Dural. Report to Hornsby Council.
- November 2007. Assistance to SMEC Australia with base-line ecological monitoring in Upper Nepean Special Area for SCA.
- James, T.A (Dec 2007-Feb 2008). Targeted survey for *Hibbertia superans.* Report to Indigenous Business Services.
- November 2007- January 2008. Targeted survey for *Gentiana wingecarribiensis* and *Prasophyllum uroglossum* at Wingecarribee and Hanging Rock Swamps. Report to NSW Department of Environment & Climate Change (DECC).
- March 2008. Flora survey for upgrade of Great Western Highway at Bullaburra. Report to nghenvironmental for RTA.
- James, T.A. (March 2008). Flora survey of Plumpton Park Reserve. Report to Blacktown City Council.
- James, T.A. (April 2008). Review of Water Street DA, Wahroonga. Report to Ku-ring-gai Council.
- James, T.A. (April 2008). Flora survey of Gum Tree Reserve, Guildford and Bolaro Avenue, Greystanes. Report to Holroyd City Council.
- May 2008-June 2009. Assistance to Ku-ring-gai Council to map and assess Blue Gum High Forest and Turpentine Ironbark Forest.
- James, T.A. (August 2008). Flora review of Species Impact Statement prepared for proposed industrial development at 37 Beaumont Road, Mt. Ku-ring-gai. Report to Hornsby Shire Council.
- James, T. A. (May 2009). Preliminary flora report for proposed residential development at 38-40 Grove Avenue, Narwee.
- James, T.A. & Barker, C. (2006-2009). Monitoring of flora and fauna at Hyland Road Reserve. Report to Holroyd City Council.
- James, T. A. (Sept 2009). Ecological issues relating to the Turramurra Deferred Area within Ku-ring-gai LGA. Report to Friends of Turramurra.
- James, T.A. (Sept 2009). Targeted survey for *Pimelea spicata* at Menangle Park. Assistance to GHD Pty Ltd.
- James, T.A. (Sept 2009). Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland - 561 Appin Road, Gilead. Report to Campbelltown City Council.
- James, T.A. (Nov 2009). Peer review of subdivision proposal at Kellyville. Shale Sandstone Transition Forest & threatened species present. Report to Hills Shire Council.
- James, T.A (2010). Field survey and ecological assessment for proposed park at Water Street, Wahroonga. Report to A. Parr.
- James, T.A. (March 2010). Survey of *Pimelea spicata* at Menangle Park for GHD.
- March-April 2010. Advice on threatened species for Growth Centres Strategic Assessment under EPBC Act to EcoLogical Australia.
- Lewis Ecological Surveys & James, T.A. (May –June 2010). Flora and fauna assessment for extension of Kirkwood Road, Tweed Heads. Report to Tweed Heads Shire Council.
- Lewis Ecological Surveys & James, T.A. (May –June 2010). Compensatory habitat assessment for the Kempsey to Eungai pacific highway upgrade.
- Joint project with Australian Museum (October 2010 - March 2011) – Flora & fauna survey for Stage 2 of the Narrabeen Lagoon Multi-use Trail.
- Joint project with Australian Museum (October 2010 - December 2011) – City of Sydney Biodiversity Survey & Strategy.
- James, T.A. (2011). Investigation into land clearing of Shale Sandstone Transition Forest and Cumberland Plain Woodland - 561 Appin Road, Gilead. Expert report to DECCW.

- James, T.A. (2011) Flora survey for three reserves in Holroyd LGA to document regeneration following the cessation of mowing. Report to Holroyd City Council.
- James, T.A. (2011) Flora survey of Grey Box Reserve, Greystanes. Report to Holroyd City Council.
- Douglas, S & James, T (2011) Review of listing advice and conservation advice for Shale Sandstone Transition Forest EEC under the EPBC Act – in progress.
- James, T.A. (2011) External Review of White Box – Yellow Box – Blakeley's Red Gum grassy woodlands and derived native grassland ecological community for the Mt. Pleasant Project (EPBC 2011/5795). Report to Dept. of Sustainability, Environment, Water, Population and Communities.
- Ecological advice to SMEC Australia (July-August, 2011). Impact assessment for *Pimelea spicata* – upgrade of Camden Valley Way, western Sydney.
- Ecological advice to SMEC Australia (August-September, 2011). Survey and assessment for Eastern Flame Pea – Trans Grid Dapto substation upgrade.
- Field assistance to SMEC Australia (February 2012) - Targeted survey for *Pimelea spicata* and general survey for RTA Camden Valley Way upgrade.
- PAS2 Expert Interviews for NSW threatened species with Office of Environment & Heritage (February-August 2012).
- Plot survey and ground verification of vegetation mapping within Hills Shire Council (June 2012).
- Threatened species management plans for several species prepared for Hills Shire Council (June 2012) – multi-species plan for Paulls Road (South Maroota), individual plans for *Persoonia hirsuta* and *Epacris purpurascens* at Fred Caterson reserve.
- Joint project with Australian Museum - Narrabeen Lagoon multi-trail (stage 2) Species Impact Statement (June 2012)
- Field assistance to SMEC Australia - Western Sydney Parklands vegetation monitoring project for WSP Trust (July – August 2012).
- Biodiversity/conservation assessment for 12-14 Cabernet Circuit Orchard Hills. Unpublished report to Wayne Olling of CCA (October 2012)
- PAS Reviews for selected NSW threatened species with Office of Environment & Heritage (November 2012).
- Vegetation Peer Review for the Northern Beaches Health Service Project. Report to Health Infrastructure (January 2013).
- Flora survey and assessment on private properties within the Balmoral Release Area, Kellyville (15, 16-20, 24, 26 & 28) for the Hills Shire Council (May-June 2013).
- Preparation of a Threatened Species Plan of Management for *Dillwynia tenuifolia* endangered population along Maquires Road, Maraylya for the Hills Shire Council (May-June 2013).
- Biobanking Assessment Report for the Northern Beaches Hospital Precinct development (a State Significant Development). July 2013. Report to SMEC Australia and Health Infrastructure.
- Threatened species roadside survey and verification of threatened ecological communities for Campbelltown City Council (September-October 2013).
- Peer Review of Species Impact Statement for 34-36 Britton Street, Smithfield for Holroyd City Council (November 2013).
- Flora survey and condition assessment for Pacific Highway Upgrade Woolgoolga to Ballina (Feb - April 2014). Assistance to Ecosure for Roads and Maritime Services.
- Matching of threatened entities occurring in the Greater Sydney Region area to newly mapped vegetation/community types in the Sydney Metro CMA and other parts of the Greater Sydney Region (May-June 2014) for Office of Environment and Heritage (Sydney).
- Parramatta Park baseline flora survey and report for Parramatta Park & Western Sydney Parklands Trust (September 2014).
- Assistance to SMEC with survey and biodiversity report for commonwealth-owned land at Badgerys Creek (Sept-Oct 2014). Report to Department of Infrastructure and Regional Development.
- Identification of Shale Sandstone Transition Forest in the Hills Shire – report to Hills Shire Council (July 2015).
- Assistance with field survey to SMEC Australia at the Holsworthy Training Area for Department of Defence (September 2015).
- Assistance with field survey (base line monitoring) to SMEC Australia at the Kapooka Biodiversity Offset Site near Wagga Wagga for Roads and Maritime Services (Sept-Oct 2015).

- Assistance to SMEC Australia in preparation of a Species Impact Statement for the Mona Vale Road upgrade for RMS (Nov 15-Jan16).
- Assistance to Ecosure in field survey/assessment for Mosman Flora and Fauna Bushland Audit (Jan-Feb 2016).
- Ecological Survey of Sackville Cemetery – report to The Hills Shire Council (May 2016)
- Field survey with 20 m x 20 m plot sampling for OEH Western Cumberland Plain and Bargo Gap Project (targeting transitional areas) – June 2016
- Field survey with 20 m x 20 m plot sampling for OEH Wingecarribee Shire Project – February 2017
- Field survey for vegetation management advice at Greendale property, western Sydney (April 2017)
- Vegetation Benchmark Values Project for the Hills Shire Council (June 2017)
- Attendance on OEH Saving Our Species expert panel (2017-2018) for several threatened ecological communities
- Provide Roadside Vegetation Management RAM workshop training for Hawkesbury River County Council (Feb 2018)
- Field survey and assessment for Persoonia nutans at TestSafe Site, Londonderry for OEH (June 2018)
- Flora and fauna assessment for expansion of Sackville Cemetery for the Hills Shire Council (June 2018)
- Strategic assessment for Cumberland Plain Conservation Plan – expert report for *Pimelea spicata* – report to Department of Planning & Environment (May-August 2018)
- Rapid Assessment/monitoring workshop for Fairfield City Council (Sept 2018)
- Review of master list for selection of plant species for landscaping and restoration appropriate to range of habitats found within the Western Sydney Parklands. Report to Western Sydney Parklands
- Independent Peer Review of SIS for Lot 11 Progress Circuit, Prestons. Report to Liverpool City Council
- Preliminary advice re impacts on GDE’s at Menangle Park and additional vegetation assessment. Report to Campbelltown City Council

NSW Land & Environment Court cases:

- Grand United Friendly Society v Minister for the Environment - 87A Hammers Road, Toongabbie**.** Land & Environment Court.Proceedings No. 40292 of 1997. Engaged as a consultant by NPWS. Issues relating to <u>Cumberland Plain Woodland</u> and <u>Shale Sandstone Transition Forest.</u>
- Australand v Penrith City Council, Erskine Park (Dec 1999-April 2000). Land & Environment Court Proceedings. Engaged as a consultant by Penrith City Council. <u>Cumberland Plain Woodland and Sydney Coastal River-flat Forest.</u>
- Penrith City Council v Norman Mathie & Others – 392-476 Luddenham Road, Luddenham. Land & Environment Court Proceedings No. 50080-82 of 1999. Engaged as a consultant by Penrith City Council. Issues relating to <u>Cumberland Plain Woodland and Sydney Coastal River-flat Forest.</u>
- Blacktown City Council v Megarry Excavations and Roadworks Pty Ltd. Land & Environment Court Proceedings No 40141 of 2000. Engaged as a consultant by Blacktown Council. Issues relating to <u>Cumberland Plain Woodland and Shale Gravel Transition Forest.</u>
- Mark Topic v Liverpool CityCouncil. North Liverpool Road. Land & Environment Court Proceedings No 0155 of 2000. Engaged as a consultant by Liverpool City Council. Issues relating to <u>Cumberland Plain Woodland</u>

- Australand v Liverpool City Council. Land & Environment Court Proceedings No 10374, 10375, 10376, 10377 of 2003. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland and Sydney Coastal River-flat Forest
- Development Approval Managers v Liverpool City Council. Land & Environment Court Proceedings No. 10453 (Stage 3), No. 10455 (Stage 4) and No. 10454 (Stage 5) of 2003. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland and Sydney Coastal River-flat Forest
- BGP Properties v Lake Macquarie City Council - Lots 1 & 4 Cowlishaw Street, Redhead. Land & Environment Court Proceedings No 10042 of 2003. Engaged as a consultant by Lake Macquarie City Council. Issues relating to Sydney Freshwater Wetlands and Tetratheca juncea.
- Bentley v Hugh Gordon, Bentley v BGP Properties, Bentley v Whet Investments - Lots 1 & 4 Cowlishaw Street, Redhead. Land & Environment Court Proceedings No 50069-80 of 2003. Engaged as a consultant by NSW National Parks & Wildlife Service. Issues relating to Sydney Freshwater Wetlands and Tetratheca juncea.
- Blue Mountains City Council ats Blaxland Park Pty Ltd**.** - 60 Winnicoopa Road, Blaxland. Land and Environment Court Proceedings No. 10033 of 2004. Court appointed expert. Survey, identification & assessment of *Eucalyptus sclerophylla* Bench Woodland and *Lomandra brevis* in Repsonse to Agreed Questions.
- Providence Projects Pty Ltd v Gosford City Council – Lot 17 Meacham Way, Woy Woy. Land and Environment Court Proceedings No. 11626 of 2004 & 10101 of 2005. Court appointed expert. Review of issues relating to the identification of Umina Coastal Sandplain Woodland.
- Liverpool City Council ats Muslim League of NSW – 264 Wilson Road, Green Valley. . Land & Environment Court Proceedings No 10394 of 2005. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland.
- Liverpool City Council ats AV Jennings – Stage 24 Dalmeny Drive, Prestons. Land & Environment Court Proceedings No 10395 of 2006. Engaged as a consultant by Liverpool City Council. Issues relating to Cumberland Plain Woodland.
- Director General, Department of Environment & Conservation v Serenity Cove Business Park Pty Ltd – 238-258 Captain Cook Drive, Kurnell. Land & Environment Court Proceedings No 50003-5005 of 2006. Engaged as a consultant by the Department of Environment & Conservation. Issues relating to Swamp Sclerophyll Forest on Coastal Floodplains (formerly Sydney Coastal Esutary Swamp Forest), Sydney Freshwater Wetlands & Kurnell Dune Forest.
- Sutherland Shire Council ats Rocla Pty Ltd. Land & Environment Court Proceedings No 10447 of 2005. Engaged by Sutherland Shire Council. Issues relating to Swamp Sclerophyll Forest on Coastal Floodplains and Sydney Freshwater Wetlands.
- Wollongong City Council ats Albert David Moulds. Land & Environment Court Proceedings No 10488 & 10563 of 2006. Engaged as Court Appointed Expert. Issues relating to Illawarra Subtropical Rainforest and *Cynanchum elegans.*
- Gerroa Environment Protection Society v Department of Planning and Cleary Bros. Pty Ltd. Land & Environment Court Proceedings No 10801 of 2007. Issues relating to Swamp Sclerophyll Forest, Bangalay Sand Forest and Littoral Rainforest.
- Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 1-9 Buckingham Road, Killara. Issues relating to Blue Gum High Forest.
- Kaligem Pty Ltd v Ku-ring-gai Council. Proceeding No: 10823 of 2008 Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 5-7, Lonsdale Avenue, Pymble. Issues relating to Sydney Turpentine Ironbark Forest.
- Proceedings No: 10496 of 2009 Ecological advice to Warringah Council and Land & Environment Court in relation to proposed development at Beacon Hill. Issues relating to threatened species & general environmental impact. Proceedings No 10973 & 10794 of 2009.
- Ecological advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at 35 Billyard Avenue, Wahroonga. Issues relating to Blue Gum High Forest. Proceedings 10908 of 2009 (NSWLEC 1222).
- Expert advice to the Environmental Defenders Office and Land & Environment Court in relation to proposed development at Jordan Springs, St. Marys. Proceedings 40873 of 2011.

- Expert advice to the Office of Environment and Heritage and Land & Environment Court in relation to alleged clearing of endangered ecological communities (Cumberland Plain Woodland and Shale Sandstone Transition Forest) at Gilead, western Sydney. Proceedings 50604 of 2011.
- Expert advice to Ku-ring-gai Council and Land & Environment Court in relation to proposed development at Knox Grammar School, Warrawee. Issues relating to Blue Gum High Forest. Proceedings 10762 of 2011.
- Expert advice to The Hills Shire and NSW Land & Environment Court re proposed subdivision at 186-186A Cattai Ridge Rd Maraylya (Case No. 11216 of 2015).
- Expert advice to Cumberland Council and Land & Environment Court in relation to deemed refusal of DA (Fife Capital Pty Ltd) - Land and Environment Court Proceedings No. 2016/00310627
- Expert advice to Northern Beaches Council and Land & Environment Court in relation to deemed refusal of DA - Land and Environment Court Proceedings No. 53907 of 2017. Issues **- i**mpacts on *Swamp Sclerophyll Forest on Coastal Floodplains*, Warriewood.
- Provision of expert ecological advice in the matter of Liverpool City Council ats Timpag Investments Pty Ltd (2017/00234018)

Expert report – *Pterostylis saxicola*

Expert report on *Pterostylis saxicola*, the Sydney Plains Greenhood, in the Greater Macarthur and Wilton Growth Areas, Peter H. Weston, June 2018

Expert report on the Sydney Plains Greenhood, *Pterostylis saxicola* in the Western Sydney Aerotropolis Growth Area and Greater Penrith to Eastern Creek Urban Release Investigation Area, Peter H. Weston, September 2018

Strategic assessment for Cumberland Plain Conservation Plan

Expert report on *Pterostylis saxicola*, the Sydney Plains Greenhood, in the Greater Macarthur and Wilton Growth Areas

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Pterostylis saxicola (photo Wayne Cherry)

1. Introduction

1.1 PURPOSE

I was engaged by the Department of Planning and Environment in early June 2018, to produce an expert report on the distribution and abundance of *Pterostylis saxicola* (Orchidaceae) within the proposed Greater Macarthur and Wilton Growth Areas (collectively termed "the study area"). The aim of this exercise was to assess whether *P. saxicola* (the "focal species") is native to either of the Growth Areas and, if so, to assess where suitable habitat is located and to estimate the area of habitat of *P. saxicola* in the study area.

According to Section 6.5.2 of the Biodiversity Assessment Method, an expert report must:

- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- estimate the number of individuals or area of habitat (the latter being the unit of measurement that applies to *Pterostylis saxicola*) for the biodiversity certification assessment area, including a description of how the estimate was made
- demonstrate what information was considered, rejected and discounted in relation to the determination made in the expert report, and
- identify the expert and provide evidence of their expert credentials.

1.2 PROJECT CONTEXT

The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney, including the two growth areas that define the geographic scope of this report: the Greater Macarthur Growth Area and the Wilton Growth Area. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

1.3 STUDY AREA

The Greater Macarthur and Wilton Growth Areas are located in the south western part of the Sydney Metropolitan Area, between latitudes 33°57'29"S and 34°16'44"S and longitudes 150°37'12"E and 150°54'47"E (the area outlined in blue in figures 13 to 15).

1.4 CREDENTIALS OF EXPERT

I prepared this report as an independent botanical consultant but I am also currently an Honorary Research Associate at the at the New South Wales state herbarium (the National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust). In 2016, I retired from my role as a Senior Principal Research Scientist at the state herbarium, having worked there since

1982 as a Systematic Botanist and as curator of the herbarium's collections of specimens of Orchidaceae (including *Pterostylis saxicola*) (see my *Curriculum Vitae*, attached). I now work, part-time, at the National Herbarium of New South Wales as an Honorary Research Associate. I have published, either as sole author or as a co-author, 16 papers on the systematics and ecology of the Orchidaceae in the peer-reviewed scientific literature, including the most comprehensive phylogenetic analysis of the predominantly Australian subtribe Diurideae yet published (Weston *et al.* 2014). As curator of Orchidaceae at the state herbarium, I examined all specimens of *P. saxicola* incorporated into the collection between 1986 and 2016. I was invited to contribute to floristic treatments of the Orchidaceae for *Flora of New South Wales*, (see my *Curriculum Vitae*, attached). I was also asked to be lead author of the essay on the ecology of the Orchidaceae that accompanied the "Ecology of Sydney Plants" (Weston *et al.* 2005). Throughout my career I have participated in numerous collecting trips in the field, collecting specimens in all Australian states for the state herbarium. In documenting these specimens I had to describe the habitat at each collecting site, including associated plant species, substrate, aspect, degree and kind of disturbance. I have also cultivated numerous species of *Pterostylis* as an orchid enthusiast and advised horticulturalists at the Royal Botanic Gardens on appropriate techniques for cultivating species of *Pterostylis* and other orchids.

1.5 JUSTIFICATION FOR USE OF EXPERT REPORT

Pterostylis saxicola has been collected once, questionably, within the study area, at Minto. However, two specimens of *P. saxicola* held by the state herbarium (NSW884619, NSW521907), and several observations recorded in the Bionet Wildlife Atlas, have been collected only 0.5-1.5 km east and 1.0 km south of the boundaries the Greater Macarthur Growth Area, raising the strong possibility that suitable habitat for *P. saxicola* might exist in the study area.

Moreover, the OEH Threatened Species Data Collection indicates that *Pterostylis saxicola* has the potential to occur in the following plant communities within the Wilton and Greater Macarthur Growth Areas:

- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain

If this were so, *Pterostylis saxicola* might once have lived there, or still exist in the study area as unrecorded populations.

Pterostylis saxicola is a perennial, deciduous herb that can only be identified with confidence when flowering in Spring (late September to early November). At other times of year, the plants are either not visible at all when dormant from December to March, or are visible only as leaf rosettes, which resemble the leaves of other, closely related, co-occurring species of *Pterostylis* so closely that they cannot be distinguished with confidence. Conventional surveying during October would therefore be the most appropriate way to test for its presence, if unlimited access to the study area were allowed. Although surveys were undertaken on all areas of land where landowners granted access, the timing of these was inappropriate for this species, as they were conducted between November 2017 and May 2018.

These limitations and the possibility that *Pterostylis saxicola* might be native to the Greater Macarthur and Wilton Growth Areas triggered the need for an expert report.

1.6 SPECIES SURVEYS

An initial 726 letters were sent to landholders within the Growth Areas in late 2017. A second letter was sent in March 2018, and targeted door knocking occurred in May 2018. From this, just under 20% of landholders have responded. Surveys were undertaken on all areas of land where landowners granted access. Of the 14,984 hectares within the Wilton and Macarthur Growth Areas, of which 5,385 ha is potential native vegetation that could be impacted by development, DPE has completed surveys across 3,360 hectares (62% of the total survey area). Floristic surveys were undertaken from November 2017 to May 2018, which, unsurprisingly, resulted in no sightings of *Pterostylis saxicola*, which was dormant or recently re-shooting from subterranean tubers for most of that time.

2. Species information

2.1 SPECIES DESCRIPTION

The following morphological description of *Pterostylis saxicola* is a modified version of that published by Jones and Clements (1997), updated with data gathered from more recently collected specimens held by the National Herbarium of N.S.W.

Tuberous, terrestrial herb. Tubers oblate, c. 15-20 mm wide. Leaves oblong-elliptical to ovate-elliptical or obovate, 10-45 mm long, 5-15 mm wide, 5-10 in a radical rosette, green, the margins entire, shortly petiolate, apex subacute to apiculate, often withered at anthesis. Inflorescence 10.5-35 cm tall, slender, with 3-6 ensheathing, lanceolate sterile bracts. Floral bracts lanceolate, 6-19 mm long, 3-4 mm wide, acuminate, closely sheathing. Pedicels 3-26 mm long, slender, straight or slightly curved. Ovary narrowly obovoid, 3-5 mm long, 1-2 mm wide, reddish brown. Flowers 1-10, porrect to semi-erect, 12-12 mm long, transparent with dark red-brown markings and suffusions in the galea, the lateral sepals wholly red-brown, shiny; galea gibbous at the base, curved medially, decurved suddenly to the apex; petal flanges poorly developed, not touching and not closing off the base of the galea. Dorsal sepal 11-13 mm long, cucullate, obliquely erect, Abruptly decurved in distal quarter, apical point c. 3 mm long, filamentous, acuminate. Lateral sepals deflexed, ovate in outline when flattened, fused part 7-10 mm long, 9-11 mm wide, shallowly concave, the margins strongly incurved, glabrous; sinus narrow; free points filamentous, c. 5 mm long, curved forwards, divergent, 8-10 mm apart at the tips. Petals ovate-lanceolate, 11-14 mm long, 3.5-5 mm wide, nearly straight, transparent, with brown basal markings and two or three brown lines, dorsal margin brown, ciliate, proximal flange poorly developed. Labellum highly irritable, attached by a ligulate basal claw c. 2 mm long, c. 2 mm wide; lamina broadly obovate, 4.5-6 mm long, 2.5-3.5 mm wide, dark red-brown, constricted in the proximal quarter, adaxial surface shallowly concave to broadly grooved, apex obtuse; marginal trichomes 3-5 pairs, white, the longest pair c. 3.5 mm long, arising near the proximal constriction, basal lobe large, with 1-3 pairs of trichomes c. 0-.7 mm long, abaxial surface with a narrow central channel extending from the basal lobe to the apex. Column porrect from the end of the ovary, 10-12 mm long, c. 2.5 mm wide; column wings c. 3.3 mm long, c. 2.5 mm wide, more or less rectangular, anterior margins ciliate. Stigma elliptical to broadly scutiform, c. 5 mm long, c. 2.5 mm wide, the upper margins irregular. Anther c. 1.2 mm long, obtuse. Pollinia linear-oblong to clavate, c. 2 mm long, yellow, mealy. Fruiting capsules obovoid, 7-8 mm long, c. 4-5 mm wide, brownish, erect.

2.2 LIFE CYCLE

Pterostylis saxicola is a perennial, deciduous, tuberous herb that germinates from a minute, dust-like seed. Like all other orchids, germination is reliant on invasion of the seed by the hyphae of a specific fungal associate, which, in the case of *P. saxicola*, is an unnamed species of *Ceratobasidium* (Basidiomycota: Cantharellales) (Sommerville *et al.* 2008). The first morphological change that an orchid seed undergoes during germination is swelling to form a protocorm, a rootless, shootless 'blob'. The orchid fungus forms an intracellular relationship with its host, usually in the roots and/or tubers and is thus classed as an endomycorrhiza. It forms hyphal coils, called pelotons, in the cells of its host, which are beneficial to the orchid in that they provide the host plant with nutrients such as soluble sugars (Rasmussen 1995, Warcup 1990). The duration of the association varies according to the life history of the particular orchid species, with some species of orchids being completely dependent on their mycorrhizal fungi for life while other species are capable of living without their fungi from shortly after germination. The ease of cultivation of *Pterostylis* species and the green colour of almost all plant parts strongly suggest that adult plants are not obligately dependent on their mycorrhizal associates.

Plants of *Pterostylis saxicola*, like those of most other species in Orchidaceae subfamily Orchidoideae, are deciduous, with the whole shoot system growing anew every year from a dormant tuber. The new shoot usually starts growing from an apical meristem on the tuber in late summer, with new shoots usually breaking the soil surface by March. The shoot develops into a "rosette" of crowded leaves just above ground level and in late winter a terminal raceme starts growing from the centre of the rosette, reaching anthesis in Spring. While the shoot is growing above ground, a new replacement tuber is growing below ground, from the base of the shoot. Some species of *Pterostylis* multiply and spread vegetatively by producing additional new tubers on the ends of long roots but the subgenus to which *P. saxicola* belongs, *Oligochaetochilus*, does not share this attribute (Jones 2006).

Almost all species of *Pterostylis* are deceptively pollinated by male flies that attempt to copulate with the labellum of the flower. The labellum mimics a female fly of a particular species (or species group) in size, appearance and texture and by exuding an allomone that is identical to the pheromone released by the female flies (Phillips *et al.* 2013, Kuiter & Findlater-Smith 2017). In species of *Pterostylis* for which the pollination process has been studied and described, the labellum is highly motile ("irritable"), like that of *Pterostylis saxicola*, and a male fly that lands on it is tossed inside the hood (galea) formed by the dorsal sepal and lateral petals, and trapped there. The only escape route provided by the flower is a tunnel through which the male fly must squeeze in order to escape. In the process of negotiating its exit, the fly is forced to rub past the stigma of the flower, depositing on it any pollinaria that it was already carrying. The fly is then forced to contact the anther, sticking a pollinarium on its thorax, before it can finally escape. The pollinator of *Pterostylis saxicola* is still unknown, but the pollinators of other species of *Pterostylis* subgenus

Oligochaetochilus, where known, are males of unnamed species of *Orfelia* (Mycetophilidae) (Kuiter & Findlater-Smith 2017). Sexually deceptive pollination has evolved multiple times in the Australian terrestrial orchid flora, involving hundreds of species (Weston *et al.* 2014). Most of those for which pollinators have been identified are pollinated by the males of only one species of insect and *P. saxicola* is most likely pollinated by a single species of fly too.

Fruiting capsules of *Pterostylis saxicola* mature quickly, with the most proximal capsules sometimes dehiscing before the most distal flowers have withered. They split down six sutures to release thousands of minute, wind-dispersed seeds in November to early December.

2.3 DISTRIBUTION AND ABUNDANCE

Records for *Pterostylis saxicola* are widely distributed across the Cumberland Plain and lower Blue Mountains in an area bounded by Scheyville, Freemans Reach, Glenbrook, Douglas Park, Picnic Point, Ryde (an unvouchered record) and Cattai, with an outlying record from the Gingra Range in Kanangra Boyd National Park (Bionet Atlas, National Herbarium of New South Wales specimen database, all accessed 26/7/2018). It has been recorded at altitudes ranging from 30 to 400 metres. It is very sporadically distributed, partly because much of this land has been cleared for agriculture and suburban development but the outlying record suggests that any habitat model is unlikely to be a powerful predictor of the presence of populations at particular locations.

Plants are usually gregarious, with most collectors and observers noting multiple plants co-occurring together. At two sites for which I had highly precise grid references, and which I characterised in detail, I found pre-flowering leaf rosettes in clusters: 10 plants in a 10x10 cm patch (figure 1, site PS1, Appendix 1), two plants 5 cm apart, and 57 in a patch smaller than one square metre. As *P. saxicola* does not usually multiply vegetatively (Jones 2006), these clusters must be the result of seeds germinating close to their parents.

2.4 HABITAT REQUIREMENTS

The habitat model published in the endangered species profile for *Pterostylis saxicola* (NSW Office of Environment and Heritage 2018, hereafter "NOEH 2018") states that it is "most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *P. saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils". This description applies accurately to the habitat associated with some records in the southern half of the species' distribution but not to those found elsewhere. The distributional range and habitat requirements of *P. saxicola* can be subdivided into two main sub-populations and one outlying population.

The northern sub-population is in an area bounded by Scheyville, Freemans Reach, "The Ironbarks" near Glenbrook, Toongabbie, Ryde, Glenhaven and Cattai. The substrate underlying the sites at Scheyville, Freemans Reach and Ryde is deep Ashfield Shale (Wianamatta Group), but the Cattai, Toongabbie and Glenbrook records came from Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition zones. All of these sites are in gently rolling country, not on rugged sandstone outcrops.

I visited and characterised one of these sites at Scheyville National Park (site PS1, Appendix 1), the location of which was recorded with very high precision. I found pre-flowering *Pterostylis* rosettes

Figure 1. Pre-flowering rosettes of *Pterostylis saxicola* growing on Ashfield Shale in Scheyville National Park (site PS1, Appendix 1).

Figure 2. Site Ps1 with *Pterostylis saxicola* growing on the side of the track, next to the backpack, in Cumberland Plain Woodland on Ashfield Shale in Scheyville National Park (site PS1, Appendix 1).

there that were consistent with *Pterostylis saxicola* (figure 1, site PS1, Appendix 1). The population there was growing on the side of a track just below the crest of a ridge, the land sloping at about 5° to the south east, on Ashfield Shale, in Cumberland Plain Woodland (*sensu* Keith 2004) dominated by *Eucalyptus moluccana* and *E. crebra*, a plant community that I identified using the community identification tools in Bionet as 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain. This site was inconsistent with the species profile for *P. saxicola* (NOEH 2018) in both substrate (Ashfield Shale) and landform (gentle slope near ridge top). The closest sandstone outcrop to the site was at least 3.6 km to the east, the shale cap at the site being about 20-30 m thick according to the geological map covering this area (NSW Department of Minerals and Energy 1991).

The plant communities associated with recorded sites for *Pterostylis saxicola* in its northern sub-population, as determined from collectors' and observers' notes and from identification of precisely specified sites on vegetation maps (Tozer *et al.* 2010), are map unit GW p29 Cumberland Shale Plains Woodland, and map unit GW p2 Cumberland Shale Sandstone Transition Forest.

Most records from the southern sub-population, in an area bounded by Macquarie Fields, Minto, Douglas Park, Woronora River and Picnic Point differ strikingly in habitat from the northern records. In cases where they have highly precise locality data and/or detailed habitat descriptions, collections and observations from this area have been made on Hawkesbury Sandstone, on the rims and sides of the gorges of the Nepean, Georges and Woronora Rivers. Observers' notes repeatedly describe the soils as very shallow sands overlying sandstone rock shelves, as stated in the published habitat model (NOEH 2018). However, contrary to that model, only some of them were recorded above cliff lines. The only evidence of shale influence on the environment seems to be associated plant community types, with some precisely georeferenced sites being mapped by Tozer *et al.* (2010) to Cumberland Shale Sandstone Transition Forest (their map unit GW p2).

I visited and characterised four sites at which *Pterostylis saxicola* had previously been collected in the southern sub-population, at Simmos Beach Recreation Reserve Macquarie Fields (sites PS2, PS3), Boronia Road Reserve, Kentlyn (site PS4), and Amberdale Reserve, Picnic Point (site PS5, Appendix 1). At one of these I found pre-flowering rosettes identical to those of *P. saxicola* at the precise grid reference I had been provided by a previous collector, Karen Sommerville (figures 3-4, site PS3, Appendix 1). They were growing in a thin layer of dark brown humus-rich sand on a flat sandstone outcrop on a gently sloping ridge top. Other sites at which *P. saxicola* had previously been collected but where I did not find pre-flowering rosettes were similar, with sandstone rock shelves covered in a thin layer of sandy soil that was partly covered by mosses and lichens. Several plant species were associated with *P. saxicola* at all four of these southern sites: *Angophora bakeri*, *Banksia spinulosa*, *Hakea sericea*, *Leptospermum trinervium*, *Lomandra obliqua*, and *Persoonia levis*.

The plant community types that I identified at these locations, using the community identification tool in Bionet, were:

- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain;
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney.

Figure 3. Pre-flowering rosettes of *Pterostylis saxicola* growing at Simmos Beach Recreation Reserve, Macquarie Fields (site PS3, Appendix 1).

Figure 4. PCT 1081 Red Bloodwood - grey gum woodland on the edges of the Cumberland Plain, at site PS3 (Appendix 1)

- 1789 Smooth-barked Apple - Blackbutt - Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau.

In addition to these plant community types, observational records of *Pterostylis saxicola* with highly precise grid references from outside the study area were assigned to map units using the maps and classification system of Tozer *et al.* (2010). However, in order to produce a unified, internally consistent habitat model, a standard plant community classification system needs to be adopted, and I have chosen the Bionet Vegetation Classification because that is the system that has been used for detailed mapping of the study area. Consequently, the relevant map units of Tozer *et al.* (2010) were converted to their equivalents in the Bionet classification, as indicated in the references cited with each plant community type in Bionet, reproduced in table 1 below.

Map unit of Tozer *et al.* (2010)	Equivalent PCT in the Bionet vegetation classification
GW p2 Cumberland Shale Sandstone Transition Forest	1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain
GW p29 Cumberland Shale Plains Woodland	849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain
DSF p37 Kowmung-Wollondilly Grassy Gorge Woodland	870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges
DSF p131 Coastal Sandstone Ridgetop Woodland	1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux
DSF p142 Hinterland Sandstone Gully Forest	1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney
DSF p146 Sydney Hinterland Transition Woodland	1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain

Table 1. Equivalence of some map units of Tozer *et al.* (2010) with plant community types in the Bionet Vegetation Classification.

Some of these plant community types are not represented in the study area according to the vegetation maps produced for this project. Nevertheless, they need to be incorporated into any new general habitat model for *P. saxicola*.

I am not equipped to produce a bioclimatic envelope for *Pterostylis saxicola* but univariate mean monthly rainfall and temperature statistics for the distributional range of the species can be interpreted as indicating areas of potentially suitable habitat. Climatic statistics for weather stations within its distributional range (http://www.bom.gov.au/climate/data, accessed 7/8/2018) indicate that *P. saxicola* occurs in an area where mean annual rainfall varies between 700 and 1200 mm, average minimum temperatures for the coldest month vary from 1.7° to 5.1°, winter frosts are rare to frequent and where average maximum temperatures for the warmest month vary from 27.1° to 30.3°.

Pterostylis saxicola has mostly been recorded growing in intact native vegetation but there is one notable exception: a plant described in a “Car Park growing through bitumen”, adjacent to a large area of bushland from which other substantiated records had been made. Several others have come from small patches of remnant urban bushland, in some cases less than a hectare in area, surrounded by highly disturbed land, and from a long, narrow patch less than 50 m wide. However, no records mention heavily weed-infested habitats or evidence of heavy grazing introduced herbivores. Sites with significant edge effects are probably not sustainable reserves for conserving this species.

Given the significant discrepancies between the habitat model published in the threatened species profile for *Pterostylis saxicola* (NOEH 2018) and the characteristics of sites at which substantiated collections have been made, an improved habitat model is now required.

The following model incorporates habitat information associated with all of the records of *Pterostylis saxicola* from the Bionet Atlas, Atlas of Living Australia and specimen database of the National Herbarium of New South Wales (all accessed 26/7/2018).

Occurs on the Cumberland Plain along an ecological gradient from:

- Clay soils derived from Ashfield Shale (Wianamatta Group) on flat to gently hilly landscapes in PCT 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain;
- to: clay to sandy soils derived from Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition substrates on gently hilly landscapes, in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain;
- to: thin accumulations of humus-rich sandy soil on Hawkesbury Sandstone sheets and rock shelves, on the rims and steep sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, or PCT 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, or PCT 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, or PCT 1789 Smooth-barked Apple - Blackbutt - Red Bloodwood open forest in enriched sandstone gullies of the western Woronora plateau.

Also occurs outside the Cumberland Plain on Devonian slate, in PCT 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges.

3. Description of the study area

3.1 LAND USE HISTORY

The following account is based largely on information gathered from Liston (1988), except where otherwise stated. The first human inhabitants of the study area were Aborigines who moved there many thousands of years ago. People of the Dharawal group were occupants of the study area when Europeans first started to settle in the Sydney Region in 1788. These hunter-gatherers would have managed the grassy woodlands that grew on Wianamatta Shales of the area using fire-stick farming methods (Benson & Howell 1990). In 1816 a large group of them were massacred by soldiers at Appin and by 1830 their community life in the Campbelltown area had disintegrated.

In 1788, six months after Sydney was founded, two bulls and four cows escaped from Sydney Cove. European exploration of the study area commenced in 1795, when 61 naturalised descendants of those bulls and cows were discovered near Menangle, in an area that became known as “the Cowpastures”. Those cattle had discovered a plentiful source of fodder on the alluvial flats of the Nepean River and adjacent grassy woodlands on Wianamatta Shales, which also proved to offer more fertile farming land than sandy soils derived from Hawkesbury Sandstone. By the end of 1809, 34 settlers had been granted land at Minto and Glenfield for farming. Further land was granted to settlers at Appin in 1811, Macquarie Fields and Airds in 1816 and at Campbelltown in 1820. From then to the 1950s, land use in both growth areas was dominated by agriculture, which necessitated extensive clearing of native vegetation from the more fertile alluvial and clayey soils. Agricultural activities conducted in the areas have included the cultivation of wheat (which was curtailed in 1864 when the whole crop was destroyed by an infestation of rust disease) and other cereal crops, grazing of sheep, cattle and horses, intensive production of pigs and poultry, and the cultivation of fruit and vegetables. Campbelltown grew slowly as an urban centre during the 19th century and first half of the 20th century, but population growth accelerated after 1950 due to the rezoning of agricultural land for housing development in the northern part of the Macarthur Growth Area, electrification of the railway line as far south as Macarthur in 1963, the release of the Three Cities Plan (Campbelltown-Camden-Appin) in 1972 and subsequent construction of a number of large-scale housing commission projects from 1973 (figure 5).

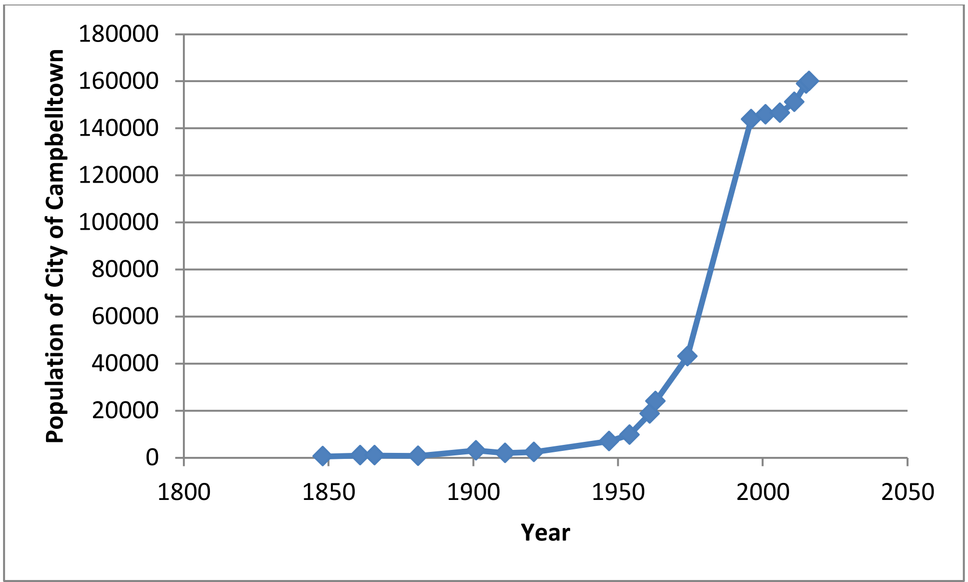

Figure 5. Population growth of Campbelltown, 1848-2016, assembled from data presented at https://www.campbelltown.nsw.gov.au/AboutCampbelltown/History/Campbelltowntimeline

Land use in the northern part of the Macarthur Growth Area is now dominated by residential housing, light industry and transport infrastructure, with only small pockets of pasture and urban bushland remaining intact, albeit weed-infested. In the southern half of the Macarthur Growth Area, south of the “waist” between Mt Annan and Glen Alpine, and in the Wilton Growth Area, land use is still largely rural, with the exception of limited residential and industrial development around Appin and Wilton. Agriculture has been largely restricted to soils derived from Wianamatta Shales and alluvium. Most areas of exposed Hawkesbury Sandstone either still support native vegetation or have been cleared for residential development.

3.2 HISTORY OF BOTANICAL EXPLORATION IN THE GROWTH AREAS

The first botanist to collect plant specimens in the same region as the growth areas was Joseph Banks’ employee, George Caley, who in 1802 made several expeditions from Prospect through the Cowpastures, reaching Mount Hunter, Menangle and Thirlmere Lakes (Webb 1995). Caley returned to the area in 1803, 1804 (during which he collected *Pterostylis saxicola* between Toongabbie and

South Creek), 1805 and 1807, once in the company of the great Scottish botanist Robert Brown. Caley mapped a section of Georges River near Ingleburn, following it to Appin, and explored the upper Nepean River system as far as Douglas Park and Appin Falls on the Cataract River (Webb 1995). On these trips, Caley and Brown made extensive botanical collections, from which Brown described numerous species that were new to science. The next botanical collector to visit the area was Franz Sieber, an Austrian who spent six months in the Sydney Region in 1823, during which time he collected specimens of 300 plant species (Ducker 1990), including many that are native to the study area. Botanical exploration of the area then became almost dormant until the late 19th century, when it intensified under the influence of J.H. Maiden, curator of the new Technological Museum, and later director of the Sydney Botanic Gardens. Botanists associated with Maiden, including R.T. Baker, J.L. Boorman, A.A. Hamilton, W.F. Blakely and E. Cheel made several thousand collections in the study area in the late 19th and early 20th centuries (National Herbarium of N.S.W. specimen database), long after much of the native vegetation on Wianamatta Shales and alluvia had been cleared for agriculture. Botanical exploration of the remnant vegetation of the study area has continued to the present day.

3.3 LANDSCAPE CONTEXT

The Greater Macarthur and Wilton Growth Areas are located on the southern to south eastern rim of the Cumberland Plain, the central part of the saucer-shaped sedimentary Sydney Basin. Here, the uppermost strata of the Sydney Basin, Cenozoic alluvia patchily overlie the Triassic Wianamatta Group rocks, mostly comprising Bringelly and Ashfield Shales, which, in turn overlie a thin layer of Mittagong Formation sandstone and shale and Triassic Hawkesbury Sandstone (Martyn 2018). Scattered small volcanic intrusions occasionally pierce the sedimentary strata, such as at Mt Annan, 0.7 km west of the "waist" in the middle of the Greater Macarthur Growth Area.

The most commonly exposed substrate in the northern part of the Greater Macarthur Growth Area is Ashfield Shale, over which patches of Bringelly Shale have been preserved on the western side, while Quaternary alluvia have accumulated in the valleys of Bow Bowing and Bunbury Curran Creeks (NSW Department of Minerals and Energy 1991, NSW Department of Mineral Resources 1985). Here, minor tributaries of the Georges River, such as Redfern, Smiths and McBarrons Creeks have exposed Hawkesbury Sandstone in narrow, shallow but steep-sided valleys.

In the southern half of the Greater Macarthur Growth Area, Bringelly Shale and Quaternary alluvium are restricted to the north west at Menangle Park. Further south, the Nepean and Georges Rivers and their tributaries have cut deep gorges through the Ashfield Shale, exposing large areas of Hawkesbury Sandstone on the steep valley sides and on the adjacent, flat to gently sloping valley borders. Large areas of transitional substrate exist here, where Ashfield Shale colluvium and soils derived from Mittagong Formation sandstones and shales thinly cover Hawkesbury Sandstone or mix with sandstone-derived soil. The landscape of the Wilton Growth Area resembles that of the southern half of the Greater Macarthur Growth Area but here the predominant substrate is Hawkesbury Sandstone over which an archipelago of thin islands of Ashfield Shale are preserved.

As the Greater Macarthur and Wilton Growth Areas are located on the southern to south eastern rim of the Cumberland Plain, they are gently tilted from south south west to north north east. However, topography also varies locally, with erosion having produced gently rolling landscapes over much of the area but steep-sided valleys contain the major water courses. The lowest point is in the far north east at Glenfield, where the banks of the Georges River are at 15 m altitude, but the land nearby rises to an altitude of 60 m at the junction of Campbelltown Road and Camden Valley Way. In the southern end of the Greater Macarthur Growth Area, just south east of Appin, the altitude reaches 260 m but drops to 230 m on the banks of the Georges River. The Wilton Growth Area varies in altitude from 105 m in the bottom of the Nepean Gorge to 310-320 m near its southern tip on the Picton Road.

Topographic variation as well as distance from the sea influences climate. The area just west of the Greater Macarthur Growth Area has the lowest average annual rainfall and the highest average January maximum temperature in the Sydney Region (Benson & Howell 1990). Both growth areas are subject to winter frosts.

3.4 NATIVE VEGETATION

In terms of the plant community types (PCTs) recognised in the Bionet Vegetation Classification and the vegetation maps that were prepared for this project, the remnant native vegetation of the growth areas consists of:

- 830 Forest Red Gum – Grey Box shrubby woodland on shale of the southern Cumberland Plain;
- 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain;
- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain;
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain;
- 883 Hard-leaved Scribbly Gum – Parramatta Red Gum heathy woodland of the Cumberland Plain;
- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain;
- 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney;
- 1292 Water Gum – Coachwood riparian scrub along sandstone streams;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain.

Plant community types 830, 849 and 850 occur on Wianamatta Shales, PCT 835 on quaternary alluvium, PCTs 883, 1081 and 1395 on Hawkesbury Sandstone under a thin layer of Ashfield Shale or shale colluvium and PCTs 1181 and 1292 on Hawkesbury Sandstone.

In the course of this project, I visited 19 sites in the field, 18 of which were either in, or adjacent to, the Growth Areas, 16 of which I characterised in detail (Appendix 1).

In the northern half of the Greater Macarthur Growth Area, native vegetation is restricted to small, mostly long, narrow patches of urban bushland, most of which line water courses. A few of these are conserved as council reserves. I visited four bushland remnants either in, or close to the northern part of the Greater Macarthur Growth Area (sites N1, N7, N13, N14, Appendix 1), two of which I characterised in detail (N1, N7). I found all of these to include substantial weed infestation, especially close to water courses. Two species of privet, *Ligustrum sinense* and *L. lucidum*, were the most common woody weeds growing on sandstone, while African Olive (*Olea europea* subsp. *cuspidata*) was common on Wianamatta Shales. Common herbaceous weeds included naturalised grasses, Bridal Creeper (*Asparagus asparagoides*) and, near watercourses, Wandering Jew (*Tradescantia fluminensis*). Dumped household and garden rubbish was common near road access points in most patches of remnant bushland.

In the southern half of the Greater Macarthur Growth Area, and in the Wilton Growth Area, patches of remnant native vegetation become progressively more plentiful, on larger blocks of land, as one moves south but they are still mostly associated with water courses. According to the vegetation maps that were prepared for this project, by far the most abundant plant community type here is PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain. This community type occurs on flat to gently sloping land, close to the interface between Ashfield Shale and Hawkesbury Sandstone, often adjacent to steep-sided sandstone gorges. Exposed sandstone surfaces are plentiful, with clayey to loamy soils derived from Ashfield Shale or shale colluvia occurring between rock outcrops and thin layers of humus rich sandy soil accumulating on flat sandstone surfaces, often colonised by mosses and lichens(e.g. site N9, figure 6).

Figure 6. Plant community type 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, on Ashfield shale colluvium over Hawkesbury Sandstone at Shingle Hill, Wilton (site N9, Appendix 1).

At one such site I found pre-flowering *Pterostylis* rosettes that closely resembled those of *P. saxicola* growing in a thin layer of dark brown sand on a sandstone shelf (figures 6 and 7).

Figure 7. Pre-flowering *Pterostylis* rosettes growing in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain at Shingle Hill, Wilton (site N3, Appendix 1).

Although almost all of PCT 1395 is coded as "intact" in the vegetation maps, I found the condition of these remnants variable, depending on the extent of grazing by stock to which they had been subjected. At one of my sites (site N3, Appendix 1), a shrub stratum was completely absent and all herbaceous plants had been grazed close to the ground (figure 8).

The sides of the gorges of the Nepean and Georges Rivers and their major tributaries are typically covered by PCT 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney (e.g. site N11, figure 9). In some places this forms a mosaic with PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain.

3.5 POTENTIAL HABITAT

The new, improved habitat model that I have developed for *Pterostylis saxicola* includes the following habitats that have been mapped in the study area:

- Clay soils derived from Ashfield Shale (Wianamatta Group) on flat to gently hilly landscapes in PCT 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain.

- Clay to sandy soils derived from Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition substrates on gently hilly landscapes, in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain.
- Thin accumulations of humus-rich sandy soil on Hawkesbury Sandstone sheets and rock shelves, on the rims and steep sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, PCT 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, and PCT 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney.

Figure 8. Heavily grazed understory vegetation in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain at Allen Creek, Wilton (site N3, Appendix 1).

4. Assessment of species presence and suitable habitat

4.1 SPECIES RECORDS AND HABITAT ASSESSMENTS

Pterostylis saxicola has only been recorded once in the study area, at Minto, in 1947. The precision of this record is questionable because collectors at that time usually specified their collecting locations no more precisely than as the nearest named place. “Minto” could have meant “East Minto”, which, after 1973 became known as Minto Heights, most of which is outside the study area.

Figure 9. PCT 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, east of Appin (site N12, Appendix 1).

However, *Pterostylis saxicola* has been collected or observed at several sites within 1 km of the eastern side of the Greater Macarthur Growth Area and at one site between the growth areas, within 1 km of the north eastern corner of the Wilton Growth Area and within 2 km of the south western corner of the Greater Macarthur Growth Area. No formal habitat assessment has ever been conducted in the study area.

4.2 PRIOR SPECIES SURVEYS

No formal, targeted surveys had been conducted for *Pterostylis saxicola* specifically in the study area prior to the start of this project, although Teresa James surveyed known sites of occurrence in 2007. Floristic surveys were undertaken in the study area from November 2017 to May 2018, starting at the tail end of the flowering period of *P. saxicola,* proceeding through its dormancy period, during which it persists as a subterranean tuber, to the time when plants would probably have been visible as newly emerged, pre-flowering rosettes. Only in the first two to four weeks of the survey period would plants of *P. saxicola* have been morphologically identifiable, so survey effort for this species in this project has been negligible.

4.3 ASSESSMENT OF SPECIES PRESENCE

Pterostylis saxicola is highly likely to be growing, unrecorded, in both the Greater Macarthur Growth Area and the Wilton Growth Area.

4.4 JUSTIFICATION FOR DETERMINATION

Evidence and arguments against the hypothesis that *Pterostylis saxicola* is, or once was native to the study area

Pterostylis saxicola has been recorded only once, dubiously, in the study area despite a 210 year history of botanical exploration there. This species, like most orchids, is highly reliant on associated, highly specialised symbionts for germination and pollination, so even if all other habitat variables were suitable for its growth and reproduction in the study area, it could not reproduce sustainably there if either of those symbionts were absent. Perhaps *P. saxicola* has only been recorded once in the study area because one or both of its obligate symbionts is absent there.

Evidence and arguments for the hypothesis that *Pterostylis saxicola* is native to the study area

Pterostylis saxicola has been recorded outside the study area in four plant community types (PCTs 849, 1081, 1181 and 1395) that occur in the study area, some abundantly. At each of those recorded sites the substrates mapped there by geologists (Ashfield Shale, Mittagong Formation shales and sandstones, Hawkesbury Sandstone and transitions between them) are substrates that occur in the study area. Indeed, Ashfield Shale and Hawkesbury Sandstone are the two most abundant substrates there. The whole of the study area also seems to be climatically suitable for *P. saxicola*. Its highest point, less than 320 metres in altitude, at the southern tip of the Wilton Growth Area, is comfortably within the species' altitudinal range of 30-400 metres. One has to conclude that extensive suitable habitat for *P. saxicola* occurs in the study area.

It is reasonable, however, to ask why the species has not been collected more often there. To address this question, a histogram of records over time is instructive (see figure 10, below).

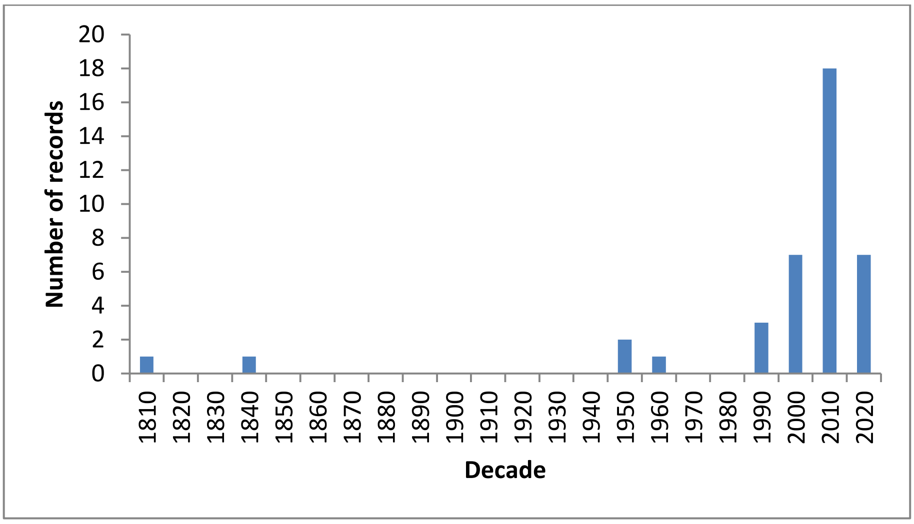

Figure 10. Histogram of the number of observational records and collections of *Pterostylis saxicola* per decade since 1800.

From 1804 to 1989, *Pterostylis saxicola* was recorded only six times. In 1997 it was recognised as specifically distinct, named and described. Botanists, conservation biologists, ecologists and orchid enthusiasts suddenly became interested in it. The collection of specimens and observations accelerated, encouraged by funding for rare plant surveys and an *ex-situ* conservation project. Most of this activity was concentrated on publicly accessible land, which accounted for 19 of the 26 records made since 1997, 18 of which were additional records from previously recorded sites. Most exploratory effort expended on *P. saxicola* was being put into detailed surveys of known populations. New populations were still being discovered as incidental benefits of other botanical work, not as the result of targeted searches in previously unexplored areas. The dearth of new records from the southern part of the study area was probably due to a lack of searches there. Absence of evidence is not necessarily evidence of absence.

Targeted exploration of new territory for previously unknown populations of *Pterostylis saxicola* would, in any case be a potentially frustrating task. This orchid is sporadically distributed, not continuously spread through its habitat. It is also difficult to find, even at locations at which it is relatively common: the plants are small, cryptically coloured, and only recognisable for a period of six weeks or less while flowering. Moreover, most of the potential habitat in the study area is on private land, much of which is inaccessible because the landowners have not given permission for biodiversity surveyors to work on their land.

4.5 LIKELIHOOD OF SPECIES PRESENCE

Figures 10 and 11 show frequency histograms of populations of *Pterostylis saxicola* from the Bionet Wildlife Atlas and state herbarium's specimen database, categorised in latitudinal and longitudinal samples 0.05 degrees wide. Populations are here defined as records, or clusters of records separated by at least 1 km. These diagrams display two perspectives of the spatial relationship between the study area and distribution and abundance of known populations of *P. saxicola*. The bimodal clustering of populations into northern and southern sub-populations is clear in the latitudinal

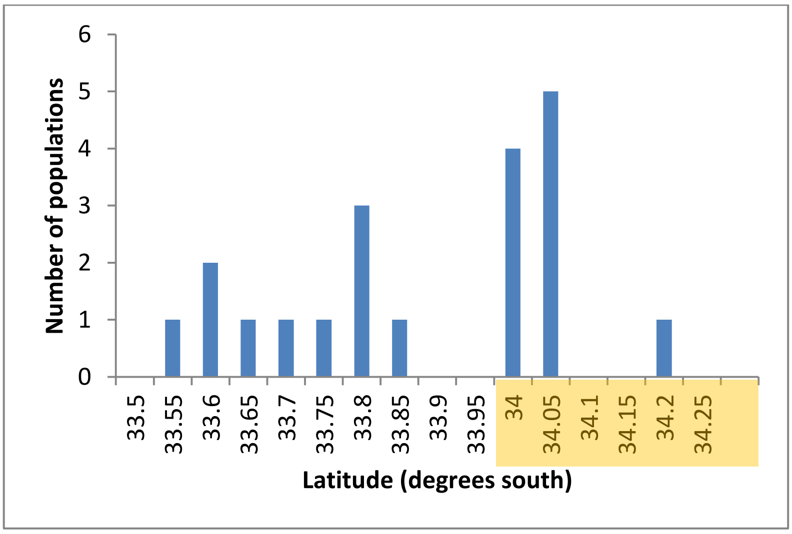

Figure 11. Frequency histogram of populations of *Pterostylis saxicola* from the Bionet Wildlife Atlas and state herbarium specimen database, classified according to latitude. The orange rectangle indicates the latitudinal extent of the study area.

distribution. The longitudinal distribution of records more closely approximates the typical Gaussian curve of many species distributions (Brown 1984). The study area is nested within the longitudinal distribution of the species and extensively overlaps the latitudinal one, despite the existence of only one dubious record from there.

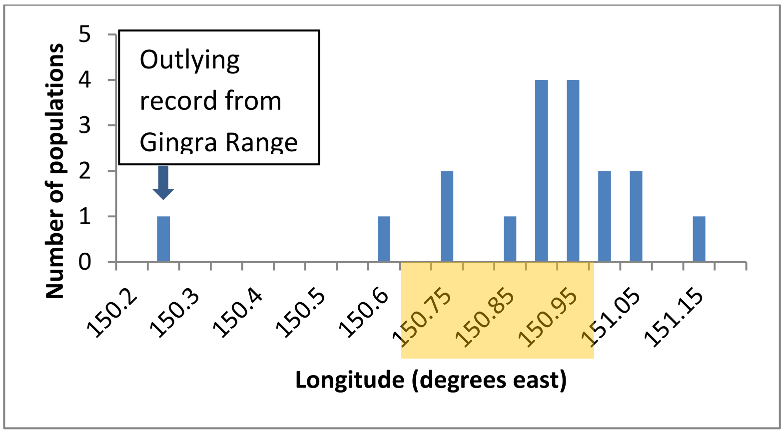

Figure 12. Frequency histogram of populations of *Pterostylis saxicola* from the Bionet Wildlife Atlas and state herbarium specimen database, classified according to longitude. The orange rectangle indicates the longitudinal extent of the study area.

If we accept the simplifying assumption that population frequencies are unbiased, then these frequency distributions can be interpreted as probability distributions, suggesting that *Pterostylis saxicola* is highly likely to be native to the study area.

4.6 ASSESSMENT OF SUITABLE HABITAT

Pterostylis saxicola has been recorded from outside the study area in four plant community types (PCTs 849, 1081, 1181 and 1395) that also occur in the study area (see sections 2.4, 3.3, 3.4, 4.4 above). These communities in the study area occur on suitable substrates (Hawkesbury Sandstone, Mittagong Formation, Ashfield Shale – see sections 3.3, 3.4), so the full extent of these plant community types should be regarded as potential ly suitable habitat for *P. saxicola* there.

Four classes of vegetation condition, were mapped for this project: “intact”, “thinned”, “scattered trees”, and “native grassland”. Having seen sites in the study area representing all of these categories I would describe them as follows:

- Intact: native vegetation structure, composition and regenerative capacity remain intact, sometimes with disturbance or thinning of the understorey and usually with weed incursion in the northern part of Greater Macarthur Growth Area;
- Thinned: the structure of native vegetation has been altered, with the canopy reduced in density and the understorey dominated by herbaceous plants;
- Scattered trees: Most canopy trees and most or all shrubs have been removed so that the structure, composition and regenerative capacity of the native vegetation have been significantly altered by land use;

- Native grassland: native vegetation has been altered so profoundly that only native grasses remain, usually intermixed with exotic species.

Although some of the patches of bushland in which *P. saxicola* has been recorded are smaller than one hectare, all but one record were reported in intact vegetation. The one exception is an extraordinary, unvouchered record of this species at the “Car Park growing through bitumen Simmos Beach Reserve, Macquarie Fields”. A bitumen carpark is not a sustainable habitat for any native ground orchid but in this case a flat bitumen surface covered in a thin layer of soil might have functionally approximated a sandstone surface covered in a thin layer of humic sand for long enough for a seed to germinate, reach reproductive maturity and flower. Some species of terrestrial orchids, most notably some species of *Microtis*, can reasonably be described as weedy, readily colonising some anthropogenic habitats, but I would not include any species of *Pterostylis* in that category. I have seen some of the vegetatively multiplying species, such as *P. curta* and *P. nutans*, persisting at the margins of mown lawns but I have never seen any species of *Pterostylis* subgenus *Oligochaetochilus* growing in highly disturbed environments. *P. saxicola* has not been recorded from pastures that are largely or totally devoid of trees and shrubs, so vegetation classed as “scattered trees” and “native grassland” can be rejected as suitable habitat.

The modified eucalypt-dominated communities classed as “thinned” are the only disturbed environments that could arguably be classed as marginally suitable habitats for *Pterostylis saxicola*. An argument justifying the inclusion of thinned vegetation in an estimate of potentially suitable habitat is that such modified vegetation is capable of regenerating to the equivalent of intact condition, if the processes that caused its degradation cease to operate. Those processes include the selective culling of native plants. If thinned vegetation is managed so that regrowth of native plants is not suppressed and introduced weeds are actively removed, then suitable habitat for *P. saxicola* could be re-created from thinned vegetation. A good example of an area that has such a history and now provides suitable habitat for *P. saxicola* is Scheyville National Park, which was used for grazing and farming from the early 19th century to 1940, after which it was used as a military training base and later for a large migrants’ hostel (NSW National Parks and Wildlife Service 2000). After 1972 the vegetation there was fortuitously allowed to regenerate spontaneously and much of it now has the character of residual, intact native vegetation and hosts arguably the most significant population of *P. saxicola* in the northern Cumberland Plain. If patches of thinned land that had previously supported PCTs 849, 1081, 1181 and 1395) in the study area were appropriately managed, then a similar outcome is likely to prevail there too.

However, eucalypt forests and woodlands have often been thinned in the study area to facilitate grazing by non-native herbivores: cattle, sheep and horses (see section 3.1). Grazing by stock is one of the threats listed in the threatened species profile of *P. saxicola* (NOEH 2018), because most terrestrial orchids, including *Pterostylis* are highly palatable. Duncan *et al.* (2005), in discussing threats to threatened terrestrial orchid species in Victoria, considered grazing of terrestrial orchids by introduced mammal species to be potentially “devastating”. Clearly, intact vegetation usually provides a much more suitable habitat for *P. saxicola* than similar but thinned vegetation. At issue is whether thinned, continually grazed vegetation provides any suitable habitat for the sustained existence of *P. saxicola* at all. Given that *P. saxicola* has not been reported from thinned vegetation (as distinct from highly fragmented remnants of intact vegetation), and that regeneration of thinned vegetation to intact condition would require active management if the land were embedded within a suburban context, I conclude that thinned vegetation does not presently constitute suitable habitat for the sustained existence of *P. saxicola*. It could, however, be regenerated to provide suitable habitat under sustained appropriate land management. Consequently, I have treated only intact patches of PCTs 849, 1081, 1181 and 1395 as suitable habitat for *P. saxicola*.

4.7 SPECIES POLYGONS

My species polygons for *Pterostylis saxicola* (figures 13 and 14) include all intact patches of PCTs 849, 1081, 1181 and 1395 in the Greater Macarthur and Wilton Growth Areas. They were prepared with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by Biosis Pty Ltd. A shape file for these polygons is held by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment.

My arguments justifying these polygons have been set out in sections 2.3, 2.4, 4.4, 4.5 and 4.6.

4.8 ESTIMATE OF AREA OF HABITAT

The areas estimated to represent suitable habitat for *Pterostylis saxicola* in figures 13 to 15 are as follows:

- Greater Macarthur Growth Area
    - Habitat mapped – 1,784.36 ha
    - Habitat impacted by development footprint – 46.51 ha
- Wilton Growth Area
    - Habitat mapped – 962.15 ha
    - Habitat impacted by development footprint – 38.92 ha

These estimates were calculated with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by Biosis Pty Ltd. My arguments justifying the polygons from which these estimates were calculated have been set out in sections 2.3, 2.4, 4.4, 4.5 and 4.6.

5. Information used in the assessment

My assessment was based on information obtained from a diversity of sources:

- Databases of observational and vouchered specimen records of *Pterostylis saxicola*:
    - National Herbarium of New South Wales specimen database;
    - Bionet Wildlfie Atlas;

- Interviews with collectors, observers, propagators and scientists of *P. saxicola* (see section 6, acknowledgements);
- Fieldwork at 19 sites (see Appendix 1):
    - Five sites at which *P. saxicola* had previously been collected;
    - 14 sites in or near the study area that had potentially suitable habitat;
- The scientific and scholarly literature (see section 7, references);
- Vegetation maps for the study area prepared by Biosis Pty Ltd, provided by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment;
- My personal knowledge and experience, gained from 47 years as a native orchid enthusiast and 40 years as a professional botanist.

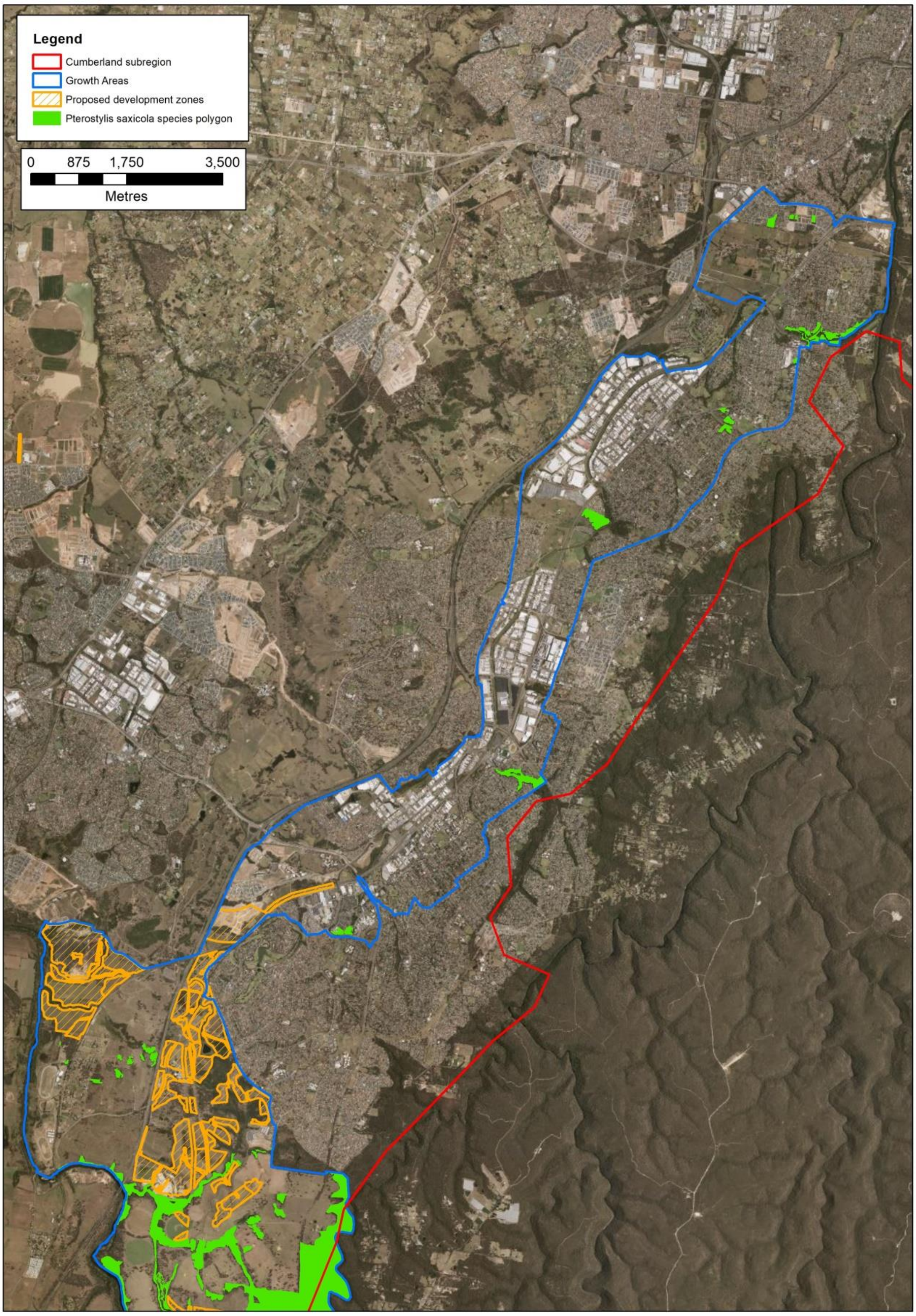

Figure 13. Species polygons for *Pterostylis saxicola* (green colouring) in the northern part of the Greater Macarthur Growth Area (outline in blue). The urban development footprint is marked with yellow cross-hatching.

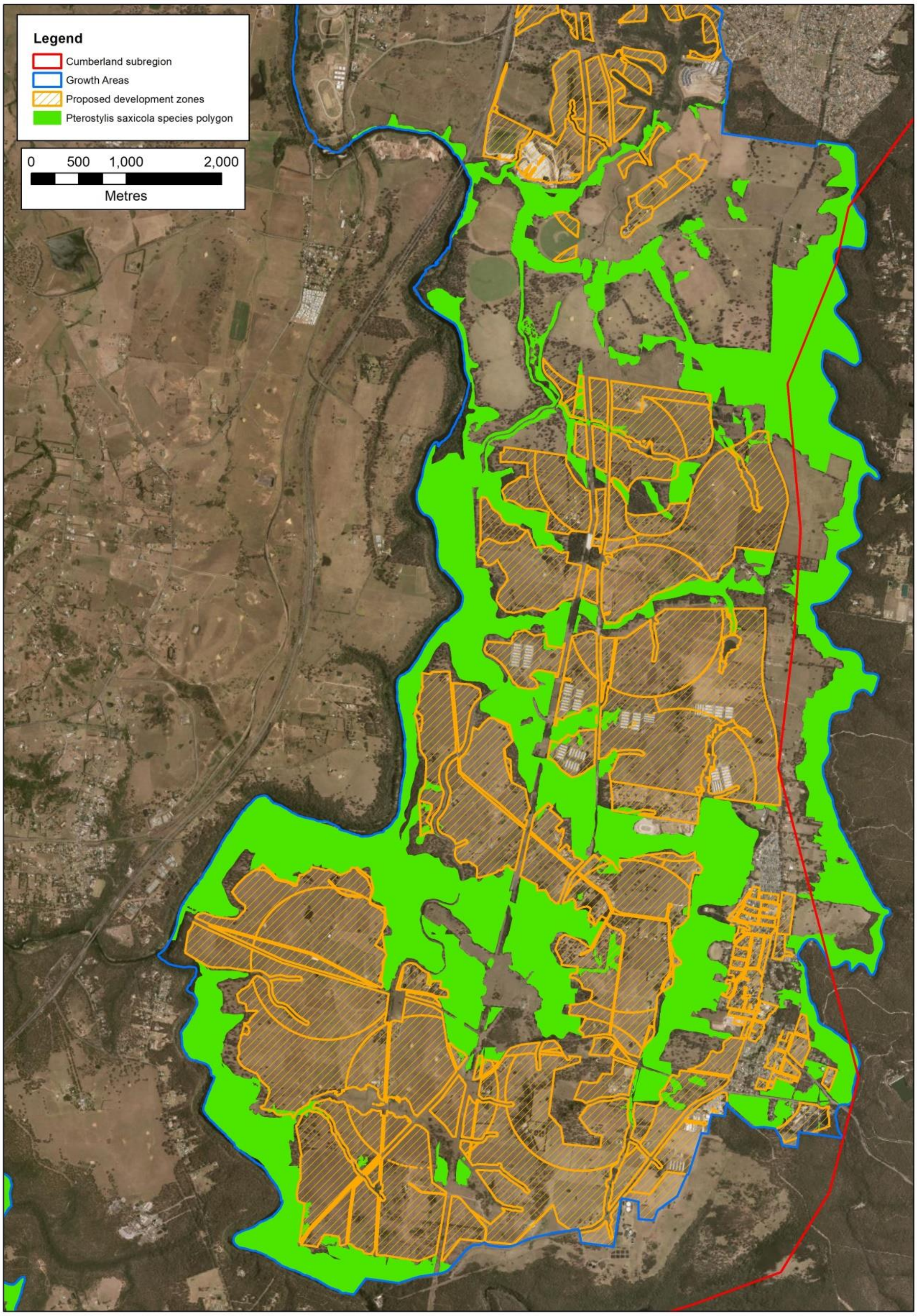

Figure 14. Species polygons for *Pterostylis saxicola* (green colouring) in the southern part of the Greater Macarthur Growth Area (outline in blue). The urban development footprint is marked with yellow cross-hatching.

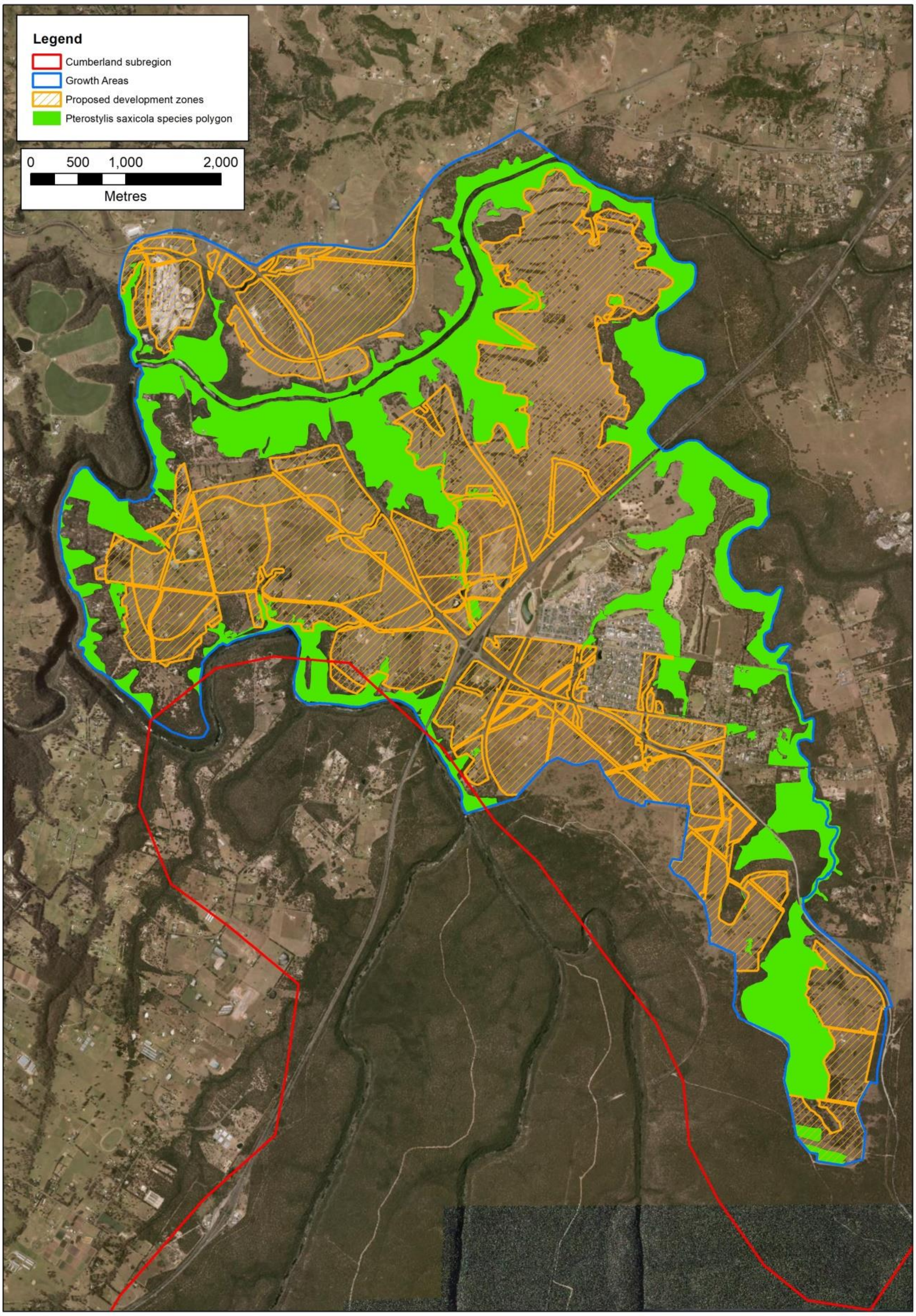

Figure 15. Species polygons for *Pterostylis saxicola* (green colouring) in the Wilton Growth Area (outline in blue). The urban development footprint is marked with yellow cross-hatching.

6. Acknowledgements

I am grateful to Andrew Orme, Teresa James, Karen Sommerville, Greg Steenbeeke, Wayne Cherry and David Keith, for happily being interviewed, and for generously sharing their knowledge about populations of *Pterostylis saxicola*. Wayne Cherry gave me permission to use his photograph of a flower of *Pterostylis saxicola* on the title page of this report. Darren James (DAJ Environmental), kindly assisted me in producing species polygons and area estimates using the ArcMap software package.

7. References

Benson D (1992) The natural vegetation of the Penrith 1:100,000 map sheet. *Cunninghamia* 2: 541-596.

Benson D, Howell J (1990) 'Taken for Granted: The Bushland of Sydney and its Suburbs'. Kangaroo Press, Kenthurst, NSW, Australia.

Brown JH (1984) On the relationship between abundance and distribution of species. *American Naturalist* 124: 255-279.

Ducker SC (1990) Early Austrian influence on Australian botany. Pp. 297-304 in Short PS (ed) 'History of Systematic Botany in Australasia'. Australian Systematic Botany Society, Melbourne

Duncan M, Pritchard A, Coates F (2005) Major threats to endangered orchids of Victoria. *Selbyana* 26: 189-195.

Jones DL (2006) 'A Complete Guide to Native Orchids of Australia Including the Island Territories'. New Holland, Sydney, Australia.

Jones DL, Clements MA (1997) Characterisation of *Pterostylis gibbosa* and description of *Pterostylis saxicola*. *The Orchadian* 12: 128-136, 144.

Keith DA (2004) 'Ocean Shores to Desert Dunes: The Native Vegetation of New South Wales and the ACT'. N.S.W. Department of Environment and Conservation, Sydney, NSW, Australia.

Kuiter RH, Findlater-Smith MJ (2017) 'Overview of *Pterostylis* Pollination (Orchidaceae) in Victoria'. Aquatic Photographics, Seaford, Victoria, Australia.

Liston C (1988) 'Campbelltown, the Bicentennial History'. Allen & Unwin, North Sydney, NSW, Australia.

Martyn J (2018) 'Rocks and Trees: A Photographic Journey Through the Rich and Varied Geology, Scenery and Flora of the Sydney Region'. STEP Inc, Turramurra, NSW, Australia.

NSW Department of Minerals and Energy (1991) 'Penrith 100K Geological Sheet 9035'. Sydney, NSW, Australia.

NSW Department of Mineral Resources (1985) 'Wollongong-Port Hacking 100K Geological Sheet 9029-9129'. Sydney, NSW, Australia.

NSW National Parks and Wildlife Service (2000) 'Scheyville National Park and Pitt Town Nature Reserve Plan of Management'. Sydney, NSW, Australia.

NSW Office of Environment and Heritage (2018) Sydney Plains Greenhood – profile. http://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10705 (accessed 25 July 2018).

Phillips RD, Scaccabarozzi D, Retter BA, Hayes C, Brown GR, Dixon KW, Peakall R (2013) Caught in the act: pollination of sexually deceptive trap-flowers by fungus gnats in *Pterostylis* (Orchidaceae). *Annals of Botany* 113: 629–641.

Rasmussen HN (1995) "Terrestrial Orchids: From Seed to Mycotrophic Plant". Cambridge University Press, Cambridge, UK.

Sommerville KD, Siemon JP, Wood CB, Offord CA (2008) Simultaneous encapsulation of seed and mycorrhizal fungi for long-term storage and propagation of terrestrial orchids. *Australian Journal of Botany* 56: 609–615.

Tozer MG, Turner K, Keith DA, Tindall D, Pennay C, Simpson C, MacKenzie B, Beukers P, Cox S (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Warcup JH (1990) Mycorrhiza. Pp. 21–26 in Bates RJ, Weber JZ (eds) 'Orchids of South Australia'. Flora and Fauna of South Australia Handbook Committee, Adelaide, SA, Australia.

Webb JB (1995) 'George Caley: Nineteenth Century Naturalist: a Biography'. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

Weston PH, Perkins AJ, Indsto JO, Clements MA (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier R, Bernhardt P (eds) 'Darwin's Orchids: Then and Now'. University of Chicago Press, Chicago, Ill, USA.

Weston PH, Perkins AJ, Entwisle TJ (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15.

8. Appendices

APPENDIX 1: Characterisation of habitat at selected sites

The tables on following pages record data that I collected at sites both within and outside the study area. Two of these sites (N13, N14) received “over the fence” assessments and were not characterised in detail. Each site that was characterised in detail was centred either on an arbitrarily selected plant of *Pterostylis saxicola* (sites numbered PS1, PS3) or at places where the focal species had previously been reported (sites PS2, PS4, PS5) or at an arbitrarily point in the case of sites examined as potential habitat in or near the growth areas (sites N1–N14). At each site the precise latitude and longitude, altitude, substrate, soil description, slope and aspect were also recorded. Also, at each site all woody plant species and a few species of herbaceous plants that could be reliably identified from vegetative characters were recorded within a radius of 30 metres. Attributes of sites at which *P. saxicola* had been found (sites PS1–PS5) were compared with comparable attributes of sites in or near the growth areas to assess whether any sites in the growth areas closely matched *P. saxicola* sites. Locations at which *Pterostylis saxicola* has been recorded by me and/or others have had their latitudes and longitudes transformed to the nearest 10 minutes.

Site	Location	Latitude	Longitude	Altitude	substrate
PS1	Old Schofield Trail, Scheyville National Park	33°40'S	150°50'E	70 m	Ashfield Shale
PS2	Simmos Beach Recreation Reserve, Macquarie Fields	34°00'S	150°50'E	45 m	Hawkesbury Sandstone
PS3	Simmos Beach Recreation Reserve, Macquarie Fields	34°00'S	150°50'E	43 m	Hawkesbury Sandstone
PS4	Boronia Rd Reserve, Peter Meadows Creek, Kentlyn	34°00'S	150°50'E	98 m	Hawkesbury Sandstone
PS5	Amberdale Reserve, Picnic Point	34°00'S	151°00'E	36 m	Hawkesbury Sandstone
N1	Smiths Creek, Leumeah	34°03'22.6"S	150°50'24.3"E	87 m	Hawkesbury Sandstone
N2	Douglas Park bridge, Nepean River	34°11'32.5"S	150°42'48.6"E	110 m	Hawkesbury Sandstone
N3	Allens Creek, Wilton site 1	34°12'36.7"S	150°41'15.4"E	157 m	Hawkesbury Sandstone
N4	Allens Creek, Wilton site 2	34°12'25.7"S	150°41'17.9"E	201 m	Hawkesbury Sandstone
N5	Allens Creek, Wilton site 3	34°12'25.2"S	150°41'23.5"E	140 m	Hawkesbury Sandstone
N6	Ouesdale Creek, Appin	34°11'30.1"S	150°46'53.5"E	215 m	Hawkesbury Sandstone
N7	Noorumba Reserve, Rosemeadow	34°06'49.3"S	150°47'27.2"E	139 m	Ashfield Shale
N8	Shingle Hill, site 1	34°12'26.8"S	150°38'50.5"E	145 m	Hawkesbury Sandstone
N9	Shingle Hill, site 2	34°12'26.8"S	150°38'50.5"E	144 m	Hawkesbury Sandstone
N10	Shingle Hill, site 3	34°12'35.3"S	150°38'54.1"E	160 m	Mittagong Formation
N11	Georges River, Appin site 1	34°12'27.4"S	150°47'50.9"E	268 m	Hawkesbury Sandstone
N12	Georges River, Appin site 2	34°12'18.4"S	150°47'50.5"E	260 m	Hawkesbury Sandstone
N13	Bicentennary Reserve, Minto	34°00'49.7"S	150°51'11.5"E	30 m	Ashfield Shale
N14	Bunbury Curran Reserve, Macquarie Fields	33°59'00.2"S	150°53'51.7"E	20 m	Hawkesbury Sandstone

Appendix 1a: Environmental data for sites visited as part of this study (continued on next page)

Site	soil description	slope	Aspect	Vegetation structure (canopy)	Vegetation structure (understory)
PS1	brown clay-loam	5°	S	Dry sclerophyll forest	moderately dense shrubby understory
PS2	brown sand	0°		Dry sclerophyll woodland	moderately dense shrubby understory
PS3	dark brown humus-rich sand	0-5°	N	Dry sclerophyll woodland	moderately dense shrubby understory
PS4	dark brown humus-rich sand	0-5°	N	Dry sclerophyll woodland	moderately dense shrubby understory, dense subcanopy
PS5	dark brown humus-rich sand	<5°	E	Dry sclerophyll woodland	moderately dense shrubby understory, dense subcanopy
N1	black sand	0°		Disturbed dry sclerophyll forest	moderately dense shrubby understory
N2	black sand	0-20°	SW	Dry sclerophyll forest	sparse shrubby understory
N3	brown sandy loam	0°		Heavily grazed dry sclerophyll forest	no shrub layer
N4	brown sandy loam	0°		Heavily grazed dry sclerophyll forest	mosaic of shrubby thickets and clear ground
N5	pale grey-brown sand	5-30°	SE	Dry sclerophyll forest	moderately dense shrubby understory
N6	brown sandy loam	5-15°	SSW	Dry sclerophyll forest	mosaic of dense to moderately dense shrubby thickets
N7	red-brown clay	0°		Dry sclerophyll forest	moderately dense shrubby understory
N8	dark brown humus-rich sand	<5°	N	Dry sclerophyll woodland	sparse to dense shrubby understory
N9	dark brown humus-rich sand	<5°	W	Dry sclerophyll woodland	sparse to moderately dense shrubby understory
N10	brown loam	<5°	N	Dry sclerophyll forest	dense shrubby understory
N11	dark brown humus-rich sand	0°		Dry sclerophyll forest	sparse to moderately dense shrubby understory
N12	dark brown humus-rich sand	0°		Dry sclerophyll forest	sparse to moderately dense shrubby understory
N13					
N14					

Appendix 1a (continued): Environmental data for sites visited as part of this study

Sites >

Associated species	PS1	PS2	PS3	PS4	PS5	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Acacia binervata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Acacia binervia	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Acacia implexa	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	1	1
Acacia mearnsii	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Acacia suaveolens	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Acacia terminalis	0	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
Acacia ulicifolia	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0
Acrotriche divaricata	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0
Actinotus helianthi	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	0	0	0	1	1	0	1	0	1	1	1	0	1	1	1	1	1
Allocasuarina torulosa	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Angophora bakeri	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Angophora costata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Astroloma pinifolium	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Astrotricha latifolia	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0
Backhousia myrtifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Banksia serrata	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Banksia spinulosa	0	1	1	1	1	0	1	0	1	0	0	0	1	1	0	1	1
Beyeria viscosa	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0
Billardiera scandens	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Bossiaea obcordata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Brachyloma daphnoides	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b: Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	PS1	PS2	PS3	PS4	PS5	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Breynia oblongifolia	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bursaria spinosa	1	0	0	0	0	1	1	0	0	1	0	1	0	1	1	0	0
Ceratopetalum gummiferum	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1
Correa reflexa	0	0	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0
Corymbia gummifera	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	1	1
Crowea exalata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Cryptandra spinescens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Dampiera stricta	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Dampiera purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Daviesia corymbosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Daviesia ulicifolia	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dillwynia acicularis	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Dillwynia sieberi	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea triquetra	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
Elaeocarpus reticulatus	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Eremophila debilis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Eucalyptus crebra	1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	0	0
Eucalyptus fibrosa	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Eucalyptus globoidea	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eucalyptus moluccana	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Eucalyptus paniculata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eucalyptus pilularis	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0
Eucalyptus piperita	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	PS1	PS2	PS3	PS4	PS5	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Eucalyptus punctata	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1
Eucalyptus sclerophylla	0	1	1	1	0	0	1	0	0	0	0	0	1	0	0	1	1
Eucalyptus sieberi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Eucalyptus sparsifolia	0	1	0	0	0	0	1	1	1	1	0	0	0	1	1	0	1
Exocarpos cupressiformis	1	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0
Exocarpos strictus	0	0	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1
Gompholobium grandiflorum	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodenia hederacea	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Grevillea arenaria	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Grevillea diffusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Grevillea sericea	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Grevillea sphacelata	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea laevipes	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0
Hakea sericea	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0
Hardenbergia violacea	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hibbertia aspera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Hovea linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Hovea purpurea	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Isopogon anemonifolius	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1
Jacksonia scoparia	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Kunzea ambigua	0	1	1	1	1	1	1	0	1	1	1	0	0	1	1	0	0
Lambertia formosa	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Lasiopetalum ferrugineum subsp. *cordatum*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	PS1	PS2	PS3	PS4	PS5	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Lasiopetalum ferrugineum subsp. *ferrugineum*	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Leptospermum parvifolium	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum polygalifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Leptospermum trinervium	0	1	1	1	1	0	1	0	0	1	0	0	1	1	1	1	1
Leucopogon ericoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Leucopogon juniperinus	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Leucopogon virgatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Lissanthe strigosa	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
Lomandra longifolia	0	0	0	0	1	1	0	0	0	1	1	0	0	1	0	1	0
Lomandra obliqua	0	1	1	1	1	0	1	0	0	0	0	0	0	1	0	0	0
Lomatia silaifolia	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Macrozamia spiralis	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca decora	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Melaleuca linearifolia	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Melaleuca nodosa	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Monotoca scoparia	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Myrsine variabilis	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
Notelaea longifolia	0	0	0	0	1	1	1	0	1	1	0	0	1	1	1	0	0
Olearia viscidula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Ozothamnus diosmifolius	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patersonia glabrata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Persoonia lanceolata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Persoonia levis	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Persoonia linearis	0	0	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	PS1	PS2	PS3	PS4	PS5	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
Persoonia pinifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Petrophile sessilis	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1
Pimelea linifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pittosporum revolutum	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pittosporum undulatum	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0
Platysace linearifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Podolobium ilicifolium	0	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0
Polyscias sambucifolia	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pteridium esculentum	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Ricinocarpos pinifolius	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Stenocarpus salignus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Stylidium laricifolium	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Stypandra glauca	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Styphelia laeta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Syncarpia glomulifera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Westringia longifolia	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
Xanthorrhoea concava	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea media	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1
Xanthosia pilosa	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Xylomelum pyriforme	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Zieria compacta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Zieria cytisoides	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study

APPENDIX 2: PETER WESTON'S CURRICULUM VITAE

Personal details

Name: Peter Henry Weston.

Address: 18 Lyle Avenue, Lindfield, New South Wales 2070, Australia.

Date and place of birth: 22 October 1956, Lower Hutt, New Zealand.

Nationality: Australian.

Academic Qualifications

i) **B.Sc.** (first class honours; equal first in order of merit) School of Biological Sciences, University of Sydney; 1975-78, conferred 7 April 1979.
Thesis title: "The evolution and classification of *Boronia* Sm."

ii) **Ph.D.**, School of Biological Sciences, University of Sydney, 1979-83; conferred 18 May 1985.
Thesis title: "Systematics and biogeography of the Persooniinae (Proteaceae)".

Awards, Fellowships and Scholarships

2014	Nancy Burbidge Medal (awarded by the Australasian Systematic Botany Society to a person who has made a longstanding and significant contribution to Australasian systematic botany. It is the foremost award that can be conferred by ASBS).
2014	Australian Biological Resources Study-sponsored Winston Churchill Fellowship for an established career researcher in taxonomy.
2009	Grady L. Webster Structural Botany Publication Award for 2008 and 2009 from the Botanical Society of America. The BSA component of the award (it is awarded in alternate years by the BSA and the American Society of Plant Taxonomists) recognizes the most outstanding paper published in the *American Journal of Botany* in the field of structural and developmental botany (i.e., anatomy and morphology) over a two-year period. It was awarded to Gregory J. Jordan, Peter H. Weston, Raymond J. Carpenter, Rebecca A. Dillon and Timothy J. Brodribb for: "The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae," American Journal of Botany, Volume 95, Issue 5; May 2008.
2006	Carrick Award for Australian University Teaching from the Australian Learning and Teaching Council (one of five members of a teaching team from the University of New England cited for Outstanding Contributions to Student Learning).
1992-93	Posting to Royal Botanic Gardens, Kew, as Australian Botanical Liaison Officer.

1982	Charles Gilbert Heydon Travelling Fellowship for the biological sciences (not taken up).
1980-82	University of Sydney Postgraduate Scholarship.
1979-82	Commonwealth Postgraduate Award.
1977	G.S. Caird Scholarship for Third Year Botany, University of Sydney.
1976	Slade Prize for Practical Plant Biology, University of Sydney.

Employment

Present Position: Honorary Research Associate, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney and independent botanical consultant.

Previous positions held:
2008-2016 Senior Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

2000-2008 Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1994-2000 Senior Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1989-1994 Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1982-1989 Scientific Officer, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1979-82 Part-time demonstrator, School of Biological Sciences, University of Sydney.

Adjunct and visiting university appointments

2013-	Adjunct Associate Professor, La Trobe University.
2011-	Adjunct Associate Professor, University of New South Wales.
2006	Visiting Lecturer, Rhodes University, Grahamstown, South Africa.
2004-2009	Adjunct Associate Professor, University of New England.
2000-2004	Adjunct Senior Lecturer, University of New England.

Administrative/management experience

2009	Acting Manager Plant Diversity
2002-2003	Member, Plant Diversity Research Program Leaders Committee
1998-99	Systematics Liaison Officer
1997-98	Member RBGS Market testing working party

1997 Member, RBGS advisory committee for restructuring senior management

1990-91 Systematics Co-ordinator

1996-98 Member, RBGS Joint Consultative Committee

Membership of Learned Societies

1996- Society of Australian Systematic Biologists

1984- Willi Hennig Society (Elected Fellow, 1992-, Council member, 1998-2000)

1979- Society of Systematic Biologists (member, Editorial Board 1993-95)

1978- Australasian Systematic Botany Society (formerly Australian Systematic Botany Society: President, 2009-2012, Vice President, 2008-2009, Chairman, Hansjörg Eichler Research Fund Committee, 1998-2002, Council member, 1996-2002)

Membership of External Committees

2015- Financial Grants Standing Committee (formerly the Grants Policy Standing Committee) of the Australasian Systematic Botany Society

2012-2013 Conference Organising Committee of *Systematics Without Borders*, a joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney (Chairman)

2011- Editorial Board, *Phytotaxa*

2008-2009 Corresponding Member, Editorial Advisory Committee, *Australian Systematic Botany*

2006-2014 Ira Butler Memorial Trophy Committee (a joint committee of the Australasian Native Orchid Society and the Orchid Society of New South Wales) (Chairman)

2004- Editorial Advisory Board, *Kew Bulletin*

2001-2006 Panel of Judges, Eureka Prize for Biodiversity Research

2000-2012 Bushland Management Advisory Committee, Lane Cove Council (Chairman, 2008-2010)

1999-2004 Editorial Advisory Committee, *Australian Systematic Botany*

Spoken presentations at conferences (not including presentations delivered by others)

2015 Building Our Botanical Capital, annual conference of the Australasian Systematic Botany Society: “A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution”.

2014 Next Generation Systematics, annual conference of the Australasian Systematic Botany Society: Nancy Burbidge Memorial Lecture: “Problems and progress in plant systematics since Nancy Burbidge”

2013 Genetics Society of Australasia conference, Sydney *Genetics in the Harbour City*: “Molecular phylogeny of the subtribe

Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2013 Joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, Sydney, *Systematics Without Borders*: "Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2012 Australasian Systematic Botany Society conference, Perth, *Local knowledge, global delivery*: "Contested, Uncontested and Potentially Controversial Taxonomic Changes in the Proteaceae: How Do They Differ?"

2011 37th annual conference of the South African Association of Botanists, *Plants in a Changing World* and 9th conference of the South African Society of Systematic Biologists, *Biodiversity Matters*; plenary address: "Cenozoic environmental change and the systematics of southern hemisphere plants"

2011 XVIII International Botanical Congress, Melbourne: "Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations".

2010 VI Southern Connection Congress, Bariloche: "Cladistic biogeography, molecular dating, fossils and the Proteaceae"

2010 VI Southern Connection Congress, Bariloche: "Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests"

2010 Australian Systematic Botany Society conference *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*; Keynote address: "Cenozoic environmental change and the systematics of southern hemisphere plants"

1999 XVI International Botanical Congress, Saint Louis: "Historical biogeography of Proteaceae".

1997 II Southern Connection Congress, Valdivia: "Cladistic biogeography of a key woody group: Proteaceae".

1997 First Biennial International Conference of the Systematic Association, Oxford: "Rolf Sattler's Plant Morphology and Cladistic Analysis".

1996 *An International Symposium on the Biology of Proteaceae*, Melbourne: "ITS squence variation in the Proteaceae and what it tells us about phylogeny".

1993 Joint conference of The Systematics Associations and The Linnean Society on *Models in Phylogeny Reconstruction*, London: "Direct methods for polarising character transformation series".

1990 IXth meeting of the Willi Hennig Society, Canberra: "Transoceanic cladistic patterns in the Proteaceae".

2003 The Third International Conference on *the Comparative Biology of the Monocotyledons*, Ontario: "Co-evolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators".

2005 XVII International Botanical Congress, Vienna: “Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae)”.
2006 Australian Systematic Botany Society conference, Cairns, *Plant Diversity in the Tropics*: “A new suprageneric classification of the Proteaceae”.
2007 5th Southern Connection Congress, Adelaide: “‘I’m not dead yet’ – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation)”.
1989 Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney: “Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae”.
1988 Symposium on *Panbiogeography of New Zealand*, Wellington: “Problems with the statistical testing of panbiogeographic hypotheses”.
1985 Australian Flora Foundation Symposium on *Waratahs*, Canberra: “Drifting waratahs or continents?”
1984 Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra: “A reappraisal of Nelson's direct method of character analysis”.

Refereeing manuscripts, grant applications, reports and examining postgraduate theses (last five years)

2016: *Australian Systematic Botany*; *Botanical Journal of the Linnean Society*, *National Research Foundation* (South Africa).
2015: *American Journal of Botany*; Australian Research Council (4); *Australian Systematic Botany*; *Muelleria*; *Nuytsia*; *Phytotaxa*; *PLOS One*; *Telopea* (6).
2014: Australian Research Council (3); *Australian Systematic Botany* (2); *Cunninghamia*; *Journal of Biogeography* (2); *Muelleria*; National Research Foundation (South Africa); *Orchadian*; *Perspectives in Plant Ecology, Evolution and Systematics*; *Plant Systematics and Evolution*; *Telopea* (3).
2013: Australian Research Council; *Australian Systematic Botany*; *Biology Letters*; *Cladistics*; *Diversity and Distributions*; *Evolution*; *Journal of Biogeography*; *New Zealand Journal of Botany*; *Taxon*; *Telopea*.
2012: Australian Research Council (3); *Australian Systematic Botany*; “Darwin, Then and Now” (chapter of book published by University of Chicago Press); *Diversity and Distributions*; *Journal of Biogeography*; National Research Foundation (South Africa); *Phytokeys*.

Research

My research has been in the theoretical and practical aspects of systematic botany, with emphasis on the theory and practice of phylogenetic analysis, and the broader uses to which phylogenetic knowledge may be applied. I have phylogenetically analysed groups in the plant families Proteaceae, Fabaceae, Orchidaceae, Rutaceae, Winteraceae and Lauraceae, contributed to more general analyses of angiosperm phylogeny, and used the results of these analyses to improve biological classification and to test theories of historical biogeography, trait evolution, co-evolution and adaptation. I have earned an international reputation for my contributions to both theoretical and empirical developments in this field.

Herbarium curation and collections

My curatorial responsibilities at the National Herbarium of New South Wales have included the families Rutaceae (1982-1998), Proteaceae (1982-2016), Orchidaceae (1986-2016) and Fabaceae subfamily Faboideae (1986-2016). I have collected plant specimens (mostly angiosperms) in Australia, England, New Zealand, New Caledonia, Chile, South Africa, and Argentina, mostly for the herbarium and living collections of the Royal Botanic Gardens and Domain Trust, Sydney. Duplicates of my collections have been distributed to over 20 herbaria in 8 different countries.

Teaching

I have been actively involved in the preparation and teaching of four third year undergraduate courses in biosystematics:
Western Sydney University (2015-2017): “Principles of Evolution” (unit 300980), “Botany” (unit 300836).
University of New South Wales (2010-2016): “Assembling the Tree of Life” (BIOS3221)
University of New England (2000-2010): Biosystematics (Biosyst 301, Biosyst 302, Evol 301/501).
Botany Department, Rhodes University, Grahamstown, South Africa (February-March 2006): “Plant Biodiversity” course in collaboration with Associate Professor Nigel Barker.

I am currently co-supervising one postgraduate student:
Nanette Thomas (Ph.D., University of New England): Systematics of *Tasmannia* informs Biogeography of Winteraceae.

Postgraduate and honours students I have previously co-supervised include:
Margaret Stimpson (Ph.D., University of New England): Systematics, evolution and ecology of the *Banksia spinulosa* complex (graduated 2017).
Melita Milner (Ph.D., Australian National University): Phylogeography of *Lomatia and Telopea* (Proteaceae) in south eastern Australia (graduated 2015).
Samanta Oon (B.Sc. Honours, University of New South Wales): *Lomatia* likes it both ways: rampant bidirectional introgression of chloroplast genomes between two morphologically distinct species of Lomatia (Proteaceae) (graduated 2015).
Zoe Reynolds (B.Sc. Honours, Australian National University): Phylogenetic, taxonomic and functional turnover in Proteaceae assemblages (graduated 2013).
Emma McIntosh (B.Sc. Honours, University of Sydney): Hybridization and introgression between *Lomatia myricoides* and *L. silaifolia* (Proteaceae) (graduated 2011).
Margaret Stimpson (M.Sc.Stud., University of New England): Review of the *Banksia spinulosa* species complex (Proteaceae) (graduated 2011).

James Indsto (M.Sc., University of Wollongong): Pollination Ecology and Molecular Systematics of *Diuris* (Orchidaceae) of the Sydney Region (graduated 2010).
Nanette Thomas (Grad.Dip.Sci., University of New England): Phylogenetic analysis of Winteraceae (graduated 2009).
David McKenna (Ph.D., University of Wollongong: Demographic and ecological indicators for rarity in obligate-seeding *Persoonia* (Proteaceae) shrubs of the Sydney region, graduated 2007).
Paul Rymer (Ph.D., University of Wollongong: Plant rarity: species distributional patterns, population genetics, pollination biology and seed dispersal in *Persoonia* (Proteaceae), graduated, 2006).
Georgina Lloyd (B.Sc. Honours, University of Sydney: Pseudocopulation in two species of *Cryptostylis*: Implications for maintaining species integrity, graduated 2004)
Andrew Perkins (Ph.D., University of Sydney: Phylogenetic Systematics of the Genus *Calochilus* (Orchidaceae), graduated 2002).
Jim Mant (Ph.D., Australian National University: Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae), graduated 2002).
Siegfried Krauss (Ph.D., University of Wollongong: Systematic pattern and evolutionary process in the complex species *Persoonia mollis* (Proteaceae), graduated 1995).

I have examined 14 honours and postgraduate theses:
Australian National University (Ph.D., 2003, 2007, 2008)
University of Melbourne (Ph.D., 1995, 2011)
University of Newcastle (M.Phil., 2003)
University of Queensland (Ph.D., 2003)
University of Sydney (Ph.D., 1991, 1994, 1997, 2009)
University of Wollongong (B.Sc. Hons., 2001, 2003)
Victoria University (Ph.D., 2007)

Competitive Research and Infrastructure Grants

Peakall, R., Pichersky, E., Linde, C., Weston, P.H. (2015-2019) The biosynthesis and evolution of novel semiochemicals in orchids. $644,800, Australian Research Council Discovery Grant DP150102762.

Hoebee, S.E., Weston, P.H., & Edwards, T.J. (2015-18) Evolution in action or the demise of iconic Australian flora? $217,700, Australian Research Council Discovery Grant DP150100508.

He, T., Lamont, B., Weston, P.H., & Cowling, R. (2012-2014) Origin and evolution of plant functional traits in relation to fire. $310,000, Australian Research Council Discovery Grant DP120103389.

Rossetto, M., Crayn, D.M. & Weston, P.H. (2008-2010) Integrating molecular and morphological data for generic delimitation and species identification in Lauraceae. $73,333, Australian Biological Resources Study.

Cantrill, D., Murphy, D. & Weston, P.H. (2008-10) Understanding the origins of the Australian flora by integrating molecular phylogenies and fossil data in the Proteaceae. $88,900, Hermon Slade Foundation.

Rossetto, M. & Weston, P.H. (2007-2009) Speciation in the Australian flora: testing explanatory hypotheses in waratahs and their allies. $78,000, Hermon Slade Foundation.

Considine, J.A., Krauss, S.L. & Weston, P.H. (2002-2004) A biological basis for the efficient breeding of native plants for export markets: a case study with the Australian Goodeniaceae. $168,126, ARC – Linkage (Krauss and Weston representing industry partners)

Whelan, R.J., Ayre, D.J., England, P., Auld, T.D., & Weston, P.H. (2000-2002) Ecology and genetics of fire-sensitive *Persoonia* species: threatened species recovery and management. $126,480, Australian Research Council (ARC– SPIRT, Auld and Weston representing industry partners).

Trent, R. *et al.* (2000) Enhancement of DNA sequencing equipment for the Sydney University and Prince Alfred Molecular Analysis Centre. $600,000, Australian Research Council (ARC-REIF).

Weston, P.H. (1999-2001) Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae). $75,000, Hermon Slade Foundation.

Weston, P.H. (1997-2000) Taxonomic revision of *Dillwynia* (Fabaceae: Faboideae: Mirbelieae). $62,836, Australian Biological Resources Study.

Weston, P.H. & Thomson, J.A. (1993) A molecular approach to the evolution and biogeography of the Queensland tree waratahs. $4000, Queensland Wet Tropics Management Authority

Weston, P.H. & Thomson, J.A. (1991-92) A molecular approach to the evolution and biogeography of the waratahs. $80,100, Australian Research Council (large grants scheme).

Weston, P.H. (1984) Establishment of a data bank for eucalypt specimens held by NSW. $20,000, Australian Biological Resources Study.

Scientific Publications

[the numbers in square brackets following a reference indicates: 1. the journal's 2016-17 impact factor according to ISI Web of Knowledge, then the number of literature citations for the paper found by Google Scholar, as of 23 May 2018]

H-index = 32, total number of citations = 3831 as of 24 May 2018

1. Craw, R.C. & **Weston, P.H.** (1984) Panbiogeography: a progressive research program? *Systematic Zoology* 33: 1-13. [8.917, 90]

2. **Weston, P.H.**, Carolin, R.C., & Armstrong, J.A. (1984) A cladistic analysis of *Boronia* Sm. and *Boronella* Baill. (Rutaceae). *Australian Journal of Botany* 32: 187-203. [0.793, 48]

3. Morrison, D.A. & **Weston, P.H.** (1985) Analysis of morphological variation in a field sample of *Caladenia catenata* (Smith) Druce (Orchidaceae). *Australian Journal of Botany* 33: 185-195. [0.793, 11]

4. Crisp, M.D. & **Weston, P.H.** (1987a) Waratahs - how many species? Pp. 3-15, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 13]

5. Crisp, M.D. & **Weston, P.H.** (1987b) Cladistics and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae. Pp. 65-130, in C.H. Stirton (ed.) *Advances in Legume Systematics Part 3* (Royal Botanic Gardens: Kew). [-, 126]

6. **Weston, P.H.** (1987) *Persoonia* (Proteaceae). Pp. 348-350, in N.G. Marchant *et al*. (eds.) *Flora of the Perth Region* (Western Australian Herbarium: Perth). [-, 0]

7. **Weston, P.H.** & Crisp, M.D. (1987) Evolution and biogeography of the Waratahs. Pp. 17-34, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 14]

8. **Weston, P.H.**, Wilson, P.G., & Hill, K.D. (1987) Identification of *Cannabis*. *Department of Agriculture New South Wales Miscellaneous Bulletin* 25: 148-150. [-, 0]

9. **Weston, P.H.** (1988a) A revision of *Hicksbeachia* (Proteaceae). *Telopea* 3: 231-239. [0.6, 3]

10. **Weston, P.H.** (1988b) Indirect and direct methods in systematics. Pp. 27-56, in C.J. Humphries (ed.) *Ontogeny and Systematics* (Columbia Univ. Press: New York). [-, 75]

11. **Weston, P.H.** (1989) Problems with the statistical testing of panbiogeographic hypotheses. *New Zealand Journal of Zoology* 16: 511. [0.811, 6]

12. **Weston, P.H.** (1990) Notes on *Boronia* (Rutaceae) in New South Wales, including descriptions of three new species. *Telopea* 4: 121-128. [0.6, 6]

13. **Weston, P.H.** & Johnson, L.A.S. (1991) Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales. *Telopea* 4: 269-306. [0.6, 9]

14. Crisp, M.D. & **Weston, P.H.** (1991) *Almaleea*, a new genus of Fabaceae from south-eastern Australia. *Telopea* 4: 307-311. [0.6, 10]

15. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae), a new genus from New Guinea and eastern Australia. *Telopea* 4: 497-507. [0.6, 12]

16. **Weston, P.H.** (1991) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium*, *Pultenaea* and *Dillwynia* (Fabaceae). Pp. 2-19, 452-455, 456-461, 481-497, 499-504, in G. Harden (ed.) *Flora of New South Wales* vol. 2 (New South Wales Univ. Press: Sydney). [-, 0]

17. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae) and *Almaleea* (Fabaceae). Pp. 29-30, 497-498, in G. Harden (ed.) *op. cit.* [-, 0]

18. **Weston, P.H.** & Porteners, M.F. (1991) *Boronia*, *Eriostemon* and *Phebalium* (Rutaceae). Pp. 227-236, 250-254, 255-263, in G. Harden (ed.) *op. cit.* [-, 0]

19. Porteners, M.F. & **Weston, P.H.** (1991) *Correa* and *Crowea* (Rutaceae). Pp. 247-249, 254-255, in G. Harden (ed.) *op. cit.* [-, 0]

20. Crisp, M.D. & **Weston, P.H.** (1991) *Telopea*. Pp. 30-31, in G. Harden (ed.) *op. cit.* [0.6, 0]

21. Gross, C.L. & **Weston, P.H.** (1992) *Macadamia jansenii* (Proteaceae), a new species from central Queensland. *Australian Systematic Botany* 5: 725-28. [0.75, 7]

22. Crisp, M.D. & **Weston, P.H.** (1993) Geographic and ontogenetic variation in morphology of Australian waratahs (*Telopea*: Proteaceae). *Systematic Biology* 42: 49-76. [14.387, 74]

23. Gilmore, S., **Weston, P.H.**, & Thomson, J.A. (1993) A simple, rapid, inexpensive and widely applicable technique for purifying plant DNA. *Australian Systematic Botany* 6: 139-148. [0.75, 38]

24. **Weston, P.H.** (1993) Key to genera, *Cyrtostylis*, *Cryptostylis*, *Zeuxine*, *Cheirostylis*, *Pseudovanilla*, *Erythrorchis*, *Epipogium*, *Gastrodia*, *Oberonia*, *Liparis*, *Dendrobium*, *Calanthe*, *Phaius*, *Geodorum*, *Dipodium*, *Cymbidium*, *Sarcochilus*, *Rhinerrhiza*, *Peristeranthus*, *Papillilabium*, *Schistotylus*, *Plectorrhiza*, *Taeniophyllum* (Orchidaceae). Pp. 134-138, 218-219, 219-221, 221-233, 236-247, in G. Harden (ed.) *Flora of New South Wales* vol. 4 (New South Wales Univ. Press: Sydney). [-, 0]

25. **Weston, P.H.** & Hill, K.D. (1993) *Bulbophyllum* (Orchidaceae). Pp. 233-236, in G. Harden (ed.) *op. cit.* [-, 0]

26. **Weston, P.H.** & Crisp, M.D. (1994) Cladistic biogeography of Waratahs and their allies (Embothrieae: Proteaceae) across the Pacific. *Australian Systematic Botany* 7: 225-249. [0.75, 72]

27. **Weston, P.H.** (1994) The Western Australian species of subtribe Persooniinae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 6: 51-165. [0.6, 17]

28. **Weston, P.H.** & Johnson, L.A.S. (1994) Three new species of *Persoonia* (Proteaceae) from Queensland. *Telopea* 6: 31-37. [0.6, 1]

29. **Weston, P.H.** (1994) Methods for rooting cladistic trees. Pp. 125-155, in D.J. Siebert, R.W. Scotland and D.M. Williams (eds.) *Models in Phylogeny Reconstruction* (Oxford Univ. Press: Oxford). [-, 36]

30. Crisp, M.D. & **Weston, P.H.** (1995) Mirbelieae. Pp. 245-282, in J.J. Doyle and M.D. Crisp (eds.) *Advances in Legume Systematics Part 7: Phylogeny* (Royal Botanic Gardens: Kew). [-, 36]

31. Crisp, M.D. & **Weston, P.H.** (1995) Subtribe Embothriinae (Proteaceae). *Flora of Australia* 16: 382-390. [-, 0]

32. Crisp, M.D., Linder, H.P. & **Weston, P.H.** (1995) Cladistic biogeography of plants in Australia and New Guinea: congruent pattern reveals two endemic tropical tracks. *Systematic Biology* 44: 457-473. [8.917, 119]

33. Thomson, J.A., **Weston, P.H.** & Tan, M.K. (1995) A molecular approach to tracing the major lineages in *Pteridium*. Pp. 21-28, in R.T. Smith and J.A. Taylor (eds.) *Bracken: an Environmental Issue* (University of Leeds: Leeds). [-, 13]

34. **Weston, P.H.** (1995) Key to the genera of Proteaceae in Australia, Subfamily Persoonioideae, Subfamily Bellendenoideae, Subtribe Gevuininae, Subtribe Hicksbeachiinae. *Flora of Australia* 16: 41-46, 47-125, 125-127, 409-410. [-, 0]

35. Bernhardt, P. & **Weston, P.H.** (1996) The pollination ecology of *Persoonia* (Proteaceae) in eastern Australia. *Telopea* 6: 775-804. [0.6, 46]

36. **Weston, P.H.** & Crisp, M.D. (1996) Trans-Pacific biogeographic patterns in the Proteaceae. Pp. 215-232, in A. Keast & S.E. Miller (eds.) *The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Processes* (SPB Academic Publishing: Amsterdam). [-, 34]

37. **Weston, P.H.** & Johnson, L.A.S. (1997) *Persoonia hindii* (Proteaceae), a new species from the Newnes Plateau, New South Wales. *Telopea* 7: 199-203. [0.6, 5]

38. Jobson, P.C. & **Weston, P.H.** (1998) *Dillwynia glaucula* (Fabaceae: Mirbelieae), a new species from the Southern Tablelands, New South Wales. *Telopea* 8: 1-5. [0.6, 1]

39. **Weston, P.H.** (1999) *Persoonia pauciflora* (Proteaceae), a new species from the Hunter Valley, New South Wales. *Telopea* 8: 159-164. [0.6, 4]

40. Crisp, M.D., Gilmore, S.R. & **Weston, P.H.** (1999) The phylogenetic relationships of two anomalous species of *Pultenaea* (Fabaceae: Mirbelieae) from molecular and morphological data, and description of a new genus. *Taxon* 48: 701-714. [2.447, 19]

41. Jobson, P.C. & **Weston, P.H.** (1999) Two new species of *Dillwynia* (Fabaceae: Mirbelieae), from the Southern Tablelands of New South Wales. *Telopea* 8: 363-369. [0.6, 0]

42. Thomson, J.A., **Weston, P.H.** and Tan, M.K. (1999) A molecular approach to tracing major lineages in *Pteridium*: update and amendment. Pp. 35-36 in J.A. Taylor & R.T. Smith (eds.) *Bracken Fern: Toxicity, Biology and Control* (International Bracken Group: Aberystwyth). [-, 1]

43. **Weston, P.H.** (2000) Process morphology from a cladistic perspective. Pp. 124-144 in R. Scotland & T. Pennington (eds.) *Homology and Systematics: Coding Characters for Phylogenetic Analysis* (Taylor & Francis: Basingstoke). [-, 25]

44. Indsto, J. & **Weston, P.H.** (2000) Near-ultraviolet reflectance in *Dendrobium* (Orchidaceae). Pp. 326-334 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 5]

45. Kores, P.J., **Weston, P.H.**, Molvray, M., & Chase, M.W. (2000) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 449-456 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 60]

46. Savolainen, V., Fay, M.F., Albach, D.C., Backlund, A., van der Bank, M., Cameron, K.M., Johnson, S.A., Lledo, M.D., Pintaud, J.-C., Powell, M., Sheahan, M.C., Soltis, D.E., Soltis, P.S., **Weston, P.H.**, Whitten, W.M., Wurdack, K.J., & Chase, M.W., (2000) Phylogeny of the eudicots: a nearly complete familial analysis based on *rbc*L gene sequences. *Kew Bulletin* 55: 257-309. [0.577, 451]

47. Crisp, M.D. & **Weston, P.H.** (2000) *Telopea* (Proteaceae) Pp. 115-117 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

48. **Weston, P.H.** (2000) *Persoonia* (Proteaceae) Pp. 89-105 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

49. **Weston, P.H.** & Crisp, M.D. (2000) *Alloxylon* (Proteaceae) P. 115 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

50. Hill, R.S. & **Weston, P.H.** (2001) Southern (austral) ecosystems. Pp. 361-370 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* vol. 5 (Academic Press: San Diego). [-, 1]

51. Kores, P.J., Molvray, M., **Weston, P.H.**, Hopper, S.D., Brown, A., Cameron, K.M., and Chase, M.W (2001) A phylogenetic analysis of Diurideae (Orchidaceae) based on plastid DNA sequence data. *American Journal of Botany* 88: 1903-1914. [3.05, 129]

52. Jobson, P.C. & **Weston, P.H.** (2001) *Dillwynia rupestris* (Fabaceae: Mirbelieae), a new species from the New England Tableland of New South Wales. *Telopea* 9: 323-327. [0.6, 0]

53. Barker, N.P., **Weston, P.H.**, Rourke, J.P., & Reeves, G. (2002) The relationships of the southern African Proteaceae as elucidated by internal transcribed spacer (ITS) DNA sequence data. *Kew Bulletin* 57: 867-883. [0.577, 32]

54. Mant, J.G., Schiestl, F.P., Peakall, R., & **Weston, P.H.** (2002) A phylogenetic study of pollinator conservatism among sexually deceptive orchids. *Evolution* 56: 888-898. [4.201, 92]

55. **Weston, P.H.** (2002) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium* (Fabaceae), Pp. 3-20, 622-632 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

56. **Weston, P.H.** & Duretto, M.F. (2002) *Boronia* (Rutaceae). Pp. 265-276 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 3]

57. **Weston, P.H.** & Harden, G.J. (2002) *Correa, Philotheca*, *Eriostemon, Crowea, Phebalium, Nematolepis*, *Leionema* (Rutaceae) Pp. 289-310, in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 4]

58. **Weston, P.H.** & Jobson, P.C. (2002) *Dillwynia* (Fabaceae). Pp. 542-549 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

59. **Weston, P.H.** & de Kok, R. (2002) *Pultenaea* (Fabaceae). Pp. 549-565 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 1]

60. **Weston, P.H.** & Kooyman, R.M. (2002) Systematics of *Eidothea* (Proteaceae), with the description of a new species, *E. hardeniana*, from the Nightcap Range, north-eastern New South Wales. *Telopea* 9: 821-832. [0.6, 15]

61. Bernhardt, P., Sage, T., **Weston, P.H.**, Azuma, H., Lam, M., Thien, L.B., & Bruhl, J. (2003) The pollination of *Trimenia moorei* (Trimeniaceae): floral volatiles, insect/wind pollen vectors, and stigmatic self-incompatibility in a basal angiosperm. *Annals of Botany* 92: 445-458. [4.041, 81]

62. Qiu, H. & **Weston, P.H.** (2003) Proteaceae. *Flora of China* 5: 192-199 (Science Press: Beijing and Missouri Botanical Garden Press: St Louis). [-, 0]

63. Thien, L.B., Sage, T.L., Jaffré, T., Bernhardt, P., Pontieri, V., **Weston, P.H.**, Malloch, D., Azuma, H., Graham, S.W., McPherson, M.A., Rai, H.S., Sage, R.F., & Duprey, J.-L. (2003) The population structure and floral biology of *Amborella trichopoda* Baillon (Amborellaceae). *Annals of the Missouri Botanical Garden* 90: 466-490. [2.838, 71]

64. Mill, R.R. & **Weston, P.** (2004). Proposals to reject the names *Polypodiopsis* and *Polypodiopsis muelleri* (*Plantae vasculares, incertae sedis*). *Taxon* 53: 203-205. [2.447, 2]

65. **Weston, P.H.** (2004) Proteaceae. Pp. 313-316 in N. Smith, S.A. Mori, A. Henderson, D.W. Stevenson & S.V. Heald (eds.) *Flowering Plants of the Neotropics* (The New York Botanical Garden and Princeton University Press: Princeton). [-, 0]

66. **Weston, P.H.** & Turton, M. (2004) *Phebalium bifidum* (Rutaceae), a new species from the Capertee Valley, New South Wales. *Telopea* 19: 787–792. [0.6, 2]

67. Entwisle, T.J. & **Weston, P.H.** (2005) Majority rules, when systematists disagree. *Australian Systematic Botany* 18: 1–6. [0.75, 28]

68. Indsto, J.O., **Weston, P.H.**, Clements, M.A. & Whelan, R.J. (2005) Highly sensitive DNA fingerprinting of orchid pollinia remnants using AFLP. *Australian Systematic Botany* 18: 207–213. [0.75, 9]

69. Jordan, G.J., Dillon, R.A. & **Weston, P.H.** (2005) Solar radiation as a factor in the evolution of scleromorphic leaf anatomy in Proteaceae. *American Journal of Botany* 92: 789–796. [3.05, 92]

70. Kurzweil, H., **Weston, P.H.** & Perkins, A.J. (2005) Morphological and ontogenetic studies on the gynostemium of some Australian members of Diurideae and Cranichideae (Orchidaceae). *Telopea* 11: 11–33. [0.6, 9]

71. Mant, J., Bower, C.C., **Weston, P.H.** & Peakall, R. (2005) Phylogeography of pollinator-specific sexually deceptive *Chiloglottis* taxa (Orchidaceae): evidence for sympatric divergence? *Molecular Ecology* 14: 3067–3076. [6.086, 27]

72. Mant, J., Peakall, R. & **Weston, P.H.** (2005) Specific pollinator attraction and the diversification of sexually deceptive *Chiloglottis* (Orchidaceae). *Plant Systematics and Evolution* 253: 185–200. [1.239, 33]

73. Mant, J., Brown, G.R. & **Weston, P.H.** (2005) Opportunistic pollinator shifts among sexually deceptive orchids indicated by a phylogeny of pollinating and non-pollinating thynnine wasps (Tiphiidae). *Biological Journal of the Linnean Society* 86: 381–395. [2.288, 16]

74. Rymer, P.D., Whelan, R.J., Ayre, D.J. & **Weston, P.H.** (2005) Reproductive success and pollinator effectiveness differ in common and rare *Persoonia* species (Proteaceae). *Biological Conservation* 123: 521–532. [4.022, 50]

75. **Weston, P.H.**, Perkins, A.J., & Entwisle, T.J. (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15. [-, 30]

76. **Weston, P.H.** & Barker, N.P. (2006) A new suprageneric classification of the Proteaceae, with an annotated checklist of genera. *Telopea* 11(3): 314-344. [0.6, 81]

77. Indsto, J.O., **Weston, P.H.**, Clements, M.A., Dyer, A.G., Batley, M. & Whelan, R.J. (2006) Pollination of *Diuris maculata* (Orchidaceae) by male *Trichocolletes venustus* bees. *Australian Journal of Botany* 54: 669-679. [0.793, 35]

78. **Weston, P.H.** (2007) Proteaceae. Pp. 364-404 in K. Kubitzki (ed.) *Families and Genera of Vascular Plants* Volume IX (Springer Verlag: Berlin). [-, 26]

79. **Weston, P.H.** (2007) Proteaceae. Pp. 268-269 in V.H. Heywood, R.K. Brummitt, A. Culham & O. Seberg (eds.) *Flowering Plant Families of the World* (Royal Botanic Gardens, Kew: London). [-, 0]

80. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2007) Floral phyllotaxis and floral architecture in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 168: 285–306. [1.748, 33]

81. Indsto, J.O., **Weston, P.H.**, Clements, M., Dyer, A., Batley, M. & Whelan, R. (2007) Generalised pollination of *Diuris alba* R.Br. (Orchidaceae) by small bees and wasps. *Australian Journal of Botany* 55: 628-634. [0.793, 15]

82. Barker, N.P., **Weston, P.H.**, Rutschmann, F. & Sauquet, H. (2007) Molecular dating of the “Gondwanan” plant family Proteaceae is only partially congruent with the timing of Gondwanan break-up. *Journal of Biogeography* 34: 2012-2027. [4.248, 157]

83. Jordan, G.J., **Weston, P.H.**, Carpenter, R.J., Dillon, R.A. & Brodribb, T.J. (2008) The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae. *American Journal of Botany* 95:521-530. [3.05, 74]

84. Mast, A.R., Willis, C.L., Jones, E.H., Downs, K.M., & **Weston, P.H.** (2008) A smaller *Macadamia* from a more vagile tribe: Inference of phylogenetic relationships and divergence times in *Macadamia* and relatives (tribe Macadamieae; Proteaceae). *American Journal of Botany* 95: 843-870. [3.05, 53]

85. Sauquet, H., **Weston, P.H.**, Anderson, C.L., Barker, N.P. Cantrill, D.J., Mast, A.R., & Savolainen, V. (2009) Contrasted patterns of hyperdiversification in Mediterranean hotspots. *Proceedings of the National Academy of Sciences of the U.S.A.* 106: 221-225. [9.661, 161]

86. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2009) Comparative gynoecium structure and development in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 170: 21-41. [1.748, 21]

87. Sage, T.L., Hristova-Sarkovsi, K., Koehl, V., Lyew, J., Pontieri, V., Bernhardt, P., **Weston, P.**, Bagha, S., & Chiu, G. (2009) Transmitting tissue architecture in relictual-basal angiosperms: implications for transmitting tissue origins. *American Journal of Botany* 96: 183-206. [3.05, 31]

88. Crisp, M.D., Arroyo, M.T.K., Cook, L.G., Gandolfo, M.A., Jordan, G.J., McGlone, M.S., **Weston, P.H.**, Westoby, M., Wilf, P., & Linder, H.P. (2009) Phylogenetic biome conservatism on a global scale. *Nature* 458: 754-758. [40.137, 441]

89. Indsto, J.O., **Weston, P.H.**, & M.A. Clements (2009) A molecular phylogenetic analysis of *Diuris* (Orchidaceae) based on AFLP and ITS reveals three major clades and a basal species. *Australian Systematic Botany* 22: 1-15. [0.75, 6]

90. Sauquet, H., **Weston, P.H.**, Barker, N.P. Anderson, C.L., Cantrill, D.J. & Savolainen, V. (2009) Using fossils and molecular data to reveal the origins of the Cape proteas (subfamily Proteoideae). *Molecular Phylogenetics and Evolution* 51: 31-43. [4.419, 38]

91. Rossetto, M., Thurlby, K.A.G., Offord, C.A., Allen, C.B., & **Weston, P.H.** (2011) The impact of distance and a shifting temperature gradient on genetic connectivity across a heterogeneous landscape. *BMC Evolutionary Biology* 11(126):1-11. [3.221, 17]

92. Byrne, M., Steane, D., Joseph, L., Yeates, D., Jordan, G.J., Crayn, D., Aplin, K., Cantrill D., Cook, L.G., Crisp, M.D., Keogh, J.S., Melville, J., Moritz, C., Porch, N., Sniderman, J.M.K., Sunnucks P., & **Weston, P.H.** (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. *Journal of Biogeography* 38: 1635–1656. [4.590, 187]

93. Mast, A.R., Milton, E.F., Jones, E.H., Barker, R.M., Barker, W.R., & **Weston, P.H.** (2012) Time-calibrated phylogeny of the woody Australian genus *Hakea* (Proteaceae) supports multiple origins of insect-pollination among bird-pollinated ancestors. *American Journal of Botany* 99: 472-487. [3.05, 28]

94. Stimpson, M.L., **Weston, P.H.**, Telford, I.R.H., & Bruhl, J.J. (2012) First instalment in resolution of the *Banksia spinulosa* complex (Proteaceae): *B. neoanglica*; a new species supported by phenetic analysis, ecology and geography. *Phytokeys* 14: 57–80. [0.686, 6]

95. Rossetto, M., Allen, C., Thurlby, K., **Weston, P.H.**, & Milner, M. (2012) Genetic structure and bio-climatic modelling support allopatric over parapatric speciation along a latitudinal gradient. *BMC Evolutionary Biology* 12:149. [3.221, 12]

96. Clark, V.R., Perera, S.J., Stiller, M., Stirton, C.H., **Weston, P.H.**, Stoev, P., Coombs, G., Morris, D., Ratnayake-Perera, D., Barker, N.P., & MacGregor, G.K. (2012) A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation. *SpringerPlus* 1:56 [0.982, 3]

97. Milner, M.L., Rossetto, M., Crisp, M.D., & **Weston, P.H.** (2012) The impact of multiple biogeographic barriers and hybridization on species-level differentiation. *American Journal of Botany* 99: 2045–2057. [3.05, 13]

98. Ford, A.J. & **Weston, P.H.** (2012) A taxonomic revision of *Hollandaea* Anon. (Proteaceae). *Austrobaileya* 8: 670-687. [-, 0]

99. Hidayat, T., **Weston, P.H.**, Yukawa, T., Ito, M., & Rice, R. (2012) Phylogeny of subtribe Aeridinae (Orchidaceae) inferred from DNA sequences data: advanced analyses including Australasian genera. *Jurnal Teknologi (Sciences and Engineering)* 59 (suppl. 1): 87-95. [0.096, 4]

100. **Weston, P.H.** & Hill, R.S. (2013) Southern (austral) ecosystems. Pp. 612-619 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* second edition, vol. 6 (Academic Press: Waltham, MA). [-, 9]

101. Jordan, G.J., Brodribb, T.J., Blackman, C.J., & **Weston, P.H.** (2013) Climate drives vein anatomy in Proteaceae. *American Journal of Botany* 100: 1483-1493.
[3.05, 16]

102. **Weston, P.H.** & Woods, L.A. (2013) Correction of a typographical error in the protologue of *Banksia conferta* A.S.George var. *penicillata* A.S. George. *Telopea* 15: 67–69. [0.6, 0]

103. Milner, M.L., McIntosh, E.J., Crisp, M.D., **Weston, P.H.**, & Rossetto, M. (2013) Microsatellite variation for phylogenetic, phylogeography and population genetic studies in *Lomatia* (Proteaceae). *Australian Systematic Botany* 26: 186-195. [0.75, 2]

104. **Weston, P.H.** (2014) What has molecular systematics contributed to our knowledge of the Proteaceae? Pp. 365-397 in P. Besse (ed.) *Molecular Plant Taxonomy: Methods and Protocols*, *Methods in Molecular Biology*, vol. 1115 (Springer: New York). [-, 11]

105. McIntosh, E., Rossetto, M., **Weston, P.H.**, & Wardle, G. (2014) Maintenance of strong morphological differentiation despite ongoing natural hybridization between sympatric species of *Lomatia* (Proteaceae). *Annals of Botany* 113: 861-872. [4.041, 15]

106. Stimpson, M.L., Bruhl, J.J. & **Weston, P.H.** (2014) Could this be Australia's rarest *Banksia*? *Banksia vincentia* (Proteaceae), a new species known from fourteen plants from south-eastern New South Wales, Australia. *Phytotaxa* 163: 269–286. [1.24, 1]

107. Thomas, N., Bruhl, J.J., Ford, A., & **Weston, P.H.** (2014) Molecular dating of Winteraceae reveals a complex biogeographic history involving both ancient Gondwanan vicariance and long-distance dispersal. *Journal of Biogeography* 41: 894-904. [4.590, 23]

108. **Weston, P.H.**, Perkins, A.J., Indsto, J.O., & Clements, M.A. (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier, R. & P. Bernhardt (eds.) *Darwin's Orchids: Then and Now* (University of Chicago Press: Chicago). [-, 7]

109. Kooyman, R.M., Wilf, P., Barreda, V.D., Carpenter, R.J., Jordan, G.J., Sniderman, J.M.K., Allen, A., Brodribb, T.J., Crayn, D., Feild, T.S., Laffan, S.W., Lusk, C., Rossetto, M., & **Weston, P.H.** (2014) Paleo-Antarctic rainforest into the modern Old World tropics: the rich past and threatened future of the 'southern wet forest survivors'. *American Journal of Botany* 101: 2121 – 2135. [3.05, 33]

110. Lambers, H., Clode, P., Hawkins, H.-J., Laliberté, E., Oliveira, R., Reddell, P., Shane, M.W., Stitt, M., & **Weston, P.H.** (2015) Metabolic adaptations of the non-mycotrophic Proteaceae to soil with a low phosphorus availability. *Annual Plant Reviews* 48: 289–336 (Plaxton, W.C. & Lambers, H. (eds.) *Phosphorus Metabolism in Plants in the Post-genomic Era: From Gene to Ecosystem* (Wiley-Blackwell Publishing: Chichester, UK)). [-,19]

111. Mast, A.R., Olde, P., Makinson, R.O., Jones, E., Kubes, A., Miller, E. & **Weston, P.H.** (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646. [3.05, 12]

112. Thiele, K.R., **Weston, P.H.** & Mast, A.M. (2015) Paraphyly, modern systematics and the transfer of *Dryandra* into *Banksia* (Proteaceae): a response to George. *Australian Systematic Botany* 28: 194–202 [0.75, 1]

113. Milner, M.L., **Weston, P.H.,** Rossetto, M., & Crisp, M.D., (2015) Biogeography of the Gondwanan genus *Lomatia* (Proteaceae): vicariance at continental and intercontinental scales. *Journal of Biogeography* 42: 2440–2451. [4.590, 7]

114. Stimpson, M.L., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (2016) A morphometric analysis of the *Banksia spinulosa* complex (Proteaceae) and its complex taxonomic implications. *Australian Systematic Botany* 29: 55-86. [0.75, 0]

115. Onstein, R.E., Jordan, G.J., Sauquet, H., **Weston, P.H.**, Bouchenak-Khelladi, Y., Carpenter, R.J., & Linder, H.P. (2016) Evolutionary radiations of Proteaceae are triggered by the interaction between traits and climates in open habitats. *Global Ecology and Biogeography* 25: 1239–1251. [6.045, 9].

116. van der Merwe, M., Crayn, D., Ford, A., Rossetto, M., & **Weston, P.H.** (2016) Evolution of Australian *Cryptocarya* (Lauraceae) based on nuclear and plastid phylogenetic trees: evidence of recent landscape-level disjunctions *Australian Systematic Botany* 29: 157–166. [0.75, 2]

117. Citerne, H., Reyes, E., Le Guilloux, M., Delannoy, E., Sannier, J., Simmonet, F., Sauquet, H., Nadot, S., **Weston, P.H.**, & Damerval, C. (2017) Characterisation of CYCLOIDEA-like genes in Proteaceae, a basal eudicot family with multiple shifts in floral symmetry. *Annals of Botany* 119: 367-378. [4.041, 7]

118. **Weston, P.H.**, & Jordan, G.J. (2017) Evolutionary biogeography of the Australian flora in the Cenozoic Era. Pp. 40-62 in D.A. Keith (ed.) *Australian Vegetation*, 3rd edition (Cambridge University Press: Cambridge). [-, 0]

119. Cardillo, M., **Weston, P.H.**, Reynolds, Z., Olde, P.M., Mast, A.R., Lemmon, E., Lemmon, A. & Bromham, L. (2017) The phylogeny and biogeography of *Hakea* (Proteaceae) reveals the role of biome shifts in a continental plant radiation. *Evolution* 71: 1928–1943. [4.201, 1]

120. Holmes, G., **Weston, P.H.**, Murphy, D., Gardner, S., Connelly, C., & Cantrill, D.J. (2018) The genealogy of geebungs: phylogenetic analysis of *Persoonia* (Proteaceae) and related genera in subfamily Persoonioideae. *Australian Systematic Botany* 31: 166–189. [0.75, 0]

121. **Weston, P.H.** (in review) Proteaceae. *Flora of North America North of Mexico* 10-11 (Oxford University Press: New York and Oxford). [-,-]

122. Steenbeeke, G., Dowle, M., Laurence, M.H., Liew, E.C.Y., Newby, Z.-J., Renner, M., Sommerville, K., Weston, P.H., Ward, S. (in review) Phylogeny of selected *Microtis* (Orchidaceae) in south eastern Australia and its implications for taxonomy and conservation priorities. *Telopea* [0.6, -]

Papers in Preparation

1. Stimpson, M.L., Wright, B.R., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (in prep.) Seedling morphology helps unravel the taxonomic intricacies in the *Banksia spinulosa* complex (Proteaceae). *Botanical Journal of the Linnean Society* [2.523, -]

2. Jobson, P.C. & **Weston, P.H.** (in prep.) Recombinations in *Dillwynia* (Fabaceae: Faboideae: Mirbelieae) for Flora of South Australia.

3. Jordan, G.J. & **Weston, P.H.** (in prep.) Estimating the age of origin of functional traits.

4. **Weston, P.H.** & Garnock-Jones, P. (in prep.) A taxonomic revision of *Knightia* (Proteaceae).

Conference Abstracts

1. **Weston, P.H.** (1984) A reappraisal of Nelson's direct method of character analysis. P. 9, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

2. Wilson, P.G. & **Weston, P.H.** (1984) A preliminary cladistic analysis of the *Metrosideros* suballiance (Myrtaceae). P. 19, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

3. **Weston, P.H.** (1984) Drifting waratahs or continents? P. 9, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

4. Crisp, M.D. & **Weston, P.H.** (1984) Waratahs – one species or two? P. 5, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

5. **Weston, P.H.** (1988) Problems with the statistical testing of panbiogeographic hypotheses. Abstracts, Symposium on *Panbiogeography of New Zealand*, Wellington.

6. **Weston, P.H.** (1989) Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae. P. 37, Program and Abstracts, Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney.

7. **Weston, P.H.** & Crisp, M.D. (1990) Transoceanic cladistic patterns in the Proteaceae. P. 51, Abstracts, *Systematics and Biogeography of the Austral Biota*, IXth meeting of the Willi Hennig Society, Canberra.

8. **Weston, P.H.** (1993) Direct methods for polarising character transformation series. P. 13, Programme and Abstracts, *Models in Phylogeny Reconstruction*, a joint conference of The Systematics Association and The Linnean Society, London.

9. Crisp, M.D., Linder, H.P., & **Weston, P.H.** (1994) Cladistic biogeography of Australia: is there more than one endemic tropical track? P. 14, Program and Abstracts, *Origin and Evolution of the Flora of the Monsoon Tropics*, a symposium of the Australian Systematic Botany Society, Kuranda.

10. **Weston, P.H.** (1996) ITS sequence variation in the Proteaceae and what it tells us about phylogeny. P. 49, Abstracts, *An International Symposium on the Biology of Proteaceae*, Melbourne.

11. **Weston, P.H.** (1997) Rolf Sattler's plant morphology and cladistic analysis. P. 54, Abstracts, *First Biennial International Conference of the Systematic Association*, Oxford, U.K..

12. **Weston, P.H.** & Crisp, M.D. (1997) Cladistic biogeography of a key woody group: Proteaceae. P. 5, Abstracts, *II Southern Connection Congress*, Valdivia, Chile.

13. Kores, P.J., Molvray, M., **Weston, P.H.**, & Chase, M.W. (1998) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 33-34, Abstracts. Monocots II Conference, Sydney.

14. **Weston, P.H.** (1999) Historical biogeography of Proteaceae. Abstracts, XVI International Botanical Congress, Saint Louis.

15. **Weston, P.H.** (2002) Proteaceae: Brown and now. P. 16, Abstracts, Robert Brown 200 Conference, Sydney.

16. Mant, J.G., **Weston, P.H.**, Peakall, R., & Schiestl, F.P. (2003) Coevolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators. P. 55, Abstracts, *Monocots III*, The Third International Conference on the Comparative Biology of the Monocotyledons, Ontario, U.S.A..

17. **Weston, P.H.,** Clements, M.A., Indsto, J.O., Mant, J., Peakall, R., & Perkins, A.J. (2005) Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae). XVII International Botanical Congress, Vienna.

18. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2006) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 39 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

19. **Weston, P.H.** (2006) A new suprageneric classification of the Proteaceae. P. 45 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

20. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K.. (2006). Floral architecture and phyllotaxis in Calycanthaceae (Laurales). Abstract 192, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

21. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2006). A phylogenetic approach to the evolution of pollen morphology in Proteaceae (Proteales). Abstract 405, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

2. Milton, E.F., **Weston, P.H.**, Mast, A. (2006) The diversification of ecologically significant traits in the species-rich Australian genus *Hakea* (Proteaceae). Abstract 324, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

23. Mast, A., **Weston, P.H.**, Jones, E., Sauquet, H., Cantrill, D., Jordan, G., & Barker, N. . (2006) The timing of disjunctions in the southern hemisphere family Proteaceae: Sensitivity analysis with 6 genes, multiple calibration points, and 70+ genera. Abstract 327, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

24. Willis, C.L., **Weston, P.H.**, & Mast, A. (2007) Inference of phylogenetic relationships in *Macadamia* and relatives (tribe Macadamieae; Proteaceae) using three chloroplast and three nuclear DNA regions. Abstract 1677, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

25. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K. (2007) Structure and development of the gynoecium in Calycanthaceae (Laurales). Abstract 1121, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

26. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). Abstract 1593, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

27. Milton, E.F., **Weston, P.H.**, Barker, W., Barker, R., & Mast, A. (2007) Inference of phylogenetic relationships in *Hakea* (Proteaceae) using morphology and four chloroplast and three nuclear DNA regions. Abstract 1712, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

28. Kubes, A., **Weston, P.H.**, Makinson, R.O., Olde, P., & Mast, A.R. (2007) Resolving relationships in *Grevillea* (Proteaceae), the third largest Australian plant genus. Abstract 1814, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

29. **Weston, P.H.**, Barker, N.P., Rutschmann, F., & Sauquet, H. (2007) 'I'm not dead yet' – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation). P. 76, Conference Program, 5th International Southern Connection Congress, Adelaide.

30. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 58, Conference Program, 5th International Southern Connection Congress, Adelaide.

31. Mast, A., Jones, E., Barker, R., Barker, W., **Weston, P.H.** (2009) The phylogeny and age of the woody Australian genus *Hakea* (Proteaceae) and the evolution of its leaf and fire persistence features. Abstract 335, Botany & Mycology 2009 (Botanical Society of America conference, Snowbird, Utah)

32. Holmes, G.D., Porter, C., Murphy, D.J., **Weston, P.H.** and Cantrill, D.J. (2009) What are the relationships among Snottygobbles and Geebungs? A preliminary phylogeny of *Persoonia* (Proteaceae). P 45, Conference Booklet, *Systematic Botany: from Science to Society*, a conference of the Australian Systematic Botany Society, Armidale.

33. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests. P. 29, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

34. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Cladistic biogeography, molecular dating, fossils and the Proteaceae. P. 18, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

35. Baum, M., Crisp, M., Rossetto, M. & **Weston, P.** (2010) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 20, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

36. **Weston, P.H.** (2010) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 68, *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*, a conference of the Australian Systematic Botany Society, Lincoln University, New Zealand.

37. **Weston, P.H.** (2011) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 34, Abstracts 2nd Book, *Plants in a Changing World*, (37th annual conference of the South African Association of Botanists, Rhodes University, South Africa).

38. **Weston, P.H.**, Indsto, J.O., Perkins, A.J., Clements, M.A., & Peakall, R. (2011) Total evidence phylogenetic analysis of the orchid tribe Diurideae and what it tells us about the evolution of pollination systems. P. 152, Abstract Book, XVIII International Botanical Congress, Melbourne.

39. **Weston, P.H.**, Wilson, P.G., Conn, B.J., Rymer, P.D. (2011) Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations. P. 266, Abstract Book, XVIII International Botanical Congress, Melbourne.

40. Nguyen, C.H., Beattie, G.A.C., Holford, P., Mabberley, D.J., & **Weston, P.H.** (2011) Determining the origin and diversification of *Murraya paniculata*: one or more species? P. 354, Abstract Book, XVIII International Botanical Congress, Melbourne.

41. Milner, M., Crisp, M.D., Rossetto, M., & **Weston, P.H.** (2011) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 281, Abstract Book, XVIII International Botanical Congress, Melbourne.

42. **Weston, P.H.** (2012) Contested, uncontested and potentially controversial taxonomic changes in the Proteaceae: how do they differ? P. 49, Program and Abstracts, *Local Knowledge, Global Delivery* (Australasian Systematic Botany Society 2012 Perth Conference Committee: Perth).

43. **Weston, P.H.,** Jones, E.H., Olde, P.M., Makinson, R.O., & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 101, *Genetics in the Harbour City* (Program and abstracts of the annual conference of the Genetics Society of Australasia, Sydney).

44. Onstein, R., Jordan, G., Bouchenak-Khelladi, Y., Xing, Y., Wright, I., Sauquet, H., Carpenter, R., **Weston, P.** & Linder, P. (2013) Leaf trait evolution in the Proteaceae. P. 11, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

45. Cantrill, D.J., Lewis, E., Murphy, D.J. & **Weston, P.H.** (2013) Variation in pollen morphology within *Persoonia* (Proteaceae) supports clades revealed by molecular data. P. 19, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

46. **Weston, P.H.**, Jones, E.H., Olde, P.M., Makinson, R.O. & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 20, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

47. Schulte, K., Micheneau, C., Simpson, L., **Weston, P.**, Crayn, D. & Clements, M. (2013) The *Dendrobium* alliance revisited: A molecular phylogenetic approach towards reconciling taxonomic concepts in Dendrobiinae (Orchidaceae). P. 32, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

48. Stimpson, M.L., Prychid, C.J., **Weston, P.H.** Whalley, R.D.B. & Bruhl, J.J. (2013) Structure and function of the cotyledonary node in the *Banksia spinulosa* complex (Proteaceae). P. 68, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

49. **Weston, P.H.** (2014) Problems and progress in plant systematics since Nancy Burbidge. P. 17, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

50. Thomas, N., Bruhl, J., Ford, A. & **Weston, P.** (2014) Molecular dating of Winteraceae reveals a complex biogeographical history involving both ancient Gondwanan vicariance and long-distance dispersal. P. 28, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

51. **Weston, P.H.** Reyes, E. & Sauquet, H. (2015) A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution. P. 35, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

52. Schulte, K., Micheneau, C., Field, A., **Weston, P.**, Crayn, D. & Clements, M. (2015) The *Dendrobium* alliance revisited: examining macroevolutionary patterns in Dendrobiinae (Orchidaceae). P. 30, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

53. Thiele, K., Barker, W.R., Crayn, D.M., Waycott, M., Holland, A., Breitwieser, I., Lockhart, P., Bayly, M., **Weston, P.H.**, & Schulte, K. (2015) Progress towards a decadal plan for Australasian biodiversity

science – an update. P. 33, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

Articles in Magazines, Newsletters, etc.

1. Weston, P.H. (1988c) Proteaceae. Australian Plants 14: 259.

2. Weston, P.H. (1988d) The flower - part 2. *Australian Plants* 14: 262-263.

3. Weston, P.H. (1992) A special tree [an article about *Idiospermum australiense*]. *Friends of the Royal Botanic Gardens Newsletter* 14: 4.

4. Weston, P.H. & Crisp, M.D. (1995) Phylogenetic analysis. *Australasian Biotechnology* 5(5): 291-293.

5. Weston, P.H. (1998) Lust, lies and fungus flies. *The Gardens* 39: 8-9.

6. Weston, P.H. (2000) Flower wasps and bird orchids. *The Gardens* 44: 5.

7. Weston, P.H. (2000) An intriguing case of snottygobbles. *The Gardens* 44: 11.

8. Weston, P.H. (2001) The Nightcap Oak comes out of the bush and into the spotlight. *The Gardens* 50: 6.

9. Weston, P.H. (2001) New tree species discovered in Australia. *Forest Genetic Resources* 29: 26.

10. Weston, P.H. & Kooyman, R.M. (2002) *Eidothea hardeniana*: botany and ecology of the 'Nightcap Oak'. *Australian Plants* 21: 339-342, 344.

11. Weston, P.H. (2003) Proteaceae subfamily Persoonioideae: botany of the geebungs, snottygobbles and their relatives. *Australian Plants* 22: 62-78, 91.

12. Weston, P.H. (2005) Sex and Death in the Sydney Tropical Centre. *The Gardens* 65: 6-7, republished in re-edited form in *Australian Orchid Review* 70(5): 32-33.

14. Weston, P.H. (2009) From the President. *ASBS Newsletter* 141: 1-3.

15. Weston, P.H. (2010) Madagascar: a world of botanical wonders. *The Gardens* 84: 10-11.

16. Weston, P.H. (2010) From the President. *ASBS Newsletter* 142: 1.

17. Weston, P.H. (2010) From the President. *ASBS Newsletter* 143: 1-3.

18. Weston, P.H. (2010) From the President. *ASBS Newsletter* 144-145: 1.

19. Weston, P.H. (2010) ASBS President’s Report 2009–2010. *ASBS Newsletter* 144-145: 4-6.

20. Weston, P.H. (2010) Life Membership awarded to John Clarkson. *ASBS Newsletter* 144-145: 16.

21. Weston, P.H. (2010) ASBS 2010 Conference Report, Lincoln, Canterbury, New Zealand. *ASBS Newsletter* 144-145: 17-21.

22. Weston, P.H. (2011) From the President. *ASBS Newsletter* 146: 1-2.

23. Weston, P.H. (2011) From the President. *ASBS Newsletter* 147-148: 1-3.

24. Weston, P.H. (2011) Award of Nancy T. Burbidge Medals to Professors Pauline Ladiges and Michael Crisp. *ASBS Newsletter* 147-148: 3-8.

25. Weston, P.H. (2011) The ARC-ERA journal ranking project has been aborted. *ASBS Newsletter* 147-148: 11-12.

26. Weston, P.H. (2011) Recent advances and new developments in biogeographical reconstruction methods. *ASBS Newsletter* 147-148: 14.

27. Weston, P.H. (2011) [Book review of] The Flowering of Australia’s Rainforests: A Plant and Pollination Miscellany. By Geoff Williams and Paul Adam. *ASBS Newsletter* 147-148: 21-23.

28. Weston, P.H. (2011) From the President. *ASBS Newsletter* 149: 1-2.

29. Weston, P.H. (2011). ASBS President’s Report 2010-2011. *ASBS Newsletter* 149: 4-7.

30. Weston, P.H. (2012) From the President. *ASBS Newsletter* 150: 1-2.

31. Weston, P.H. (2012) New proposals to change ASBS rules. *ASBS Newsletter* 150: 4-10.

32. Weston, P.H. (2012) From the President. *ASBS Newsletter* 151: 1-2.

33. Weston, P.H. (2012) A remarkable botanical find: the double discovery of *Danhatchia australis* in Australia. *The Gardens* 94: 27.

34. Weston, P.H. (2012) From the President. *ASBS Newsletter* 152: 1-2.

35. Weston, P.H. (2013) Exploring southern Africa. *The Gardens* 96: 18-19.

36. Weston, P.H. (2013) ASBS President’s Report 2011-2012. *ASBS Newsletter* 153: 7-10.

37. Weston, P. (2013) Not an exact science. *Sydney Morning Herald,* 19 June 2013: 19.

38. Weston, P.H. (2015) Funding research. *The Gardens* 103:33.

39. Weston, P.H. (2016) Building a database of floral characters for researching the iconic Australian plant family Proteaceae. Report to the Winston Churchill Memorial Trust (https://www.churchilltrust.com.au/media/fellows/Weston_P_2014_Building_a_database_of_floral_characters_of_Proteaceae.pdf).

Strategic assessment for Cumberland Plain Conservation Plan Expert report on the Sydney Plains Greenhood, *Pterostylis saxicola* in the Western Sydney Aerotropolis Growth Area, and Greater Penrith to Eastern Creek Urban Release Investigation Area

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1. Introduction

1.1 Purpose of the expert report

I was engaged by the Department of Planning and Envionment in September 2018, to produce an expert report on the distribution and abundance of *Pterostylis saxicola* (Orchidaceae) within the proposed Western Sydney Aerotropolis, and Greater Penrith to Eastern Creek Growth Areas (collectively termed "the study area"). This immediately followed my submission of a similar report on the same species for the Greater Macarthur and Wilton Growth Areas (Weston unpublished). The aim of this exercise was to assess whether *P. saxicola* is native to either of the Growth Areas and, if so, to assess where suitable habitat is located and to estimate the area occupied by *P. saxicola* in the study area and within the development footprint.

According to Section 6.5.2 of the Biodiversity Assessment Method, an expert report must:

- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- estimate the number of individuals or area of habitat (whichever unit of measurement applies to the species/individual) for the biodiversity certification assessment area, including a description of how the estimate was made
- demonstrate what information was considered, rejected and discounted in relation to the determination made in the expert report, and
- identify the expert and provide evidence of their expert credentials.

1.2 Project context

The Department of Planning and Environment is leading a strategic biocertification of several identified growth areas within Western Sydney, including the two growth areas that define the geographic scope of this report: the Western Sydney Aerotropolis Growth Area and the Greater Penrith to Eastern Creek Urban Release Investigation Area. The strategic biodiversity assessment is an integral part of the Cumberland Plain Conservation Plan that will determine the impact of urban development on threatened species and ecological communities within these growth areas. The Plan will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation.

1.3 Study area

The stu8dy area is located in the western to south western part of the Sydney Metropolitan Area, between latitudes 33.712°S and 33.941°S and longitudes 150.654°E and 150.857°E (figure 1).

1.4 Reasons for use of expert report

Pterostylis saxicola has never been collected within the study area. However, sites at which the species has been collected or observed, according to the Bionet Wildlife Atlas, are known beyond all sides of the study area, suggesting that it is part of the distributional range of *P. saxicola*. Moreover, according to Tozer *et al.* (2010), at least one of the plant community types in which known populations of *P. saxicola* occur, PCT 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, is scattered throughout the study area, raising the strong possibility that suitable habitat for *P. saxicola* might exist there. If this were so, *P. saxicola* might once have lived there, or still exist in the study area as unrecorded populations.

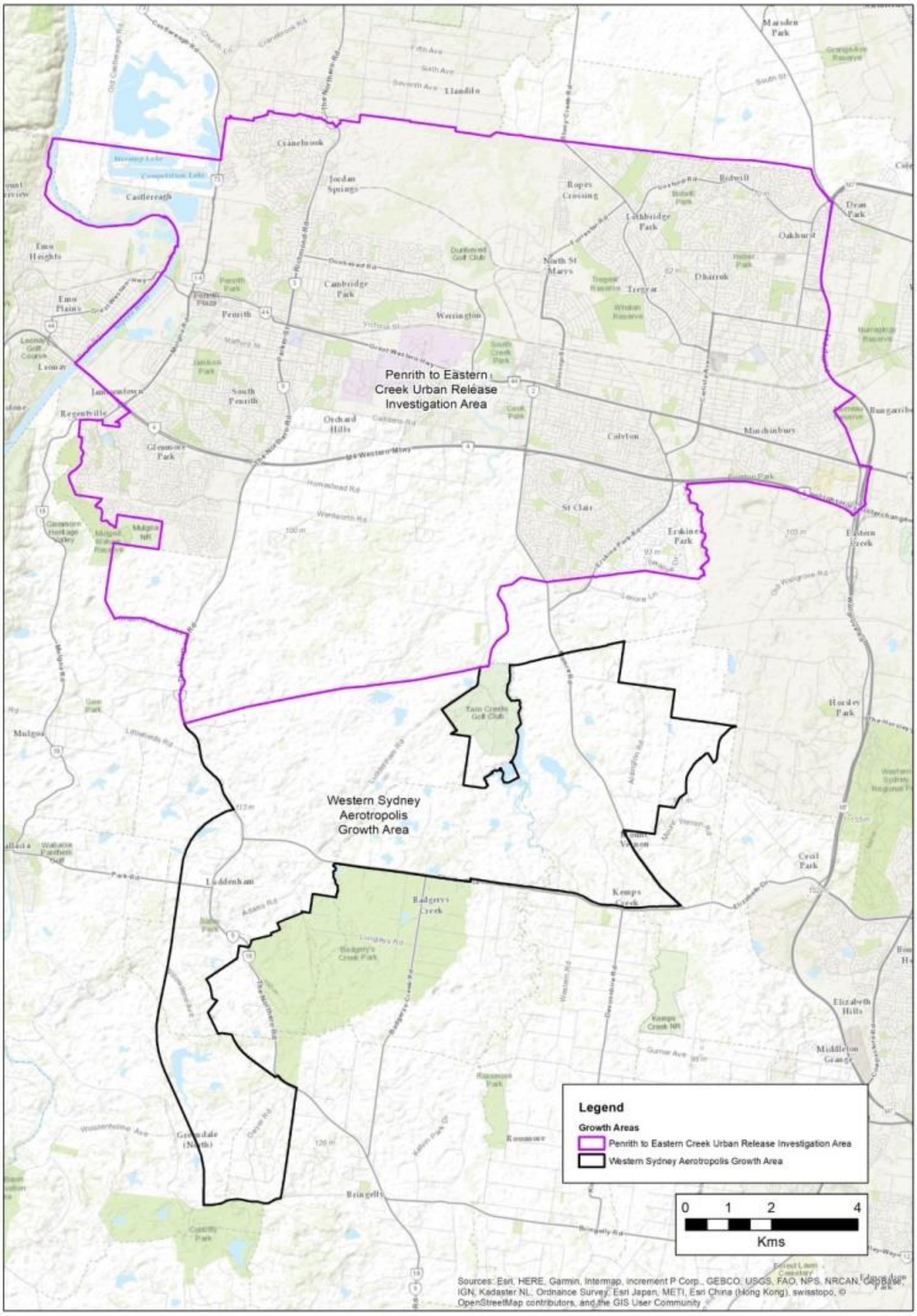


Figure 1. The Greater Penrith to Eastern Creek Urban Release Investigation Area (outlined in purple) and the Western Sydney Aerotropolis Growth Area (outlined in black). © OpenStreetMap contributors.

Pterostylis saxicola is a perennial, deciduous herb that can only be identified with confidence when flowering in Spring (late September to early November). Fortunately, the timing of the field work that I conducted for this project, 7 October to 22 November 2018, largely overlapped with this flowering period. However, the cryptic coloration and small size of this plant render it a challenging subject for conventional surveying: "drive by" surveys are not feasible and even experienced orchid spotters need to be standing within a few metres of a flowering plant to notice it. Moreover, plants may not flower if climatic conditions during the growing season from March to December (see section 2.2 below) are poor, as they have been in 2018 due to drought. Another limitation to conventional surveying was lack of access to a substantial proportion of the remnant native vegetation in the study area. Although sizeable blocks of the remnant bushland are found in public reserves, most of the native vegetation occurs on private land or land managed by the Australian Department of Defence and only 13.5% of landowners granted permission for surveys to be conducted on their land. The Australian Department of Defence land was not surveyed. These limitations and the possibility that *P. saxicola* might be native to the study area triggered the need for an expert report.

An alternative approach involves the construction of a general habitat model for *Pterostylis saxicola*, which can then be used, in conjunction with environmental maps, to identify suitable habitat on all land tenures across the study area.

1.5 Credentials of expert

I prepared this report as an independent botanical consultant but I am also currently an Honorary Research Associate at the New South Wales state herbarium (the National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust). In 2016, I retired from my role as a Senior Principal Research Scientist at the state herbarium, having worked there since 1982 as a Systematic Botanist and as curator of the herbarium's collections of specimens of Orchidaceae (including *Pterostylis saxicola*) (see my Curriculum Vitae, attached). I now work, part-time, at the National Herbarium of New South Wales as an Honorary Research Associate. I have published, either as sole author or as a co-author, 16 papers on the systematics and ecology of the Orchidaceae in the peer-reviewed scientific literature, including the most comprehensive phylogenetic analysis of the predominantly Australian subtribe Diurideae yet published (Weston et al. 2014). As curator of Orchidaceae at the state herbarium, I examined all specimens of P. saxicola incorporated into the collection between 1986 and 2016. I was invited to contribute to floristic treatments of the Orchidaceae for Flora of New South Wales, (see my Curriculum Vitae, attached). I was also asked to be lead author of the essay on the ecology of the Orchidaceae that accompanied the "Ecology of Sydney Plants" (Weston et al. 2005). Throughout my career I have participated in numerous collecting trips in the field, collecting specimens in all Australian states for the state herbarium. In documenting these specimens I had to describe the habitat at each collecting site, including associated plant species, substrate, aspect, degree and kind of disturbance. I have also cultivated numerous species of Pterostylis as an orchid enthusiast and advised horticulturalists at the Royal Botanic Gardens on appropriate techniques for cultivating species of Pterostylis and other orchids.

In June 2018 I was appointed to prepare an expert report on *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas (Weston unpublished), during the preparation of which I characterised in detail the associated plant species and other ecological attributes of five plots, each of 30 metre radius, centred on highly precise grid references of sites at which *P. saxicola* had previously been collected, at two of which I found pre-flowering leaf rosettes that were indistinguishable from those of the orchid. I am personally familiar with this taxon and the habitats in which it lives.

In November 2018 I was approved by the Office of Environment and Heritage as a species expert for *Pterostylis saxicola* under section 6.5.2 of the Biodiversity Assessment Method. This approval is current for a period of six years.

1.6 Species surveys conducted on behalf of the Department of Planning and Environment

Letters were sent by the Department of Planning and Environment (DPE) to all landholders within the development footprint to request access. A total of 432 letters were sent to landholders across the Western Sydney Aerotropolis Growth Area between November 2017 and August 2018 with 84 landholders responding positively to provide access. A further seven properties were accessed after doorknocking, resulting in a response rate of 21%.

A small number of targeted letters were sent to landholders in the Greater Penrith to Eastern Creek Urban Release Investigation Area from November 2017. However, most letters (more than 1500) were sent in August 2018, which included many urban and small acreage landholders. From this, 177 landholders provided access to their properties and an additional three landholders provided permission via doorknocking (12% response rate). Not all of these properties were surveyed as some did not support vegetation patches of interest. In addition, the Open Spaces Team at Penrith Council facilitated access to 64 lots owned by Council. Surveys were undertaken by DPE's contract ecologists on all areas of land where landowners granted access. Access to the Defence Establishment Orchard Hills, which includes large patches of native vegetation, was not provided.

A targeted survey for threatened species was conducted on lands where access was granted. Vegetation transects and random meanders for threatened flora were conducted by the Ecoplanning Pty Ltd and Biosis Pty Ltd in accessible areas proposed for certification, with particular attention to areas of likely habitat. The survey included effort through each plant community type and vegetation zone, and extended into suitable habitat adjacent to the edge of the future urban area where potential indirect impacts to high quality habitat may occur (up to ~50m). Likely habitat for most flora species comprised areas of lower disturbance. This included areas with a predominantly native understorey (with or without a canopy), the base of scattered trees in paddocks, paddocks with an apparent low grazing pressure, and known topographic/habitat preferences for certain flora. *Pterostylis saxicola* was not found in the study area during this survey.

The percentages of remnant native vegetation in the growth areas that were sampled in the threatened species survey were 1.0% in Greater Penrith to Eastern Creek Urban Release Investigation Area and 7.1% in the Western Sydney Aerotropolis Growth Area. The percentages of sampled remnant native vegetation that were covered by the urban development footprint were 7.9% in Greater Penrith to Eastern Creek and 18.4% in the Western Sydney Aerotropolis. These data include a 20 m buffer from survey tracks.

2. Species information

2.1 Species description

The following morphological description of *Pterostylis saxicola* is a modified version of that published by Jones and Clements (1997), updated with data gathered from more recently collected specimens held by the National Herbarium of N.S.W.

Tuberous, terrestrial herb (see figure 2). Tubers oblate, c. 15-20 mm wide. Leaves oblong-elliptical to ovate-elliptical or obovate, 10-45 mm long, 5-15 mm wide, 5-10 in a radical rosette, green, the margins entire, shortly petiolate, apex subacute to apiculate, often withered at anthesis. Inflorescence 10.5-35 cm tall, slender, with 3-6 ensheathing, lanceolate sterile bracts. Floral bracts lanceolate, 6-19 mm long, 3-4 mm wide, acuminate, closely sheathing. Pedicels 3-26 mm long, slender, straight or slightly curved. Ovary narrowly obovoid, 3-5 mm long, 1-2 mm wide, reddish brown. Flowers 1-10, porrect to semi-erect, 12-12 mm long, transparent with dark red-brown markings and suffusions in the galea, the lateral sepals wholly red-brown, shiny; galea gibbous at the base, curved medially, decurved suddenly to the apex; petal flanges poorly developed, not touching and not closing off the base of the galea. Dorsal sepal 11-13 mm long, cucullate, obliquely erect, Abruptly decurved in distal quarter, apical point c. 3 mm long, filamentous, acuminate. Lateral sepals deflexed, ovate in outline when flattened, fused part 7-10 mm long, 9-11 mm wide, shallowly concave, the margins strongly incurved, glabrous; sinus narrow; free points filamentous, c. 5 mm long, curved forwards, divergent, 8-10 mm apart at the tips. Petals ovate-lanceolate, 11-14 mm long, 3.5-5 mm wide, nearly straight, transparent, with brown basal markings and two or three brown lines, dorsal margin brown, ciliate, proximal flange poorly developed. Labellum highly irritable, attached by a ligulate basal claw c. 2 mm long, c. 2 mm wide; lamina broadly obovate, 4.5-6 mm long, 2.5-3.5 mm wide, dark red-brown, constricted in the proximal quarter, adaxial surface shallowly concave to broadly grooved, apex obtuse; marginal trichomes 3-5 pairs, white, the longest pair c. 3.5 mm long, arising near the proximal constriction, basal lobe large, with 1-3 pairs of trichomes c. 0-.7 mm long, abaxial surface with a narrow central channel extending from the basal lobe to the apex. Column porrect from the end of the ovary, 10-12 mm long, c. 2.5 mm wide; column wings c. 3.3 mm long, c. 2.5 mm wide, more or less rectangular, anterior margins ciliate. Stigma elliptical to broadly scutiform, c. 5 mm long, c. 2.5 mm wide, the upper margins irregular. Anther c. 1.2 mm long, obtuse. Pollinia linear-oblong to clavate, c. 2 mm long, yellow, mealy. Fruiting capsules obovoid, 7-8 mm long, c. 4-5 mm wide, brownish, erect.

2.2 Life cycle

Pterostylis saxicola is a perennial, deciduous, tuberous herb that germinates from a minute, dust-like seed. Like all other orchids, germination is reliant on invasion of the seed by the hyphae of a specific fungal associate, which, in the case of *P. saxicola*, is an unnamed species of *Ceratobasidium* (Basidiomycota: Cantharellales) (Sommerville et al. 2008). The first morphological change that an orchid seed undergoes during germination is swelling to form a protocorm, a rootless, shootless 'blob'. The orchid fungus forms an intracellular relationship with its host, usually in the roots and/or tubers and is thus classed as an endomycorrhiza. It forms hyphal coils, called pelotons, in the cells of its host, which are beneficial to the orchid in that they provide the host plant with nutrients such as soluble sugars (Rasmussen 1995, Warcup 1990). The duration of the association varies according to the life history of the particular orchid species, with some species of orchids being completely dependent on their mycorrhizal fungi for life while other species are capable of living without their fungi from shortly after germination. The ease of cultivation of *Pterostylis* species and the green colour of almost all plant parts strongly suggest that adult plants are not obligately dependent on their mycorrhizal associates as adult plants.

Plants of *Pterostylis saxicola*, like those of most other species in Orchidaceae subfamily Orchidoideae, are deciduous, with the whole shoot system growing anew every year from a dormant tuber. The new shoot usually starts growing from an apical meristem on the tuber in late summer, with new shoots usually breaking the soil surface by March. The shoot develops into a "rosette" of crowded leaves just above ground level and in late winter a terminal raceme starts growing from the centre of the rosette, reaching anthesis in Spring. While the shoot is growing above ground, a new replacement tuber is growing below ground, from the base of the shoot. Some species of *Pterostylis* multiply and spread vegetatively by producing additional new tubers on the ends of long roots but the subgenus to which *P. saxicola* belongs, *Oligochaetochilus*, does not share this attribute (Jones 2006).

Figure 2. Flowering plant of *Pterostylis saxicola*, at Scheyville National Park, showing the basal rosette of crowded leaves lying flat on the ground and a terminal, erect inflorescence, bearing one open flower from the side and an unopened flower bud.

Figure 3. Flower of *Pterostylis saxicola*, at Scheyville National Park, frontal view, showing galea, labellum and paired lateral sepals.

Almost all species of *Pterostylis* are deceptively pollinated by male flies that attempt to copulate with the labellum of the flower. The labellum mimics a female fly of a particular species (or species group) in size, appearance and texture and by exuding an allomone that is identical to the pheromone released by the female flies (Phillips et al. 2013, Kuiter & Findlater-Smith 2017). In species of *Pterostylis* for which the pollination process has been studied and described, the labellum is highly motile ("irritable"), like that of *Pterostylis* saxicola, and a male fly that lands on it is tossed inside the hood (galea) formed by the dorsal sepal and lateral petals, and trapped there. The only escape route provided by the flower is a tunnel through which the male fly must squeeze in order to escape. In the process of negotiating its exit, the fly is forced to rub past the stigma of the flower, depositing on it any pollinaria that it was already carrying. The fly is then forced to contact the anther, sticking a pollinarium on its thorax, before it can finally escape. The pollinator of *P. saxicola* is still unknown, but the pollinators of other species of *Pterostylis* subgenus *Oligochaetochilus*, where known, are males of unnamed species of *Orfelia* (Mycetophilidae) (Kuiter & Findlater-Smith 2017). Sexually deceptive pollination has evolved multiple times in the Australian terrestrial orchid flora, involving hundreds of species (Weston et al. 2014). Most of those for which pollinators have been identified are pollinated by the males of only one species of insect and *P. saxicola* is most likely pollinated by a single species of fly too.

Fruiting capsules of *Pterostylis saxicola* mature quickly, with the most proximal capsules sometimes dehiscing before the most distal flowers have withered. They split down six sutures to release thousands of minute, wind-dispersed seeds in November to early December.

2.3 Distribution and abundance

Records for *Pterostylis saxicola* are widely distributed across the Cumberland Plain and lower Blue Mountains in an area bounded by Scheyville, Freemans Reach, Glenbrook, Douglas Park, Picnic Point, Ryde (an unvouchered record) and Cattai, with an outlying record from the Gingra Range in Kanangra Boyd National Park (Bionet Atlas, National Herbarium of New South Wales specimen database, all accessed 26/7/2018). It has been recorded at altitudes ranging from 30 to 400 metres. It is very sporadically distributed, partly because much of this land has been cleared for agriculture and suburban development but the outlying record suggests that any habitat model is unlikely to be a powerful predictor of the presence of populations at particular locations.

Plants are usually gregarious, with most collectors and observers noting multiple plants co-occurring together. At two sites for which I had highly precise grid references, and which I characterised in detail, I found plants in clusters: 10 plants in a 10x10 cm patch, two plants 5 cm apart, and 57 in a patch smaller than one square metre. As *P. saxicola* does not usually multiply vegetatively (Jones 2006), these clusters must be the result of seeds germinating close to their parents.

2.4 Habitat requirements

The habitat model published in the endangered species profile for *Pterostylis saxicola* (NSW Office of Environment and Heritage 2018a) states that it is "most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *P. saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils". This description applies accurately to the habitat associated with some records in the southern half of the species' distribution but not to those found elsewhere. The distributional range and habitat requirements of *P. saxicola* can be subdivided into two main sub-populations and one outlying population.

The northern sub-population is in an area bounded by Scheyville, Freemans Reach, "The Ironbarks" near Glenbrook, Toongabbie, Ryde, Glenhaven and Cattai. The substrate underlying the sites at

Scheyville, Freemans Reach and Ryde is deep Ashfield Shale (Wianamatta Group), but the Cattai, Toongabbie and Glenbrook records came from Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition zones. All of these sites are in gently rolling country, not on rugged sandstone outcrops.

The plant communities associated with recorded sites for *Pterostylis saxicola* in its northern sub-population, as determined from collectors' and observers' notes and from identification of precisely specified sites on the vegetation maps of Tozer *et al.* (2010), are their map units GW p29 and GW p2. According to the references cited in the Bionet Vegetation Classification, these are equivalent to:

- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain (see figure 4);
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain (see figure 5).

Most records from the southern sub-population, in an area bounded by Macquarie Fields, Minto, Douglas Park, Woronora River and Picnic Point differ in habitat from the northern records. In cases where they have highly precise locality data and/or detailed habitat descriptions, collections and observations from this area have been made on Hawkesbury Sandstone, on the rims and sides of the gorges of the Nepean, Georges and Woronora Rivers. Observers' notes repeatedly describe the soils as very shallow sands overlying sandstone rock shelves, as stated in the published habitat model (NSW Office of Environment and Heritage 2018a). However, contrary to that model, only some of them were recorded above cliff lines. All of these sites occur close to outcrops of Ashfield Shale, mostly downhill from them, but for some of these sites, the only evidence of shale influence on the environment seems to be associated plant community types. Precisely georeferenced sites are mapped by Tozer *et al.* (2010) to their map units DSF p146, Sydney hinterland transition forest and their map unit GW p2, Cumberland Shale Sandstone Transition Forest. According to the references cited in the Bionet Vegetation Classification, these are equivalent to:

- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain).

In addition to the two main sub-populations, there is also an outlying, precisely georeferenced, herbarium record from the Gingra Range in Kanangra Boyd National Park. This site is on Devonian metasediments, and was mapped by Tozer *et al.* (2010) to their map unit DSF p37 Kowmung-Wollondilly Grassy Gorge Woodland.

According to the references cited in the Bionet Vegetation Classification, this is equivalent to:

- 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges.

Pterostylis saxicola has mostly been recorded growing in intact native vegetation but there is one notable exception: a plant described in a "Car Park growing through bitumen", adjacent to a large area of bushland from which other substantiated records had been made. Several others have come from small patches of remnant urban bushland, in some cases less than a hectare in area, surrounded by highly disturbed land, and from a long, narrow patch less than 50 m wide. However, no records mention heavily weed-infested habitats or evidence of heavy grazing by introduced herbivores. Sites with significant edge effects are probably not sustainable reserves for conserving this species.

Figure 4. PCT 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain, on Ashfield Shale at Scheyville National Park (my site PS1).

Figure 5. PCT 1395 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, on Mittagong Formation at Cattai (my site PS7).

3. Description of the study area

3.1 Land use history

This section is based primarily on information from penrithhistory.com, a website maintained by Penrith Library (Penrith Library 2018), except where other sources are explicitly cited. The first human inhabitants of the study area were Aborigines who moved there many thousands of years ago. People of the Darug language group were occupants of the study area when the British first started to settle in the Sydney Region in 1788 (Logan 2011). These hunter-gatherers would have managed the grassy woodlands that grew on Bringelly Shale and Cenozoic alluvia of the area using fire-stick farming methods (Benson & Howell 1990). They used the natural landscape seasonally, taking advantage of different food sources depending on availability, establishing temporary open camps of simple gunyahs on higher ground near water courses. The Nepean River and its tributaries were significant sources of fish, shellfish and useful plants while the wooded plains and gentle hills were sources of game, edible tubers, seeds, fruits and materials for making clothing, tools and shelters (Logan 2011).

In 1789, 18 months after the founding of Sydney, Captain Watkin Tench led a group from Rose Hill to the Nepean River, followed soon by further expeditions from there to Razorback in the south and downstream to the Hawkesbury River in the north (Fitzhardinge 1967). The alluvial flats of the Nepean River and adjacent grassy woodlands on Wianamatta Shales, offered more fertile farming land than sandy soils derived from Hawkesbury Sandstone surrounding the Cumberland Plain. However, violent clashes between the British and the Darug people led by Pemulwuy delayed settlement west of Prospect until 1802, when Governor King built a headquarters for his government stock reserve at what is now Rooty Hill (NSW Office of Environment and Heritage 2018b). King went on to issue land grants at what are now Penrith and Cranebrook in 1804, and Orchard Hills, St Marys and Badgerys Creek in 1806. Further land grants were made in what are now Mulgoa and Greendale in 1810, and Luddenham in 1813. In 1815 the Great Western Road was completed between Parramatta and Bathurst, placing the northern part of the study area on what soon became a major transport artery. Completion of the western railway line from Sydney to Penrith in 1867 and its extension to Bathurst in 1876 significantly enhanced accessibility of the northern part of the study area. From first settlement in the early 19th century to the 1950s, land use in the study area was dominated by timber production, agriculture and quarrying, all of which necessitated extensive clearing of native vegetation, especially from the more fertile alluvial and clayey soils. Agricultural activities conducted in the areas have included the cultivation of wheat (which was curtailed in 1861 when the whole crop was destroyed by an infestation of rust disease) and other cereal crops, grazing of sheep, cattle and horses, intensive production of pigs and poultry, and the cultivation of fruit, vegetables, turf and cut-flowers (Wilkinson 2011). Industrial facilities that processed saw logs and agricultural produce, such as timber mills, flour mills, milk processing plants, cattle sale yards, tanneries, canneries and wineries began to be built early in the 19th century and mostly continued operating well into the 20th century. A few manufacturing plants, producing textiles, munitions and bricks were also developed in the 19th and early 20th centuries.

Penrith grew slowly as an urban centre during the 19th century and first half of the 20th century, but population growth accelerated after 1960 due to the establishment of several social housing projects by the N.S.W. Housing Commission. This was followed from the 1970s by the gradual rezoning of much of the agricultural land in the northern part of the Greater Penrith to Eastern Creek Urban Release Investigation Area for urban development. Land use in this growth area is now dominated by residential housing, retail precincts, light industry and transport infrastructure, but Orchard Hills in the south is still largely rural. Most protected patches of remnant native vegetation are less than 20 Ha in area but the two largest reserves containing intact bushland, Wianamatta

Regional Park in the north and The Defence Establishment Orchard Hills in the south, cover approximately 900 Ha and 1370 Ha respectively.

The Western Sydney Aerotropolis Growth Area is still largely rural but includes a staggeringly small area of remnant bushland in public reserves. The largest patch consists of about 3.5 hectares of weed-infested Grey Box – Forest Red Gum grassy woodland in Sales Park, Luddenham. Soon it will be a small green oasis, surrounded by urban development.

3.2 Landscape context

The Sydney Basin is a geological entity, composed of sedimentary rocks, which is shaped a bit like a tilted, triangular, art deco saucer. In the middle of this structure is the Cumberland Plain, in the northern half of which is located the study area. Here, the uppermost strata of the Sydney Basin, Cenozoic alluvia, patchily overlie the Triassic Wianamatta Group, comprising Bringelly Shale, Minchinbury Sandstone and Ashfield Shale, which, in turn overlie Triassic Hawkesbury Sandstone, the Triassic Narrabeen Group and the Permian Shoalhaven Group (Martyn 2018). Scattered small Jurassic basalt diatremes occasionally pierce the sedimentary strata, such as at Lethbridge Park and Bidwill.

The most commonly exposed substrate in the study area is Bringelly Shale. Over this, the second most commonly exposed substrate, Quaternary alluvial clay, which has mostly been eroded from Bringelly Shale, has accumulated in a branching pattern across the study area on the floodplains of South Creek and its tributaries, including Kemps, Badgerys, Cosgrove, Blaxland, Claremont, Werrington and Ropes Creeks (NSW Department of Minerals and Energy 1991).

Other substrates are also exposed over a much smaller area on the northern and western margins of the Greater Penrith to Eastern Creek Urban Release Investigation Area. Two patches of Londonderry Clay, a Paleogene-Neogene alluvium, covering an area of about six square kilometres, have been preserved on the northern edge between St Marys and Shanes Park. On the western margin, between Mulgoa and the north-western corner, gravelly, sandy, silty and clayey Quaternary alluvia of the Cranebrook formation line the eastern bank of the Nepean River and its eastern tributaries, forming an extensive deposit up to four kilometres wide north of Regentville. On the western margin, several square kilometres of Ashfield Shale and a smaller area of Rickabys Creek Gravel, a Paleogene-Neogene alluvium, are exposed from Jamisontown to Glenmore Park.

The whole study area is gently tilted from south to north and all watercourses flow in that general direction. Topography varies subtly in the Greater Penrith to Eastern Creek Urban Release Investigation Area with low, rounded ridges alternating with flat-bottomed flood plains. The lowest point is in the north west corner at Upper Castlereagh, where the bank of the Nepean River is below 10 m altitude, and along the northern margin the altitude is less than 70 metres. The highest point in the Greater Penrith to Eastern Creek Urban Release Investigation Area is 93 metres in altitude at Sovereign, in the south west corner. Along the boundary between the two growth areas, altitude varies from 40 metres in the east to 90 metres in the west.

Topographic relief is still quite gentle, but more noticeable, with steeper slopes, in the Western Sydney Aerotropolis Growth Area. The altitude varies from 40 metres in the north eastern corner to 106 metres just south east of Luddenham village.

Topographic variation, as well as distance from the sea influence climate. The Cumberland Plain is the driest part of the Sydney Region and also experiences the most extreme temperatures in the region. Key climate statistics for the three weather stations in the study area, for which data are freely available, are shown in table 1. The whole study area is subject to winter frosts.

Weather station	Mean annual rainfall (mm)	Mean maximum temperature (°C)	Mean minimum temperature (°C)
Penrith Lakes AWS (1995-)	718.6	31.0	5.3
Orchard Hills Treatment Works (1970-)	832.7	28.5	5.3
Badgerys Creek McMasters F (1995-)	794.3	28.6	3.8

Table 1. Key climatic statistics for weather stations in the growth areas.

3.3 Native vegetation communities

In terms of the plant community types recognised in the Bionet Vegetation Classification and the vegetation maps that were prepared for this project, the remnant native vegetation of the study area consists of:

- 724 Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain (191.3 ha);
- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain (167.4 ha);
- 781 Freshwater wetland (68.9 ha);
- 830 Forest Red Gum - Grey Box shrubby woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion (2.8 ha);
- 835 Forest Red Gum – Rough Barked Apple grassy woodland on alluvial flats of the Cumberland Plain (989.2 ha);
- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain (2334.1 ha);
- 850 Grey Box – Forest Red Gum grassy woodland on shale of the southern Cumberland Plain (88.5 ha);
- 883 Hard-leaved Scribbly Gum - Parramatta Red Gum heathy woodland of the Cumberland Plain (6.5 ha);
- 1105 River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion (94.2 ha);
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain (2.0 ha).
- 1800 Swamp Oak open forest on river flats of the Cumberland Plain and Hunter valley (228.5 ha).

In the study area, according to the vegetation mapping that was conducted for this project, the following substrates support the following plant community types:

- Quaternary alluvium: 781, 835, 849, 850, 1105, 1800;
- Londonderry Clay: 724, 725, 835, 849;
- Bringelly Shale: 724, 725, 835, 849, 883;
- Ashfield Shale: 835, 849, 1395;
- Rickabys Creek Gravel: 849.

PCT 849 is the most abundant plant community type throughout both growth areas, growing on most of the uncleared land above the zone of floodwater inundation, most commonly on Bringelly Shale. Over 50% of the two largest patches of remnant bushland, Wianamatta Regional Park and the Defence Establishment Orchard Hills is covered in PCT 849 and it covers most of the smaller reserves too. PCT 835 covers the second largest area and also occurs throughout the study area, vegetating the uncleared flood plains of South Creek and its tributaries on Quaternary alluvium, as well as the lowest part of the adjacent slopes. The banks of those creeks as well as some other blocks of low-lying land on Quaternary alluvium, are dominated by PCT 1800. PCTs 724 and 725 are dominant on

Londonderry Clay in the northern part of the study area but also occur patchily elsewhere on Bringelly Shale, most notably in the Kemps Creek area and on a rectangular block of regenerating vegetation 0.6-0.8 km west of Luddenham Road, 0.2-0.6 km north of the Warragamba-Prospect water pipeline. PCT 1105 dominates remnant vegetation on the banks of the Nepean River north of Penrith, on Cranebrook Formation alluvium. The remaining plant community types occur only rarely as tiny fragments in the study area. About 6.5 ha of PCT 883 occurs in two patches at the eastern end of Wianamatta Regional Park and about 15 ha remains in a block 0.6 km north of Elizabeth Drive, Kemps Creek. PCT 1395 is represented by a sliver of two hectares on Ashfield Shale at Glenmore Park. PCT 830 is restricted to a fringe of under three hectares in area on the eastern the border of Mulgoa Nature Reserve.

Weed infestation is a problem throughout the study area. This is well illustrated by two sites at Claremont Meadows. The vegetation at a site beyond the eastern end of Caddens Road, on the flood plain of South Creek, which I visited but did not include in my sampling, consisted of a closed forest of *Ligustrum sinense*, *Ligustrum lucidum* (both natives of China, the latter extending to Japan) and *Olea europaea* subsp. *cuspidata* (native of Africa), with scattered emergent trees of *Eucalyptus tereticornis* and *E. amplifoli*a. This would have been a forest of PCT 835 before weed infestation converted it into a novel, derived plant community. Only 0.6 km to the west north west of that site is a superficially pristine block of PCT 724. Even here, however, *Ligustrum sinense* and *Ligustrum lucidum* already dominate the vegetation near South Creek, *Eragrostis curvifolia* is a common component of the ground stratum and seedlings of *Olea europaea* subsp. *cuspidata* are starting to establish throughout the reserve.

4. Assessment of species presence and habitat

4.1 Existing records and surveys

A search for records of *Pterostylis saxicola* in the Bionet Atlas, conducted on 3 December 2018, returned 30 observational records. Several targeted surveys of this species seem to have been conducted since 2000. Teresa James surveyed for this species across the species' distribution in Spring 2007, for the NSW Department of Environment Climate Change and Water, submitting an unpublished report, observational records at five sites and a herbarium specimen (Teresa James personal communication). From November 2010 to January 2011, Total Earth Care Pty Ltd conducted a survey of threatened plant species in the Simmos Beach Recreation Reserve, Macquarie Fields for Campbelltown City Council, submitting an unpublished report and observational records at eight sites (Lachlan Laurie personal communication). In Spring 2011, *P. saxicola* was again targeted at Simmos Beach Recreation Reserve by a research group from The Royal Botanic Gardens and Domain Trust that investigated the mycorrhizal associates of the orchid, with the aim of identifying and culturing the relevant fungus or fungi, adding seeds of this species to the seed collection at the Australian Plantbank, and germinating seeds of the orchid in septic culture. Two scientific papers were published, and three herbarium specimens collected as part of this project. All of those surveys and searches were conducted outside the study area.

Highly precise grid references associated with a number of the Bionet records enabled me to identify the plant community types (as mapped by Tozer *et al.* (2010) and substrates (as mapped by NSW Department of Minerals and Energy 1991) at sites at which these records of *Pterostylis saxicola* occurred. They were:

- 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain, on Ashfield Shale;

- 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges, on Devonian metasediments;
- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, on Hawkesbury Sandstone;
- 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, on Hawkesbury Sandstone;
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, on Hawkesbury Sandstone;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain, on Ashfield Shale-Mittagong Formation-Hawkesbury Sandstone transitional landscapes.

4.2 Surveys completed for the biocertification

Apart from the surveys conducted for this expert report, no targeted surveys for *Pterostylis saxicola* were conducted for biocertification of the study area.

4.3 Surveys completed for this assessment

4.3.1 Survey Methods

In the course of preparing my expert reports on *Grevillea juniperina* subsp. *juniperina* and *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas (Weston unpublished a,b), I characterised 20 plots of native vegetation in detail, each plot being a circle of radius 30 m (an of area 2827 m^2), centred either on a plant of *Grevillea juniperina* subsp. *juniperina* or *P. saxicola* or on an arbitrarily chosen point (at sites where both the *Grevillea* and the *Pterostylis* were absent). I have included data from five of those plots as samples from outside the study area in my analyses for this report.

I have also used the same methods to search for *Pterostylis saxicola* and characterise 34 plots in and around the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area. I chose the locations with the aim of sampling patches of accessible, remnant bushland representing as broad an ecological range and geographic extent across the two Growth Areas as time would allow, sampling more plots in areas where *Grevillea juniperina* subsp. *juniperina* had previously been recorded. Some habitats, such as freshwater wetlands, and substrates on which neither *Grevillea juniperina* subsp. *juniperina* nor *P. saxicola* had ever been recorded, such as Cranebrook Formation alluvia, were avoided. At each plot I listed all vascular plant species that could feasibly be identified, taking photographs and sometimes specimens of plants for later reference in cases where the plant's identity was in question. The latitude and longitude of the centre of each plot was determined using a GPS instrument. The altitude of each site was determined later from 1:25,000 topographic maps. The soil and topography at each site was described and the substrate identified using the Penrith 1:100,000 geological map (NSW Department of Minerals and Energy 1991) and 1:25,000 topographic maps.

I identified the plant community type in each plot using the PCT identification tool in Bionet, and my list of plant species found in each plot.

I developed an improved habitat model for *Pterostylis saxicola*, using data from the published literature, 38 observers' and collectors' records of *P. saxicola* in the Bionet Wildlife Atlas, vegetation mapping conducted for the Cumberland Plain Conservation Plan (Biosis unpublished), the geological map of the area (NSW Department of Minerals and Energy 1991) and my own botanical surveys of 7 plots where I was confident that plants of *P. saxicola* were present.

4.3.2 Results and Conclusions from my Surveys Completed for this Assessment

Site and ecological data for my plots are shown in Appendix 2. I sampled most plant community types and most substrates known in the study area in these plots, as well as one plant community type, PCT 849, in which *Pterostylis saxicola* has been recorded. However, I did not find *P. saxicola* in any plots within the study area.

According to my identifications of plant community types, *Pterostylis saxicola* was present in the following PCTs in seven of my plots outside the study area:

- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain (2 plots);
- 1081 Red Bloodwood - grey gum woodland on the edges of the Cumberland Plain (3 plots);
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney (1 plot);
- 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain (1 plot).

According to the vegetation mapping conducted for this study, two of these plant community types were found within the study area, PCT 849, which is common and widespread there, covering 2344 hectares, and PCT 1395, which is represented by a remnant of just two hectares at Glenmore Park.

Plant community types that I sampled in the study area, in which *Pterostylis saxicola* has never been recorded, were the following.

- 725 Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain (nine plots sampled);
- 835 Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain;
- 1800 Swamp Oak open forest on riverflats of the Cumberland Plain and Hunter valley (3 plots).

Substrates on which *Pterostylis saxicola* was present in my plots outside the study area were:

- Hawkesbury Sandstone (four plots);
- Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition zone (one plot);
- Ashfield Shale (two plots).

Hawkesbury Sandstone is not exposed anywhere in the study area. An area of 14.3 hectares of Ashfield Shale supports intact remnant vegetation of PCTs 849 and 1395 in the study area, in several small reserves at Glenmore Park and on private land north of Mulgoa. I inspected two of the reserves for plants of *Pterostylis saxicola* on 22 November 2018 (including my plot PEC29), when plants that had recently flowered outside the study area were still clearly visible but I could find no evidence of *P. saxicola* in either reserve. Nevertheless, *P. saxicola* might occur in small areas of suitable habitat within the study area but have been overlooked. Even mature plants do not flower every year, especially if climatic conditions have been poor (see section 2.4), as they have over the past 12 months of drought.

Pterostylis saxicola has never been recorded on the following substrates that are exposed in the study area:

- Bringelly Shale;

- Cenozoic Alluvium.

Previously, (Weston unpublished) I argued that the habitat model that was published as part of OEH's threatened species profile of *Pterostylis saxicola* (NSW Office of Environment and Heritage 2018a) needed updating. The new habitat model that I proposed there was as follows:

Occurs on the Cumberland Plain along an ecological gradient from:

- Clay soils derived from Ashfield Shale (Wianamatta Group) on flat to gently hilly landscapes in PCT 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain;
- to: clay to sandy soils derived from Hawkesbury Sandstone – Mittagong Formation – Ashfield Shale transition substrates on gently hilly landscapes, in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain;
- to: thin accumulations of humus-rich sandy soil on Hawkesbury Sandstone sheets and rock shelves, on the rims and steep sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, or PCT 1083 Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, or PCT 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney.

Also occurs outside the Cumberland Plain on Devonian slate, in PCT 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges.

4.4 Assessment of species presence

4.4.1 Likelihood of species presence

The total area of suitable habitat in the study area (see 4.5 below) is only 14.3 ha, all of which occurs in the Greater Penrith to Eastern Creek Urban Release Investigation Area. Given the rarity and sporadic distribution of this species, the likelihood of any populations remaining undetected in those remnants is low. However, it is not zero. No suitable habitat exists in the Western Sydney Aerotropolis Growth Area and it is most unlikely to occur there.

4.4.2 Justification for determining presence

Pterostylis saxicola has never been recorded in either the Greater Penrith to Eastern Creek or Western Sydney Aerotropolis Growth Area and I failed to find any plants of it in the 30 plots that I surveyed in detail. Nevertheless, a small area of suitable habitat remains near the western margin of the Greater Penrith to Eastern Creek Urban Release Investigation Area so its presence there cannot be ruled out. A precautionary approach would treat all of the remaining suitable habitat as part of the area of occupancy of this species.

4.5 Assessment of suitable habitat

4.5.1 Suitable habitat within the study area

Assessing the suitable habitat of *Pterostylis saxicola*, given the present state of knowledge of the biology of this species, has to be a descriptive exercise. The causal processes that constrain its distribution and abundance are largely unknown but probably include physiological limits to tolerance of temperature and humidity, the availability of mineral nutrients and water, factors limiting the distribution and abundance of its obligate symbionts – its pollinators and mycorrhizal associates, and the distribution and abundance of native herbivores, pathogens and parasites. Suitable habitat has to be estimated on the basis of associations between its distribution and environmental proxies such as substrate types and plant community types, and interactions between them. Multidimensional bioclimatic modelling would extend this approach to climatic variables but such analysis is beyond the scope of this report.

Records of *Pterostylis saxicola* have been mapped to six plant community types recognised in the Bionet Vegetation Classification, two of which are known to occur in the study area:

- 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain, on Ashfield Shale;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain, on Ashfield Shale-Mittagong Formation-Hawkesbury Sandstone transitional landscapes.

Pterostylis saxicola has almost always been reported from intact native vegetation (see section 2.4), which is unsurprising, given its dependence on at least two other symbiotic associates and the vulnerability of ground orchids to grazing by introduced herbivores (Duncan *et al.* 2005). It is reasonable to conclude that only intact remnants of the two plant community types listed above comprise suitable habitat for this species.

Pterostylis saxicola is known to occur naturally on four substrate types recognised by the Geological Survey of New South Wales, only one of which is known to be exposed in the study area:

- Triassic Ashfield Shale (Wianamatta Group).

The intersection of either of the above plant community types with Ashfield Shale indicates suitable habitat for *Pterostylis saxicola*.

4.5.2 Species polygons

My species polygons for *Pterostylis saxicola* (figure 6) include all patches of PCTs 849 and 1395 growing on Ashfield Shale in the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area. They were prepared with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by Biosis Pty Ltd. A shape file for these polygons is held by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment.

My arguments justifying these polygons have been set out in sections 2.3, 2.4, 4.1, 4.3, 4.4 and 4.5.1.

4.5.3 Estimate of area of habitat

The areas estimated to represent suitable habitat for *Pterostylis saxicola* in figure 7 are as follows:

- Greater Penrith to Eastern Creek Area Urban Release Investigation Area
    - Habitat mapped – 14.3 ha
    - Habitat impacted by development footprint – 0.8 ha
- Western Sydney Aerotropolis Growth Area
    - Habitat mapped – 0 ha
    - Habitat impacted by development footprint – 0 ha

These estimates were calculated with the assistance of Darren James (DAJ Environmental), using the ArcMap software package, from vegetation maps of the study area produced by

Biosis Pty Ltd. My arguments justifying the polygons from which these estimates were calculated have been set out in sections 2.3, 2.4, 4.1, 4.3, 4.4 and 4.5.1.

5. Information used in this assessment

My assessment was based on information obtained from a diversity of sources:

- Databases of observational and vouchered specimen records of *Pterostylis saxicola*:
  - National Herbarium of New South Wales specimen database;
  - Bionet Wildlfie Atlas;
- Interviews with collectors, observers, propagators and scientists of *P. saxicola* (see section 6, acknowledgements);
- Fieldwork at 42 sites (see Appendix 1):
  - Seven sites at which *P. saxicola* had previously been collected;
  - 14 sites in or near the study area that had potentially suitable habitat;
- The scientific and scholarly literature (see section 7, references);
- A GIS map of the study area with layers representing the boundaries, plant community types, development footprint, and the results of flora and fauna surveys, prepared by Biosis Pty Ltd, provided through the Biosis spatial viewer;
- Background information on the study area provided by the Biodiversity and Sustainability Branch of the NSW Department of Planning and Environment;
- My personal knowledge and experience, gained from 40 years as a professional botanist specialising in the systematics and ecology of the Orchidaceae.

6. Acknowledgements

I am grateful to Teresa James, Andrew Orme, Peter Ridgeway, Karen Sommerville, Greg Steenbeeke and Brian Towle, for generously sharing their knowledge about *Pterostylis saxicola* with me. Darren James (DAJ Environmental) and Phillip Rofe (Biodiversity and Sustainability Branch, NSWDPE) assisted me in producing species polygons and area estimates using the ArcMap software package. Judith Fulham kindly permitted and assisted me to survey the habitat of *P. saxicola* on her property at Cattai. Jenny Linklater and Igor Maric kindly facilitated my visit to Hawkesbury High School, Freemans Reach, after school hours to survey the population of *P. saxicola* there. I am grateful to Laura Torrible, Dayle Green and Greg Steenbeeke for the provision of support and advice throughout this project.

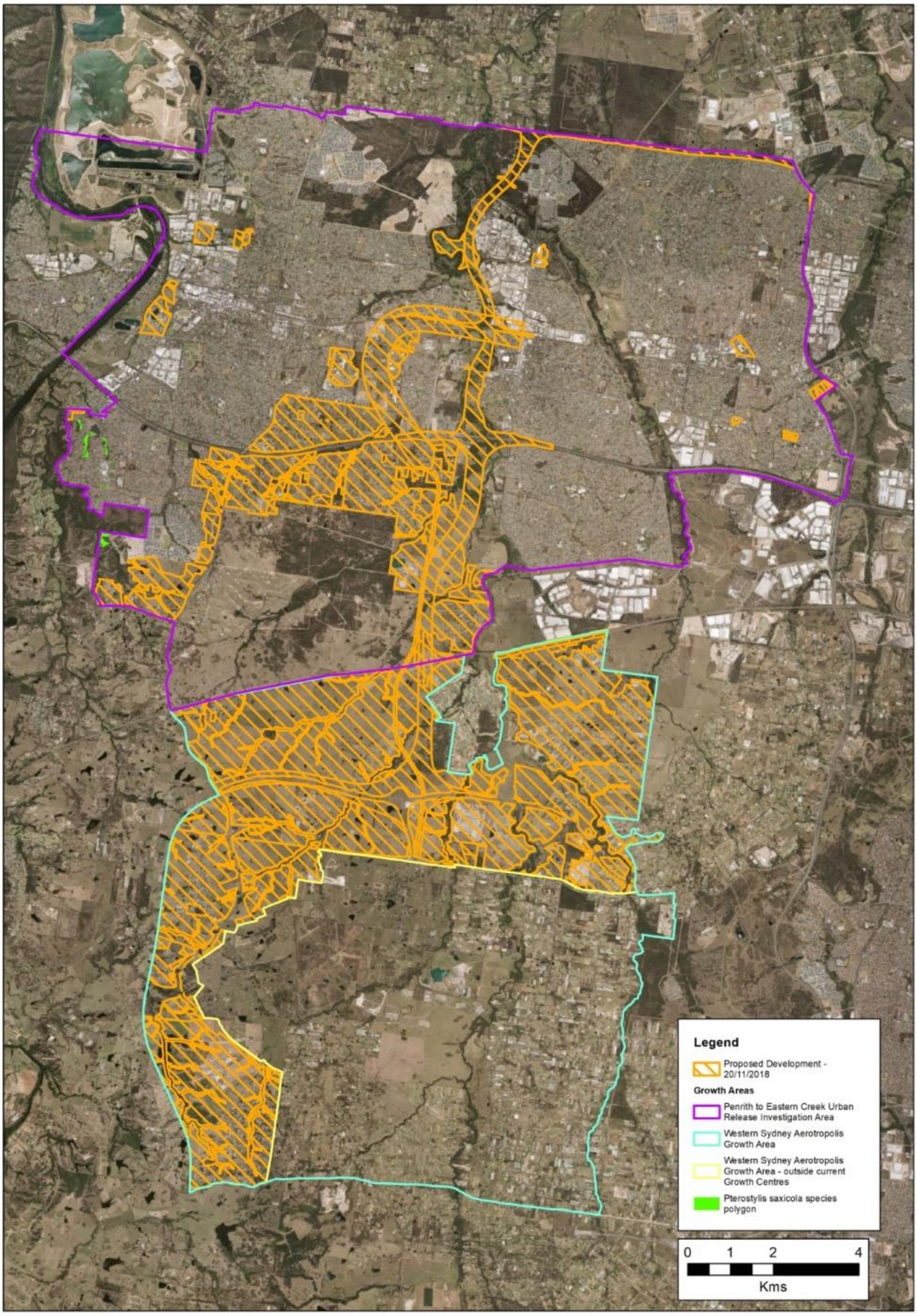


Figure 6. Polygons of suitable habitat for *Pterostylis saxicola* in the Greater Penrith to Eastern Creek Urban Release Investigation Area and Western Sydney Aerotropolis Growth Area.

7. References

Benson D, Howell J (1990) ‘Taken for Granted: The Bushland of Sydney and its Suburbs’. Kangaroo Press, Kenthurst, NSW, Australia.

Duncan M, Pritchard A, Coates F (2005) Major threats to endangered orchids of Victoria. *Selbyana* 26: 189-195.

Fitzhardinge LF (1967) Watkin Tench (1758-1833). *Australian Dictionary of Biography* 2.

Jones DL (2006) ‘A Complete Guide to Native Orchids of Australia Including the Island Territories’. New Holland, Sydney, Australia.

Jones DL, Clements MA (1997) Characterisation of *Pterostylis gibbosa* and description of *Pterostylis saxicola*. *The Orchadian* 12: 128-136, 144.

Kuiter RH, Findlater-Smith MJ (2017) ‘Overview of *Pterostylis* Pollination (Orchidaceae) in Victoria’. Aquatic Photographics, Seaford, Victoria, Australia.

NSW Department of Minerals and Energy (1991) Penrith 100K Geological Sheet 9035. Sydney, NSW, Australia.

Logan GM (2011) ‘Wianamatta Regional Park: Conservation Management Plan volume 2 ’. NSW Department of Environment, Climate Change and Water, Sydney, NSW, Australia.

Martyn J (2018) ‘Rocks and Trees: A Photographic Journey through the Rich and Varied Geology, Scenery and Flora of the Sydney Region’. STEP Inc, Turramurra, NSW, Australia.

NSW Office of Environment and Heritage (2018a) Sydney Plains Greenhood – profile. https://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10705, accessed 25/7/2018.

NSW Office of Environment and Heritage (2018b) The Rooty Hill. https://www.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=5054842, accessed 9/11/2018.

Penrith Library (2018) Penrith City Local History. penrithhistory.com (accessed 6/11/2018).

Phillips RD, Scaccabarozzi D, Retter BA, Hayes C, Brown GR, Dixon KW, Peakall R (2013) Caught in the act: pollination of sexually deceptive trap-flowers by fungus gnats in Pterostylis (Orchidaceae). *Annals of Botany* 113: 629–641.

Rasmussen HN (1995) “Terrestrial Orchids: From Seed to Mycotrophic Plant”. Cambridge University Press, Cambridge, UK.

Sommerville KD, Siemon JP, Wood CB, Offord CA (2008) Simultaneous encapsulation of seed and mycorrhizal fungi for long-term storage and propagation of terrestrial orchids. *Australian Journal of Botany* 56: 609–615.

Tozer MG, Turner K, Keith DA, Tindall D, Pennay C, Simpson C, MacKenzie B, Beukers P, Cox S (2010) Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. *Cunninghamia* 11: 359–406.

Weston PH (unpublished a) Expert report on the Juniper-leaved Grevillea, *Grevillea juniperina* subsp. *juniperina* in the Greater Macarthur and Wilton Growth Areas. Report to Department of Planning and Environment for the Strategic assessment for Cumberland Plain Conservation Plan.

Weston PH (unpublished b) Expert report on the Sydney Plains Greenhood, *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas. Report to Department of Planning and Environment for the Strategic assessment for Cumberland Plain Conservation Plan.

Weston PH, Perkins AJ, Indsto JO, Clements MA (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier R, Bernhardt P (eds) ‘Darwin's Orchids: Then and Now’. University of Chicago Press, Chicago, Ill, USA.

Weston PH, Perkins AJ, Entwisle TJ (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15.

Wilkinson J (2011). Agriculture in the Sydney region: historical and current perspectives. NSW Parliamentary Library Research Service E-brief 2/2011: 1-13. https://www.parliament.nsw.gov.au/researchpapers/Documents/agriculture-in-the-sydney-region-historical-and-/Agriculture%20in%20the%20Sydney%20region%202.pdf (accessed 9/11/2018).

8. Appendices

8.1 Appendix 1: Characterisation of habitat at selected sites

The tables on following pages record data that I collected at sites both within and outside the study area. Each site was centred on an arbitrarily selected plant of *Grevillea juniperina* subsp. *juniperina* or *Pterostylis saxicola*, or at an arbitrarily chosen point where the focal taxon was absent from the site. At each site the precise latitude and longitude, altitude, substrate, and soil description, were recorded. Also, at each site all plant species that could be reliably identified were recorded within a radius of 30 metres. Locations at which *Pterostylis saxicola* has been recorded by me and/or others have had their latitudes and longitudes transformed to the nearest 10 minutes.

Site	Location	Latitude	Longitude	Altitude (m)	Substrate
PEC1	Wianamatta Regional Park, 50 m S of Palmyra Ave, Ropes Crossing	33°43'10.7"S	150°46'34.6"E	30	Londonderry Clay
PEC2	Wianamatta Regional Park, S boundary, Ropes Crossing	33°43'52.6"S	150°46'27.5"E	30	Londonderry Clay
PEC3	Tregear Reserve, Tregear	33°44'45.0"S	150°47'15.0"E	25	Quarternary alluvium
PEC4	Ropes Crossing Boulevard 60 m N of Ropes Creek, Ropes Crossing	33°44'22.3"S	150°46'43.2"E	20	Quarternary alluvium
PEC5	Ropes Crossing Boulevard 350 m N of Ropes Creek, Ropes Crossing	33°44'13.0"S	150°46'43.8"E	30	Londonderry Clay
PEC6	Links Road, St Marys	33°44'15.7"S	150°45'57.0"E	20	Londonderry Clay
PEC7	Embankment, east of entrance to Dunheved Golf Course, St Marys	33°44'44.1"S	150°45'52.5"E	25	Londonderry Clay
PEC8	Embankment, south of abandoned railway line, St Marys	33°44'46.8"S	150°46'03.1"E	25	Londonderry Clay
PEC9	Bushland between Christie St and abandoned railway line, St Marys	33°44'48.9"S	150°46'08.4"E	25	Londonderry Clay
PEC10	Abandoned railway land N of 73A Christie St, St Marys	33°44'46.3"S	150°45'59.4"E	25	Londonderry Clay
PEC11	Southern side of abandoned railway station, St Marys	33°44'48.4"S	150°46'14.2"E	30	Londonderry Clay
PEC12	Bush between Dunheved Rd and John Oxley Avenue, Werrington County	33°45'09.1"S	150°44'59.4"E	20	Quarternary alluvium
PEC13	Bush between Dunheved Rd and Dunheved Golf Course, Werrington County	33°44'49.2"S	150°45'08.4"E	30	Quarternary alluvium
PEC14	Sinclair Parade, Jordans Springs	33°42'53.3"S	150°43'44.6"E	50	Bringelly Shale
PEC15	Putland Street, Claremont Meadows	33°46'12.8"S	150°45'21.9"E	30	Bringelly Shale
PEC16	Corner of Caulfield Road and Equestrian Circuit, Claremont Meadows	33°46'42.3"S	150°45'16.8"E	40	Bringelly Shale
PEC17	Caddens Road east, Claremont Meadows	33°46'48.9"S	150°45'36.6"E	25	Quarternary alluvium
PEC18	Heaton Avenue, Claremont Meadows	33°46'49.0"S	150°44'28.7"E	35	Quarternary alluvium
PEC19	Pandorea Street, Claremont Meadows	33°46'55.1"S	150°44'35.4"E	40	Bringelly Shale
PEC20	Pandorea Street, Claremont Meadows	33°46'57.1"S	150°44'35.4"E	40	Bringelly Shale

Appendix 1a: Environmental data for sites visited as part of this study (continued on next page)

Site	Location	Latitude	Longitude	Altitude (m)	Substrate
PEC21	Flinders Lane, Orchard Hills	33°47'21.7"S	150°45'28.7"E	25	Quarternary alluvium
PEC22	Samuel Marsden Reserve, Orchard Hills	33°47'08.5"S	150°45'40.5"E	25	Quarternary alluvium
PEC23	34-64 Wentworth Rd, Orchard Hills (native vegetation on N side of fence)	33°47'56.9"S	150°44'17.1"E	50	Bringelly Shale
PEC24	Opposite 121 Wentworth Rd, Orchard Hills (through the fence plus road verges)	33°47'52.7"S	150°43'45.5"E	60	Bringelly Shale
PEC25	327 Luddenham Rd, Orchard Hills	33°49'43.2"S	150°45'30.7"E	40	Bringelly Shale
PEC26	Plumpton Park, Plumpton	33°45'10.3"S	150°50'05.9"E	50	Bringelly Shale
PEC27	Dr Charles Mackay Reserve, Mt Druitt	33°46'29.8"S	150°49'39.1"E	70	Bringelly Shale
PEC28	Kestrel Crescent Reserve, Erskine Park	33°47'34.6"S	150°48'34.5"E	45	Bringelly Shale
PEC29	Apple Gum Reserve, Glenmore Park	33°47'00.9"S	150°39'51.0"E	40	Ashfield Shale
PEC30	Forest Redgum Reserve, Glenmore Park	33°46'43.5"S	150°39'44.7.0"E	50	Rickabys Creek Gravel
WSA1	Sales Park, Luddenham	33°52'55.5"S	150°41'26.3"E	90	Bringelly Shale
WSA2	Between Cosgrove Creek and Halmstad Boulevard, Luddenham	33°50'58.9"S	150°44'52.6"E	55	Bringelly Shale
PS1	Old Schofield Trail, Scheyville National Park	33°40'S	150°50'E	70	Ashfield Shale
PS2	Simmos Beach Recreation Reserve Macquarie Fields	34°00'S	150°50'E	45	Hawkesbury Sandstone
PS3	Simmos Beach Recreation Reserve Macquarie Fields	34°00'S	150°50'E	43	Hawkesbury Sandstone
PS4	Boronia Rd Reserve, Peter Meadows Creek, Kentlyn	34°00'S	150°50'E	98	Hawkesbury Sandstone
PS5	Amberdale Reserve, Picnic Point	34°00'S	151°00'E	36	Hawkesbury Sandstone
PS6	Hawkesbury High School, Freemans Reach	33°30'S	150°50'E	40	Ashfield Shale
PS7	Mitchell Park Road, Cattai	33°30'S	150°50'E	25	Ashfield Shale-Mittagong Formation-Hawkesbury Sandstone

Appendix 1a (continued): Environmental data for sites visited as part of this study

Site	Soil description	Vegetation structure (canopy)	Vegetation structure (understorey)	PCT (my identification)
PEC1	brown , gravelly clay-loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC2	brown , gravelly clay-loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC3	brown clay loam	dry sclerophyll woodland	grassy understory with scattered shrubs	1800
PEC4	brown clay loam	dry sclerophyll forest	dense shrubby understorey	1800
PEC5	red-brown gravelly loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC6	red-brown gravelly clay	remnant dry sclerophyll woodland	grassy understorey with scattered shrubs	849
PEC7	red-brown gravelly clay	dry sclerophyll forest	grassy, moderately dense shrubby understorey	725
PEC8	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	725
PEC9	red-brown gravelly clay	dry sclerophyll woodland	grassy, shrubby understorey	849
PEC10	red-brown gravelly clay	dry sclerophyll woodland	grassy, shrubby understorey	725
PEC11	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	849
PEC12	ochre brown clay	dry sclerophyll forest	grassy, shrubby understorey	849
PEC13	ochre brown clay	dry sclerophyll forest	grassy, shrubby understorey	849
PEC14	red-brown gravelly clay	dry sclerophyll woodland	moderately dense shrubby understorey	725
PEC15	dark brown loam	dry sclerophyll forest	grassy, moderately dense shrubby understorey	849
PEC16	gravelly dark brown loam	dry sclerophyll forest	sparse shrubby understorey	725
PEC17	brown clay	dry sclerophyll forest	moderately dense shrubby understorey	835
PEC18	brown clay	dry sclerophyll forest	moderately dense shrubby understorey	835
PEC19	dark brown loam	dry sclerophyll forest	moderately dense shrubby understorey	849
PEC20	dark brown loam	dry sclerophyll woodland	dense shrubby understorey	849

Appendix 1a (continued): Environmental data for sites visited as part of this study

Site	Soil description	Vegetation structure (canopy)	Vegetation structure (understorey)	PCT (my identification)
PEC21	grey-brown loam	dry sclerophyll forest	dense shrubby understorey	835
PEC22	pale brown loam	dry sclerophyll forest	sparse shrubby understorey	835
PEC23	Red-brown clay with lateritic pebbles	dry sclerophyll forest	dense shrubby understorey	849
PEC24	mid-brown clay	dry sclerophyll forest	dense shrubby understorey	849
PEC25	mid-brown clay	dry sclerophyll forest	dense shrubby understorey	849
PEC26	grey-brown loam	dry sclerophyll woodland	grassy understory with scattered shrubs	849
PEC27	grey-brown loam	dry sclerophyll woodland to forest	grassy understorey with sparse to dense shrub stratum	849
PEC28	mid-brown loam	dry sclerophyll woodland	grassy understorey with sparse to dense shrub stratum	849
PEC29	mid-brown loam	dry sclerophyll forest	shrubby, grassy understorey	849
PEC30	ochre brown gravelly loam with abundant, large rounded stones	dry sclerophyll forest	Grassy, sparsely to densely shrubby understorey	849
WSA1	mid-brown loam	dry sclerophyll forest	grassy, shrubby understorey	849
WSA2	red-brown gravelly loam	dry sclerophyll woodland	shrubby grassland	725
PS1	brown clay-loam	Dry sclerophyll forest	sparse shrubby understorey	849
PS2	brown sand	Dry sclerophyll woodland	moderately dense shrubby understory	1081
PS3	dark brown humus-rich sand	dry sclerophyll forest	moderately dense shrubby understory	1081
PS4	dark brown humus-rich sand	Dry sclerophyll woodland	moderately dense shrubby understory under dense subcanopy	1081
PS5	dark brown humus-rich sand	Dry sclerophyll woodland	moderately dense shrubby understory	1181
PS6	red-brown clay with lateritic pebbles	dry sclerophyll forest	Grassy, sparsely to densely shrubby understorey	849
PS7	fine, mid-brown sand	dry sclerophyll forest	Grassy, moderately to densely shrubby understorey	1395

Appendix 1a (continued): Environmental data for sites visited as part of this study

	Sites >												
Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Acacia binervia	1	0	0	0	0	0	0	1	1	0	1	0	0
Acacia brownii	1	0	0	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	1	0	0	0	0	0	0	0	0	0	0	0	0
Acacia elongata	0	0	0	0	0	0	0	0	0	1	0	0	0
Acacia falcata	1	1	0	0	0	0	1	0	1	0	1	0	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia floribunda	0	1	0	0	0	0	0	0	0	0	0	0	0
Acacia implexa	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia parramattensis	0	1	1	1	0	0	0	0	1	0	1	1	0
Acacia parvipinnula	0	0	0	0	0	0	0	0	1	0	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acrotriche divaricata	0	0	0	0	0	0	0	0	0	0	0	0	0
Ajuga australis	0	0	0	0	0	0	0	0	0	0	0	0	0
Allocasuarina littoralis	1	1	0	0	0	0	0	1	1	1	1	0	0
Angophora bakeri	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora costata	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora floribunda	0	0	1	1	0	0	1	1	1	1	1	1	1
Angophora subvelutina	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b: Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >												
Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Aristida ramosa	?	?	?	?	?	?	?	?	?	?	?	?	?
Aristida vagans	?	?	?	?	?	?	?	?	?	?	?	?	?
Arthropodium milleflorum	0	0	0	0	0	0	0	0	0	0	0	0	0
Asperula conferta	0	0	0	0	0	0	0	0	0	0	0	0	0
Astroloma humifusum	0	0	0	0	1	0	0	0	0	0	0	0	0
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrostipa verticillata	0	0	0	0	0	0	0	0	0	0	0	0	0
Banksia serrata	0	0	0	0	0	0	0	0	0	0	0	0	0
Banksia spinulosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	1	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	0	0	0	0	0	0	0	0	1	0
Brunoniella australis	0	1	0	0	1	0	0	0	1	0	1	1	0
Bursaria spinosa	1	1	1	0	1	1	1	1	1	1	0	1	1
Caesia vittata	0	0	0	0	0	0	0	0	0	0	0	0	0
Calandrinia pickeringii	0	0	0	0	0	0	0	0	0	0	0	0	0
Callistemon salignus	0	0	0	0	0	0	0	0	0	0	0	1	0
Calotis cuneifolia	0	1	0	0	0	0	0	0	0	0	0	0	0
Carex inversa	?	?	?	?	?	?	?	?	?	?	?	?	?
Casuarina glauca	0	0	1	0	1	0	0	0	0	0	0	1	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >												
Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Cheilanthes sieberi	1	0	0	0	0	0	0	0	0	0	0	0	1
Chrysocephalum apiculatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis aristata	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis glycinoides	0	0	1	1	0	0	1	0	0	0	0	0	0
Commelina cyanea	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina ensifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Corymbia gummifera	0	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sieberiana	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptandra amara	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptandra spinescens	0	0	0	0	1	0	0	0	0	0	0	0	0
Cymbidium suave	0	0	0	0	0	0	0	0	0	0	0	0	0
Daviesia ulicifolia	0	0	0	0	1	0	1	1	0	1	1	0	0
Desmodium brachypodium	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium varians	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella caerulea var. *producta*	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *longifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *stenophylla*	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella revoluta var. *revoluta*	0	0	0	0	0	0	0	0	0	0	0	0	0
Dichondra repens	0	0	0	0	0	0	0	0	1	0	1	1	0
Dichopogon fimbriatus	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

Sites >

Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Dillwynia sieberi	0	1	0	0	1	0	0	1	0	1	1	0	0
Dillwynia tenuifolia	1	0	0	0	0	0	0	0	0	0	0	0	0
Dipodium punctatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea triquetra	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	?	?	?	?	?	?	?	?	?	?	?	?	?
Einadia hastata	0	0	0	0	0	0	0	0	0	0	0	0	0
Entolasia stricta	0	0	0	0	0	0	0	0	0	0	0	0	1
Eremophila debilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalypts amplifolia	0	0	0	1	0	0	0	0	0	0	0	0	0
Eucalyptus baueriana	0	0	1	0	0	0	0	0	0	0	0	0	0
Eucalyptus crebra	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus eugenioides	0	0	0	0	0	0	0	0	0	0	0	0	1
Eucalyptus fibrosa	1	1	0	0	1	0	0	0	1	0	1	0	0
Eucalyptus globoidea	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus moluccana	0	1	1	0	1	1	0	0	1	0	0	1	1
Eucalyptus piperita	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sparsifolia	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >												
Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Eucalyptus tereticornis	0	1	1	0	1	1	0	1	1	0	1	1	1
Exocarpos cupressiformis	0	0	0	0	0	0	0	0	0	0	0	0	0
Exocarpos strictus	0	0	0	0	0	0	0	0	0	0	0	0	0
Geitonoplesium cymosum	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine tabacina	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine clandestina	0	0	0	0	0	0	0	0	0	0	0	0	0
Gompholobium grandiflorum	0	0	0	0	0	0	0	0	0	0	0	0	0
Goodenia hederacea	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea juniperina	1	1	0	0	1	1	1	1	1	1	1	0	0
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sericea	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea laevipes	0	0	0	0	0	0	0	0	0	0	0	0	0
Hakea sericea	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardenbergia violacea	0	0	1	1	0	1	1	0	0	0	1	0	0
Hibbertia diffusa	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypoxis hygrometrica	0	0	0	0	0	0	0	0	0	0	0	0	0
Imperata cylindrica	0	0	0	0	0	0	0	0	0	0	0	0	0
Indigofera australis	0	0	0	1	0	0	0	0	0	0	1	0	0
Isopogon anemonifolius	0	0	0	0	0	0	0	0	0	0	0	0	0
Jacksonia scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study (continued on next page)

	Sites >												
Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Kunzea ambigua	1	0	0	0	0	0	0	0	0	0	0	0	0
Lagenifera stipitata	1	0	0	0	0	0	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Laxmannia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma laterale	1	1	0	0	1	1	0	0	0	0	0	0	0
Leptospermum parvifolium	0	0	1	0	0	0	0	0	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0
Linum marginale	0	0	0	0	0	0	0	0	0	0	0	0	0
Lissanthe strigosa	1	0	0	0	1	0	0	1	1	0	0	0	0
Lobelia purpurascens	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra filiformis	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra longifolia	0	0	1	0	0	0	0	0	0	0	0	0	0
Lomandra multiflora	0	0	0	0	0	0	0	1	0	0	0	0	0
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Lotus australis	0	0	0	0	0	0	0	0	0	0	0	0	0
Macrozamia spiralis	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca decora	1	1	1	0	0	1	0	1	0	0	0	1	0
Melaleuca linariifolia	0	0	0	1	0	0	0	0	0	0	0	0	0
Melaleuca nodosa	1	0	0	0	1	0	0	0	0	0	0	0	0
Melaleuca styphelioides	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Melia azedarach	0	0	0	0	0	0	0	0	0	0	0	0	0
Microlaena stipoides	?	?	?	?	?	?	?	?	?	?	?	?	?
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0
Murdannia graminea	0	0	0	0	0	0	0	0	0	0	0	0	0
Notelaea longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia aspera	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia diphylla	0	0	0	0	0	0	0	0	0	0	0	0	0
Oplismenus imbecilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis perennans	0	0	0	0	0	0	0	0	0	0	0	0	0
Ozothamnus diosmifolius	1	1	0	0	0	0	0	1	0	0	0	0	0
Parsonsia straminea	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrophile sessilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus virgatus	0	0	0	0	0	0	0	0	0	0	0	0	0
Pimelea glauca	1	0	0	0	0	0	0	0	0	0	0	0	0
Pittosporum undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago debilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago gaudichaudii	0	0	0	0	0	0	0	0	0	0	0	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala japonica	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC1	PEC2	PEC3	PEC4	PEC5	PEC6	PEC7	PEC8	PEC9	PEC10	PEC11	PEC12	PEC13
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterostylis saxicola	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea microphylla	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea parviflora	0	1	0	0	0	0	0	1	0	0	0	0	0
Ranunculus lappaceus	0	0	0	0	0	0	0	0	0	0	0	0	0
Ricinocarpos pinifolius	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0
Stylidium laricifolium	0	0	0	0	0	0	0	0	0	0	0	0	0
Themeda triandra	0	0	0	0	0	0	0	0	0	0	0	0	1
Tricoryne elatior	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola hederacea	0	0	0	0	0	0	0	0	0	0	0	0	0
Wahlenbergia communis	0	0	0	0	0	0	0	0	0	0	0	0	0
Wahlenbergia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea concava	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea media	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea minor	1	0	0	0	0	0	0	0	0	0	0	0	0
Xanthosia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Acacia binervia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	1	1	1	0	1	1	0	0	0	0	1	1
Acacia elongata	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia falcata	0	0	0	0	0	1	1	0	0	0	0	0	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	0	1
Acacia floribunda	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia implexa	0	0	1	0	0	0	0	0	0	0	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia parramattensis	1	1	0	1	1	1	0	0	0	0	0	0	0
Acacia parvipinnula	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia terminalis	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acrotriche divaricata	0	0	0	0	0	0	0	0	0	0	0	0	0
Ajuga australis	0	0	0	0	0	0	0	0	0	0	1	0	0
Allocasuarina littoralis	0	0	0	0	0	0	0	1	0	0	0	0	0
Angophora bakeri	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora costata	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora floribunda	0	0	0	1	0	0	1	0	0	0	0	0	0
Angophora subvelutina	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Aristida ramosa	?	?	?	?	?	?	?	0	0	0	0	0	0
Aristida vagans	?	?	?	?	?	?	?	0	0	0	0	0	1
Arthropodium milleflorum	0	1	1	0	0	0	0	0	0	1	0	0	1
Asperula conferta	0	0	0	0	0	0	0	1	0	0	1	0	0
Astroloma humifusum	1	0	0	0	0	0	0	0	0	0	0	0	0
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrostipa verticillata	0	0	0	0	0	0	0	1	0	0	0	0	0
Banksia serrata	0	0	0	0	0	0	0	0	0	0	0	0	0
Banksia spinulosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Billardiera scandens	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	0	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	0	0	0	0	0
Breynia oblongifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Brunoniella australis	0	1	1	0	0	1	1	1	1	1	0	1	1
Bursaria spinosa	1	1	1	1	1	1	1	1	1	1	1	1	1
Caesia vittata	0	0	0	0	0	0	0	0	0	0	1	0	0
Calandrinia pickeringii	0	0	0	0	0	0	0	0	0	0	0	0	0
Callistemon salignus	0	0	0	1	0	0	0	0	0	0	0	0	0
Calotis cuneifolia	0	1	1	0	0	0	0	0	0	0	0	0	1
Carex inversa	?	?	?	?	?	?	?	0	0	0	0	0	0
Casuarina glauca	0	0	0	1	0	1	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >													
Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Cheilanthes sieberi	0	1	1	0	0	1	1	1	1	1	0	1	0
Chrysocephalum apiculatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis aristata	0	0	0	0	0	0	0	0	0	0	0	0	0
Clematis glycinoides	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina cyanea	0	0	0	0	0	0	0	0	0	0	0	0	0
Commelina ensifolia	0	0	1	0	0	0	0	0	1	0	0	0	1
Corymbia gummifera	0	0	0	0	0	0	0	0	0	0	0	0	0
Crassula sieberiana	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptandra amara	0	0	0	0	0	1	0	0	0	0	0	0	0
Cryptandra spinescens	0	0	1	0	0	0	0	0	0	0	0	0	0
Cymbidium suave	0	0	0	0	0	0	0	0	0	0	0	0	0
Daviesia ulicifolia	0	1	1	0	0	0	0	0	0	0	0	1	0
Desmodium brachypodium	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium varians	0	0	0	0	0	0	0	0	0	1	0	0	0
Dianella caerulea var. *producta*	0	0	0	0	1	0	0	0	0	0	0	0	0
Dianella longifolia var. *longifolia*	0	0	0	0	0	0	0	0	0	0	0	0	0
Dianella longifolia var. *stenophylla*	0	0	0	0	0	0	0	0	0	1	0	0	1
Dianella revoluta var. *revoluta*	0	0	1	0	0	0	0	0	0	0	0	0	1
Dichondra repens	0	1	0	0	0	1	1	1	1	1	0	0	1
Dichopogon fimbriatus	0	0	0	0	0	0	0	1	1	0	0	0	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Dillwynia sieberi	1	0	0	0	0	0	0	0	0	0	0	1	1
Dillwynia tenuifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Dipodium punctatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea triquetra	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa subsp. cuneata	1	0	0	0	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	?	?	?	?	?	?	?	0	0	0	0	0	0
Einadia hastata	0	0	1	0	0	0	0	0	0	0	0	1	0
Entolasia stricta	0	0	1	0	0	0	0	0	0	0	0	0	0
Eremophila debilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalypts amplifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus baueriana	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus crebra	0	0	0	0	0	1	0	0	0	0	0	0	0
Eucalyptus eugenioides	0	0	1	0	0	1	0	0	0	0	0	0	0
Eucalyptus fibrosa	1	1	1	0	0	0	0	0	0	0	0	0	1
Eucalyptus globoidea	0	0	0	1	0	0	0	0	0	0	0	0	0
Eucalyptus moluccana	1	1	1	0	1	1	1	1	0	1	1	0	1
Eucalyptus piperita	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sclerophylla	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus sparsifolia	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >												
Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Kunzea ambigua	0	0	0	0	0	0	0	0	0	0	0	0	0
Lagenifera stipitata	0	0	0	0	0	0	0	0	0	0	0	0	0
Lambertia formosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Laxmannia gracilis	0	0	1	0	0	0	0	0	0	0	0	0	0
Lepidosperma laterale	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum parvifolium	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	0	0	0	0	0	0
Linum marginale	0	0	0	0	0	0	0	0	0	1	0	0	0
Lissanthe strigosa	0	0	1	0	0	0	0	0	0	0	0	0	0
Lobelia purpurascens	0	1	0	0	0	1	0	1	0	0	0	0	0
Lomandra filiformis	0	0	0	0	0	0	0	1	0	0	0	1	0
Lomandra longifolia	0	0	1	1	0	0	0	0	0	0	0	0	0
Lomandra multiflora	0	0	0	0	1	1	0	0	0	0	0	0	0
Lomandra obliqua	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Lotus australis	0	0	0	0	0	0	0	0	0	0	1	0	0
Macrozamia spiralis	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca decora	0	1	0	0	0	1	0	0	0	0	0	1	0
Melaleuca linariifolia	0	0	0	1	0	0	0	0	0	0	0	0	0
Melaleuca nodosa	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca styphelioides	0	0	0	1	0	0	0	0	0	0	0	0	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Melia azedarach	0	0	0	0	0	0	0	0	0	0	1	0	0
Microlaena stipoides	?	?	?	?	?	?	?	0	0	0	0	0	1
Monotoca scoparia	0	0	0	0	0	0	0	0	0	0	0	0	0
Murdannia graminea	0	0	0	0	0	0	0	0	0	0	0	0	1
Notelaea longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia aspera	0	0	0	0	0	0	0	0	0	0	0	0	0
Opercularia diphylla	0	0	0	0	0	0	0	0	0	0	0	0	1
Oplismenus imbecilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis perennans	0	0	0	0	1	1	0	0	0	0	0	0	0
Ozothamnus diosmifolius	1	1	1	1	0	0	0	0	1	0	0	0	0
Parsonsia straminea	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia levis	0	0	0	0	0	0	0	0	0	0	0	0	0
Persoonia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0
Petrophile sessilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllanthus virgatus	0	0	0	0	0	0	0	0	0	0	0	0	1
Pimelea glauca	0	0	0	0	0	0	0	0	0	0	0	0	0
Pittosporum undulatum	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago debilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago gaudichaudii	0	0	0	0	0	0	0	0	0	1	0	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygala japonica	0	0	0	0	0	0	0	0	0	0	0	0	0

Sites >

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC14	PEC15	PEC16	PEC17	PEC18	PEC19	PEC20	PEC21	PEC22	PEC23	PEC24	PEC25	PEC26
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	0	0	0
Pterostylis saxicola	0	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea microphylla	0	0	0	0	0	0	0	0	0	0	0	0	1
Pultenaea parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus lappaceus	0	0	0	0	0	0	0	0	0	0	1	0	0
Ricinocarpos pinifolius	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanum prinophyllum	0	0	0	1	0	0	0	0	1	0	0	0	0
Stylidium laricifolium	0	0	0	0	0	0	0	0	0	0	0	0	0
Themeda triandra	0	0	0	0	1	0	0	0	0	1	0	0	1
Tricoryne elatior	0	0	0	0	0	0	0	0	0	0	0	0	0
Viola hederacea	0	0	0	0	0	0	0	1	0	0	0	0	0
Wahlenbergia communis	0	0	0	0	0	0	0	0	0	0	1	0	0
Wahlenbergia gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea concava	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea media	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthorrhoea minor	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthosia pilosa	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Acacia binervia	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia brownii	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia decurrens	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia elongata	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia falcata	1	0	1	1	0	0	0	0	0	0	0	0	0
Acacia fimbriata	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia floribunda	0	0	0	0	0	0	0	0	0	0	0	0	1
Acacia implexa	1	0	0	1	1	0	0	0	0	1	0	0	0
Acacia linifolia	0	0	0	0	0	0	0	1	1	0	1	0	0
Acacia parramattensis	0	0	1	1	0	0	0	0	0	0	0	0	0
Acacia parvipinnula	0	0	0	0	0	0	0	0	0	0	0	0	0
Acacia suaveolens	0	0	0	0	0	0	0	0	0	0	1	0	0
Acacia terminalis	0	0	0	0	0	0	0	1	1	0	1	0	0
Acacia ulicifolia	0	0	0	0	0	0	0	0	1	0	1	0	0
Acrotriche divaricata	0	0	0	0	0	0	0	0	0	1	0	0	0
Ajuga australis	0	0	0	0	0	0	?	0	?	0	0	0	0
Allocasuarina littoralis	0	0	1	1	0	1	0	0	0	1	1	0	1
Angophora bakeri	0	0	0	0	0	0	0	1	1	1	1	0	1
Angophora costata	0	0	0	0	0	0	0	0	0	0	1	0	0
Angophora floribunda	0	0	0	0	0	0	0	0	0	0	0	0	0
Angophora subvelutina	0	0	1	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Aristida ramosa	0	0	1	1	0	0	?	?	?	?	?	1	0
Aristida vagans	1	0	1	1	1	0	?	?	?	?	?	1	0
Arthropodium milleflorum	0	0	0	0	1	0	0	0	0	0	0	1	0
Asperula conferta	1	0	0	0	1	0	?	?	?	?	?	0	0
Astroloma humifusum	0	0	0	0	0	1	0	0	0	0	0	0	0
Astroloma pinifolium	0	0	0	0	0	0	0	0	0	0	1	0	0
Austrostipa verticillata	0	1	0	0	0	0	?	?	?	?	?	0	0
Banksia serrata	0	0	0	0	0	0	0	0	0	0	1	0	0
Banksia spinulosa	0	0	0	0	0	0	0	1	1	1	1	0	0
Billardiera scandens	0	0	0	0	0	0	0	0	0	0	0	0	0
Bossiaea prostrata	1	0	0	0	0	0	0	0	0	0	0	0	0
Brachyloma daphnoides	0	0	0	0	0	0	0	0	1	0	0	0	0
Breynia oblongifolia	0	0	0	1	0	0	1	0	0	0	0	1	0
Brunoniella australis	1	1	1	1	1	0	1	0	0	0	0	1`	0
Bursaria spinosa	1	1	1	1	1	1	1	0	0	0	0	1	1
Caesia vittata	0	0	1	0	1	0	?	?	?	?	?	0	0
Calandrinia pickeringii	0	0	0	0	0	0	?	?	?	?	?	0	1
Callistemon salignus	0	0	0	0	0	0	0	0	0	0	0	0	0
Calotis cuneifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex inversa	0	0	1	0	1	0	?	?	?	?	?	0	0
Casuarina glauca	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >												
Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Cheilanthes sieberi	1	0	1	1	1	0	1	1	0	1	0	1	1
Chrysocephalum apiculatum	0	0	1	0	0	0	?	?	?	?	?	0	0
Clematis aristata	0	1	0	0	0	0	0	0	0	0	0	0	?
Clematis glycinoides	0	0	0	1	0	0	0	0	0	0	0	0	?
Commelina cyanea	0	0	0	0	0	0	?	?	?	?	?	0	1
Commelina ensifolia	0	1	1	1	0	0	?	?	?	?	?	1	0
Corymbia gummifera	0	0	0	0	0	0	0	0	0	1	1	0	0
Crassula sieberiana	0	0	0	0	0	0	?	?	?	?	?	0	1
Cryptandra amara	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptandra spinescens	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbidium suave	0	0	0	0	0	0	0	0	0	0	0	0	1
Daviesia ulicifolia	0	0	1	0	0	0	1	0	0	0	0	1	0
Desmodium brachypodium	1	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium rhytidophyllum	0	0	0	0	0	0	0	0	0	0	0	1	0
Desmodium varians	0	0	0	0	0	0	?	?	?	?	?	0	0
Dianella caerulea var. *producta*	0	0	0	0	0	0	?	?	?	?	?	0	0
Dianella longifolia var. *longifolia*	0	0	0	0	1	0	?	?	?	?	?	0	0
Dianella longifolia var. *stenophylla*	1	0	1	1	0	0	?	?	?	?	?	0	1
Dianella revoluta var. *revoluta*	0	0	0	0	0	0	?	?	?	?	?	0	0
Dichondra repens	1	1	1	0	1	0	1	0	0	0	0	1	1
Dichopogon fimbriatus	0	0	0	0	0	0	?	?	?	?	?	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

	Sites >												
Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Dillwynia sieberi	1	0	0	0	0	0	1	0	0	0	0	0	0
Dillwynia tenuifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Dipodium punctatum	0	0	0	1	0	0	?	?	?	?	?	0	0
Dodonaea triquetra	0	0	0	0	0	0	0	0	0	0	1	0	0
Dodonaea viscosa subsp. cuneata	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinopogon caespitosus	0	0	0	1	0	0	?	?	?	?	?	0	0
Einadia hastata	0	1	1	0	0	0	?	?	?	?	?	1	1
Entolasia stricta	0	0	0	0	0	0	0	0	0	0	0	0	1
Eremophila debilis	1	0	0	0	0	0	1	0	0	0	0	0	0
Eriostemon australasius	0	0	0	0	0	0	0	0	0	1	0	0	0
Eucalypts amplifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus baueriana	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus crebra	1	0	0	1	1	0	1	0	0	0	0	1	0
Eucalyptus eugenioides	0	0	0	0	0	0	0	0	0	0	0	0	0
Eucalyptus fibrosa	1	1	0	1	0	0	0	0	0	0	0	0	0
Eucalyptus globoidea	0	0	0	1	0	0	0	0	0	0	0	0	1
Eucalyptus moluccana	0	1	1	0	1	0	1	0	0	0	0	0	0
Eucalyptus piperita	0	0	0	0	0	0	0	0	0	0	1	0	0
Eucalyptus punctata	0	0	0	0	0	0	0	0	1	1	1	0	1
Eucalyptus sclerophylla	0	0	0	0	0	0	0	1	1	1	0	0	0
Eucalyptus sparsifolia	0	0	0	0	0	0	0	1	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Eucalyptus tereticornis	1	1	1	1	1	0	0	0	0	0	0	1	1
Exocarpos cupressiformis	0	0	0	0	0	0	1	0	0	0	1	0	0
Exocarpos strictus	0	0	1	0	0	0	0	0	1	1	1	0	0
Geitonoplesium cymosum	0	0	0	0	1	0	0	0	0	0	0	0	0
Glycine tabacina	1	1	1	1	1	0	0	0	0	0	0	1	1
Glycine clandestina	1	0	1	1	0	0	0	0	0	0	0	0	1
Gompholobium grandiflorum	0	0	1	0	0	0	0	1	0	0	0	0	0
Goodenia hederacea	1	0	1	1	0	0	0	0	1	0	0	1	1
Grevillea juniperina	1	1	0	0	0	0	0	0	0	0	0	0	0
Grevillea mucronulata	0	0	0	0	0	0	0	0	0	0	0	0	0
Grevillea sericea	0	0	0	0	0	0	0	0	0	0	1	0	0
Grevillea sphacelata	0	0	0	0	0	0	0	1	1	0	0	0	0
Hakea laevipes	0	0	0	0	0	0	0	1	1	1	0	0	0
Hakea sericea	0	0	0	0	0	1	0	1	1	1	1	0	0
Hardenbergia violacea	1	0	1	0	0	0	1	0	0	0	0	1	0
Hibbertia diffusa	0	0	1	1	0	0	?	?	?	?	?	1	1
Hypoxis hygrometrica	1	0	0	0	0	0	?	?	?	?	?	0	0
Imperata cylindrica	0	0	0	0	0	0	0	0	0	0	0	0	1
Indigofera australis	0	0	0	0	1	0	0	0	0	0	0	0	0
Isopogon anemonifolius	0	0	0	0	0	0	0	1	1	1	0	0	0
Jacksonia scoparia	0	0	0	0	0	0	0	0	0	1	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites >

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Kunzea ambigua	0	0	0	0	0	1	0	1	1	1	1	0	1
Lagenifera stipitata	0	0	0	0	0	0	0	0	0	0	0	1	1
Lambertia formosa	0	0	0	0	0	0	0	1	1	0	1	0	0
Laxmannia gracilis	1	0	0	0	0	0	?	?	?	?	?	0	1
Lepidosperma laterale	0	0	0	0	0	0	0	0	0	0	0	0	1
Leptospermum parvifolium	0	0	0	0	0	0	0	1	0	0	0	0	0
Leptospermum trinervium	0	0	0	0	0	0	0	1	1	1	1	0	1
Linum marginale	0	0	0	0	0	0	?	?	?	?	?	0	0
Lissanthe strigosa	0	0	0	0	0	0	0	0	0	1	0	0	0
Lobelia purpurascens	0	1	0	1	1	0	?	?	?	?	?	1	1
Lomandra filiformis	1	0	0	0	0	0	?	?	?	?	?	0	0
Lomandra longifolia	0	0	1	0	0	0	0	0	0	0	1	0	1
Lomandra multiflora	1	0	0	0	0	0	0	0	0	0	0	0	1
Lomandra obliqua	0	0	0	0	0	0	0	1	1	1	1	0	0
Lomatia silaifolia	0	0	0	0	0	0	0	0	0	0	1	0	0
Lotus australis	0	0	0	0	0	0	?	?	?	?	?	0	0
Macrozamia spiralis	0	0	0	0	0	0	0	0	0	1	0	0	0
Melaleuca decora	0	1	0	0	0	1	0	0	0	0	0	0	0
Melaleuca linariifolia	0	0	0	0	0	0	0	0	0	0	0	0	0
Melaleuca nodosa	0	0	0	0	0	0	0	0	1	0	1	0	0
Melaleuca styphelioides	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites
>

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Melia azedarach	0	0	1	1	0	0	0	0	0	0	0	0	0
Microlaena stipoides	0	0	1	1	0	0	?	?	?	?	?	1	1
Monotoca scoparia	0	0	0	0	0	0	0	0	1	1	1	0	0
Murdannia graminea	0	0	0	0	0	0	?	?	?	?	?	0	0
Notelaea longifolia	0	0	0	0	0	0	0	0	0	0	1	0	0
Opercularia aspera	0	0	0	0	1	0	?	?	?	?	?	0	0
Opercularia diphylla	1	0	1	1	0	0	?	?	?	?	?	1	1
Oplismenus imbecilis	0	0	0	0	0	0	?	?	?	?	0	0	1
Oxalis perennans	0	0	0	1	1	0	?	?	?	?	?	0	1
Ozothamnus diosmifolius	0	0	0	1	0	0	1	0	1	0	0	1	0
Parsonsia straminea	0	0	0	0	0	0	0	0	0	0	0	0	1
Persoonia levis	0	0	0	0	0	0	0	1	1	1	1	0	0
Persoonia linearis	0	0	0	0	0	0	0	0	1	1	1	0	0
Petrophile sessilis	0	0	0	0	0	0	0	1	0	1	1	0	0
Phyllanthus virgatus	0	0	0	0	0	0	?	?	?	?	?	0	0
Pimelea glauca	0	0	0	0	0	0	0	0	0	0	0	0	0
Pittosporum undulatum	0	0	0	0	0	0	0	0	0	0	1	0	0
Plantago debilis	0	0	0	0	0	0	?	?	?	?	?	1	0
Plantago gaudichaudii	0	0	0	0	0	0	?	?	?	?	?	0	0
Plectranthus sp.	0	0	0	0	0	0	0	0	0	0	0	1	0
Polygala japonica	0	0	0	0	1	0	?	?	?	?	?	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Sites
>

Associated species	PEC27	PEC28	PEC29	PEC30	WSA1	WSA2	PS1	PS2	PS3	PS4	PS5	PS6	PS7
Pteridium esculentum	0	0	0	0	0	0	0	0	0	0	1	0	0
Pterostylis saxicola	0	0	0	0	0	0	1	1	1	1	1	1	1
Pultenaea microphylla	1	0	0	0	0	0	0	0	0	0	0	0	0
Pultenaea parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0
Ranunculus lappaceus	0	0	0	0	0	0	?	?	?	?	?	0	0
Ricinocarpos pinifolius	0	0	0	0	0	0	0	0	0	0	1	0	0
Solanum prinophyllum	0	1	0	0	1	0	1	0	0	0	0	1	1
Stylidium laricifolium	0	0	0	0	0	0	0	0	0	1	0	0	0
Themeda triandra	0	0	1	1	1	0	0	0	0	0	0	1	1
Tricoryne elatior	1	1	1	1	1	1	?	?	?	?	?	1	1
Viola hederacea	0	0	0	0	0	0	?	?	?	?	?	0	1
Wahlenbergia communis	1	0	0	0	0	0	?	?	?	?	?	0	0
Wahlenbergia gracilis	0	1	0	0	0	0	?	?	?	?	?	0	0
Xanthorrhoea concava	0	0	0	0	0	0	0	0	0	0	1	0	0
Xanthorrhoea media	0	0	0	0	0	0	0	1	1	0	1	0	0
Xanthorrhoea minor	0	0	0	0	0	0	0	0	0	0	0	0	0
Xanthosia pilosa	0	0	0	0	0	0	0	0	0	0	1	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

8.2 Appendix 2: Peter Weston's curriculum vitae

Personal details

Name: Peter Henry Weston.

Address: 18 Lyle Avenue, Lindfield, New South Wales 2070, Australia.

Date and place of birth: 22 October 1956, Lower Hutt, New Zealand.

Immediate family: wife (Susan) and three children (Timothy 34, Caitlin 32, Nicholas 29).

Nationality: Australian.

Interests: soccer, reading, guitar, orchid growing, cross-country skiing, bush walking.

Academic Qualifications

i) **B.Sc.** (first class honours; equal first in order of merit) School of Biological Sciences, University of Sydney; 1975-78, conferred 7 April 1979.
Thesis title: "The evolution and classification of *Boronia* Sm."

ii) **Ph.D.**, School of Biological Sciences, University of Sydney, 1979-83; conferred 18 May 1985.
Thesis title: "Systematics and biogeography of the Persooniinae (Proteaceae)".

Awards, Fellowships and Scholarships

2014	Nancy Burbidge Medal (awarded by the Australasian Systematic Botany Society to a person who has made a longstanding and significant contribution to Australasian systematic botany. It is the foremost award that can be conferred by ASBS).
2014	Australian Biological Resources Study-sponsored Winston Churchill Fellowship for an established career researcher in taxonomy.
2009	Grady L. Webster Structural Botany Publication Award for 2008 and 2009 from the Botanical Society of America. The BSA component of the award (it is awarded in alternate years by the BSA and the American Society of Plant Taxonomists) recognizes the most outstanding paper published in the *American Journal of Botany* in the field of structural and developmental botany (i.e., anatomy and morphology) over a two-year period. It was awarded to Gregory J. Jordan, Peter H. Weston, Raymond J. Carpenter, Rebecca A. Dillon and Timothy J. Brodribb for: "The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae," American Journal of Botany, Volume 95, Issue 5; May 2008.
2006	Carrick Award for Australian University Teaching from the Australian Learning and Teaching Council (one of five members of a teaching team from the University of New England cited for Outstanding Contributions to Student Learning).
1992-93	Posting to Royal Botanic Gardens, Kew, as Australian Botanical Liaison Officer.
1982	Charles Gilbert Heydon Travelling Fellowship for the biological sciences (not taken up).
1980-82	University of Sydney Postgraduate Scholarship.

1979-82	Commonwealth Postgraduate Award.
1977	G.S. Caird Scholarship for Third Year Botany, University of Sydney.
1976	Slade Prize for Practical Plant Biology, University of Sydney.

Employment

Present Position: Honorary Research Associate, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney and independent botanical consultant.

Previous positions held:
2008-2016 Senior Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

2000-2008 Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1994-2000 Senior Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1989-1994 Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1982-1989 Scientific Officer, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1979-82 Part-time demonstrator, School of Biological Sciences, University of Sydney.

Adjunct and visiting university appointments

2013-	Adjunct Associate Professor, La Trobe University.
2011-2016	Adjunct Associate Professor, University of New South Wales.
2006	Visiting Lecturer, Rhodes University, Grahamstown, South Africa.
2004-2009	Adjunct Associate Professor, University of New England.
2000-2004	Adjunct Senior Lecturer, University of New England.

Administrative/management experience

2009	Acting Manager Plant Diversity
2002-2003	Member, Plant Diversity Research Program Leaders Committee
1998-99	Systematics Liaison Officer
1997-98	Member RBGS Market testing working party
1997	Member, RBGS advisory committee for restructuring senior management
1990-91	Systematics Co-ordinator
1996-98	Member, RBGS Joint Consultative Committee

Membership of Learned Societies

1996-	Society of Australian Systematic Biologists
1984-	Willi Hennig Society (Elected Fellow, 1992-, Council member, 1998-2000)
1979-	Society of Systematic Biologists (member, Editorial Board 1993-95)

1978- Australasian Systematic Botany Society (formerly Australian Systematic Botany Society: President, 2009-2012, Vice President, 2008-2009, Chairman, Hansjörg Eichler Research Fund Committee, 1998-2002, Council member, 1996-2002)

Membership of External Committees

2015- Financial Grants Standing Committee (formerly the Grants Policy Standing Committee) of the Australasian Systematic Botany Society

2012-2013 Conference Organising Committee of *Systematics Without Borders*, a joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney (Chairman)

2011- Editorial Board, *Phytotaxa*

2008-2009 Corresponding Member, Editorial Advisory Committee, *Australian Systematic Botany*

2006-2014 Ira Butler Memorial Trophy Committee (a joint committee of the Australasian Native Orchid Society and the Orchid Society of New South Wales) (Chairman)

2004- Editorial Advisory Board, *Kew Bulletin*

2001-2006 Panel of Judges, Eureka Prize for Biodiversity Research

2000-2012 Bushland Management Advisory Committee, Lane Cove Council (Chairman, 2008-2010)

1999-2004 Editorial Advisory Committee, *Australian Systematic Botany*

Spoken presentations at conferences (not including presentations delivered by others)

2015 Building Our Botanical Capital, annual conference of the Australasian Systematic Botany Society: “A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution”.

2014 Next Generation Systematics, annual conference of the Australasian Systematic Botany Society: Nancy Burbidge Memorial Lecture: “Problems and progress in plant systematics since Nancy Burbidge”

2013 Genetics Society of Australasia conference, Sydney *Genetics in the Harbour City*: “Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications”.

2013 Joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, Sydney, *Systematics Without Borders*: “Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications”.

2012 Australasian Systematic Botany Society conference, Perth, *Local knowledge, global delivery*: “Contested, Uncontested and Potentially Controversial Taxonomic Changes in the Proteaceae: How Do They Differ?”

2011 37th annual conference of the South African Association of Botanists, *Plants in a Changing World* and 9th conference of the South African Society of Systematic Biologists, *Biodiversity Matters*; plenary address: “Cenozoic environmental change and the systematics of southern hemisphere plants”

2011 XVIII International Botanical Congress, Melbourne: “Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations”.

2010 VI Southern Connection Congress, Bariloche: “Cladistic biogeography, molecular dating, fossils and the Proteaceae”

2010 VI Southern Connection Congress, Bariloche: “Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests”

2010 Australian Systematic Botany Society conference *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*; Keynote address: “Cenozoic environmental change and the systematics of southern hemisphere plants”
1999 XVI International Botanical Congress, Saint Louis: “Historical biogeography of Proteaceae”.
1997 II Southern Connection Congress, Valdivia: “Cladistic biogeography of a key woody group: Proteaceae”.
1997 First Biennial International Conference of the Systematic Association, Oxford: “Rolf Sattler’s Plant Morphology and Cladistic Analysis”.
1996 *An International Symposium on the Biology of Proteaceae*, Melbourne: “ITS squence variation in the Proteaceae and what it tells us about phylogeny”.
1993 Joint conference of The Systematics Associations and The Linnean Society on *Models in Phylogeny Reconstruction*, London: “Direct methods for polarising character transformation series”.
1990 IXth meeting of the Willi Hennig Society, Canberra: “Transoceanic cladistic patterns in the Proteaceae”.
2003 The Third International Conference on *the Comparative Biology of the Monocotyledons*, Ontario: “Co-evolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators”.
2005 XVII International Botanical Congress, Vienna: “Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae)”.
2006 Australian Systematic Botany Society conference, Cairns, *Plant Diversity in the Tropics*: “A new suprageneric classification of the Proteaceae”.
2007 5th Southern Connection Congress, Adelaide: “‘I’m not dead yet’ – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation)”.
1989 Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney: “Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae”.
1988 Symposium on *Panbiogeography of New Zealand*, Wellington: “Problems with the statistical testing of panbiogeographic hypotheses”.
1985 Australian Flora Foundation Symposium on *Waratahs*, Canberra: “Drifting waratahs or continents?”
1984 Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra: “A reappraisal of Nelson's direct method of character analysis”.

Refereeing manuscripts, grant applications, reports and examining postgraduate theses (last five years)

2018: *Candollea*; *Flora of the Hunter Region*; *Journal of Biogeography.*
2017: *Australian Systematic Botany*; *Evolution*; *New Zealand Journal of Botany*; *Nuytsia*; *South African Journal of Botany.*
2016: *Australian Systematic Botany*; *Botanical Journal of the Linnean Society*, *National Research Foundation* (South Africa).
2015: *American Journal of Botany*; Australian Research Council (4); *Australian Systematic Botany*; *Muelleria*; *Nuytsia*; *Phytotaxa*; *PLOS One*; *Telopea* (6).
2014: Australian Research Council (3); *Australian Systematic Botany* (2); *Cunninghamia*; *Journal of Biogeography* (2); *Muelleria*; National Research Foundation (South Africa); *Orchadian*; *Perspectives in Plant Ecology, Evolution and Systematics*; *Plant Systematics and Evolution*; *Telopea* (3).

Research

My research has been in the theoretical and practical aspects of systematic botany, with emphasis on the theory and practice of phylogenetic analysis, and the broader uses to which phylogenetic knowledge may be applied. I have phylogenetically analysed groups in the plant families Proteaceae, Fabaceae, Orchidaceae, Rutaceae, Winteraceae and Lauraceae, contributed to more general analyses of angiosperm phylogeny, and used the results of these analyses to improve biological classification and to test theories of historical biogeography, trait evolution, co-evolution and adaptation. I have earned an international reputation for my contributions to both theoretical and empirical developments in this field.

Herbarium curation and collections

My curatorial responsibilities at the National Herbarium of New South Wales have included the families Rutaceae (1982-1998), Proteaceae (1982-2016), Orchidaceae (1986-2016) and Fabaceae subfamily Faboideae (1986-2016). I have collected plant specimens (mostly angiosperms) in Australia, England, New Zealand, New Caledonia, Chile, South Africa, and Argentina, mostly for the herbarium and living collections of the Royal Botanic Gardens and Domain Trust, Sydney. Duplicates of my collections have been distributed to over 20 herbaria in 8 different countries.

Teaching

I have been actively involved in the preparation and teaching of four third year undergraduate courses in biosystematics:
Western Sydney University (2015-2018): “Principles of Evolution” (unit 300980), “Botany” (unit 300836).
University of New South Wales (2010-2016): “Assembling the Tree of Life” (BIOS3221)
University of New England (2000-2010): Biosystematics (Biosyst 301, Biosyst 302, Evol 301/501).
Botany Department, Rhodes University, Grahamstown, South Africa (February-March 2006): “Plant Biodiversity” course in collaboration with Associate Professor Nigel Barker.

I am currently co-supervising one postgraduate student:
Nanette Thomas (Ph.D., University of New England): Systematics of *Tasmannia* informs Biogeography of Winteraceae.

Postgraduate and honours students I have previously co-supervised include:
Margaret Stimpson (Ph.D., University of New England): Systematics, evolution and ecology of the *Banksia spinulosa* complex (graduated 2017).
Melita Milner (Ph.D., Australian National University): Phylogeography of *Lomatia and Telopea* (Proteaceae) in south eastern Australia (graduated 2015).
Samanta Oon (B.Sc. Honours, University of New South Wales): *Lomatia* likes it both ways: rampant bidirectional introgression of chloroplast genomes between two morphologically distinct species of Lomatia (Proteaceae) (graduated 2015).
Zoe Reynolds (B.Sc. Honours, Australian National University): Phylogenetic, taxonomic and functional turnover in Proteaceae assemblages (graduated 2013).
Emma McIntosh (B.Sc. Honours, University of Sydney): Hybridization and introgression between *Lomatia myricoides* and *L. silaifolia* (Proteaceae) (graduated 2011).
Margaret Stimpson (M.Sc.Stud., University of New England): Review of the *Banksia spinulosa* species complex (Proteaceae) (graduated 2011).
James Indsto (M.Sc., University of Wollongong): Pollination Ecology and Molecular Systematics of *Diuris* (Orchidaceae) of the Sydney Region (graduated 2010).
Nanette Thomas (Grad.Dip.Sci., University of New England): Phylogenetic analysis of Winteraceae (graduated 2009).

David McKenna (Ph.D., University of Wollongong: Demographic and ecological indicators for rarity in obligate-seeding *Persoonia* (Proteaceae) shrubs of the Sydney region, graduated 2007).
Paul Rymer (Ph.D., University of Wollongong: Plant rarity: species distributional patterns, population genetics, pollination biology and seed dispersal in *Persoonia* (Proteaceae), graduated, 2006).
Georgina Lloyd (B.Sc. Honours, University of Sydney: Pseudocopulation in two species of *Cryptostylis*: Implications for maintaining species integrity, graduated 2004)
Andrew Perkins (Ph.D., University of Sydney: Phylogenetic Systematics of the Genus *Calochilus* (Orchidaceae), graduated 2002).
Jim Mant (Ph.D., Australian National University: Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae), graduated 2002).
Siegfried Krauss (Ph.D., University of Wollongong: Systematic pattern and evolutionary process in the complex species *Persoonia mollis* (Proteaceae), graduated 1995).

I have examined 14 honours and postgraduate theses:
Australian National University (Ph.D., 2003, 2007, 2008)
University of Melbourne (Ph.D., 1995, 2011)
University of Newcastle (M.Phil., 2003)
University of Queensland (Ph.D., 2003)
University of Sydney (Ph.D., 1991, 1994, 1997, 2009)
University of Wollongong (B.Sc. Hons., 2001, 2003)
Victoria University (Ph.D., 2007)

Competitive Research and Infrastructure Grants

Peakall, R., Pichersky, E., Linde, C., Weston, P.H. (2015-2019) The biosynthesis and evolution of novel semiochemicals in orchids. $644,800, Australian Research Council Discovery Grant DP150102762.

Hoebee, S.E., Weston, P.H., & Edwards, T.J. (2015-18) Evolution in action or the demise of iconic Australian flora? $217,700, Australian Research Council Discovery Grant DP150100508.

He, T., Lamont, B., Weston, P.H., & Cowling, R. (2012-2014) Origin and evolution of plant functional traits in relation to fire. $310,000, Australian Research Council Discovery Grant DP120103389.

Rossetto, M., Crayn, D.M. & Weston, P.H. (2008-2010) Integrating molecular and morphological data for generic delimitation and species identification in Lauraceae. $73,333, Australian Biological Resources Study.

Cantrill, D., Murphy, D. & Weston, P.H. (2008-10) Understanding the origins of the Australian flora by integrating molecular phylogenies and fossil data in the Proteaceae. $88,900, Hermon Slade Foundation.

Rossetto, M. & Weston, P.H. (2007-2009) Speciation in the Australian flora: testing explanatory hypotheses in waratahs and their allies. $78,000, Hermon Slade Foundation.

Considine, J.A., Krauss, S.L. & Weston, P.H. (2002-2004) A biological basis for the efficient breeding of native plants for export markets: a case study with the Australian Goodeniaceae. $168,126, ARC – Linkage (Krauss and Weston representing industry partners)

Whelan, R.J., Ayre, D.J., England, P., Auld, T.D., & Weston, P.H. (2000-2002) Ecology and genetics of fire-sensitive *Persoonia* species: threatened species recovery and management. $126,480, Australian Research Council (ARC– SPIRT, Auld and Weston representing industry partners).

Trent, R. *et al.* (2000) Enhancement of DNA sequencing equipment for the Sydney University and Prince Alfred Molecular Analysis Centre. $600,000, Australian Research Council (ARC-REIF).

Weston, P.H. (1999-2001) Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae). $75,000, Hermon Slade Foundation.

Weston, P.H. (1997-2000) Taxonomic revision of *Dillwynia* (Fabaceae: Faboideae: Mirbelieae). $62,836, Australian Biological Resources Study.

Weston, P.H. & Thomson, J.A. (1993) A molecular approach to the evolution and biogeography of the Queensland tree waratahs. $4000, Queensland Wet Tropics Management Authority

Weston, P.H. & Thomson, J.A. (1991-92) A molecular approach to the evolution and biogeography of the waratahs. $80,100, Australian Research Council (large grants scheme).

Weston, P.H. (1984) Establishment of a data bank for eucalypt specimens held by NSW. $20,000, Australian Biological Resources Study.

Scientific Publications

[the numbers in square brackets following a reference indicates: 1. the journal's 2016-17 impact factor according to ISI Web of Knowledge, then the number of literature citations for the paper found by Google Scholar, as of 13 Feb 2019]

H-index = 34, total number of citations = 4081 as of 13 Feb 2019

1. Craw, R.C. & **Weston, P.H.** (1984) Panbiogeography: a progressive research program? *Systematic Zoology* 33: 1-13. [8.917, 90]

2. **Weston, P.H.**, Carolin, R.C., & Armstrong, J.A. (1984) A cladistic analysis of *Boronia* Sm. and *Boronella* Baill. (Rutaceae). *Australian Journal of Botany* 32: 187-203. [0.793, 49]

3. Morrison, D.A. & **Weston, P.H.** (1985) Analysis of morphological variation in a field sample of *Caladenia catenata* (Smith) Druce (Orchidaceae). *Australian Journal of Botany* 33: 185-195. [0.793, 11]

4. Crisp, M.D. & **Weston, P.H.** (1987a) Waratahs - how many species? Pp. 3-15, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 13]

5. Crisp, M.D. & **Weston, P.H.** (1987b) Cladistics and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae. Pp. 65-130, in C.H. Stirton (ed.) *Advances in Legume Systematics Part 3* (Royal Botanic Gardens: Kew). [-, 131]

6. **Weston, P.H.** (1987) *Persoonia* (Proteaceae). Pp. 348-350, in N.G. Marchant *et al*. (eds.) *Flora of the Perth Region* (Western Australian Herbarium: Perth). [-, 0]

7. **Weston, P.H.** & Crisp, M.D. (1987) Evolution and biogeography of the Waratahs. Pp. 17-34, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 14]

8. **Weston, P.H.**, Wilson, P.G., & Hill, K.D. (1987) Identification of *Cannabis*. *Department of Agriculture New South Wales Miscellaneous Bulletin* 25: 148-150. [-, 0]

9. **Weston, P.H.** (1988a) A revision of *Hicksbeachia* (Proteaceae). *Telopea* 3: 231-239. [0.6, 3]

10. **Weston, P.H.** (1988b) Indirect and direct methods in systematics. Pp. 27-56, in C.J. Humphries (ed.) *Ontogeny and Systematics* (Columbia Univ. Press: New York). [-, 76]

11. **Weston, P.H.** (1989) Problems with the statistical testing of panbiogeographic hypotheses. *New Zealand Journal of Zoology* 16: 511. [0.811, 7]

12. **Weston, P.H.** (1990) Notes on *Boronia* (Rutaceae) in New South Wales, including descriptions of three new species. *Telopea* 4: 121-128. [0.6, 6]

13. **Weston, P.H.** & Johnson, L.A.S. (1991) Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales. *Telopea* 4: 269-306. [0.6, 9]

14. Crisp, M.D. & **Weston, P.H.** (1991) *Almaleea*, a new genus of Fabaceae from south-eastern Australia. *Telopea* 4: 307-311. [0.6, 10]

15. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae), a new genus from New Guinea and eastern Australia. *Telopea* 4: 497-507. [0.6, 12]

16. **Weston, P.H.** (1991) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium*, *Pultenaea* and *Dillwynia* (Fabaceae). Pp. 2-19, 452-455, 456-461, 481-497, 499-504, in G. Harden (ed.) *Flora of New South Wales* vol. 2 (New South Wales Univ. Press: Sydney). [-, 0]

17. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae) and *Almaleea* (Fabaceae). Pp. 29-30, 497-498, in G. Harden (ed.) *op. cit.* [-, 0]

18. **Weston, P.H.** & Porteners, M.F. (1991) *Boronia*, *Eriostemon* and *Phebalium* (Rutaceae). Pp. 227-236, 250-254, 255-263, in G. Harden (ed.) *op. cit.* [-, 0]

19. Porteners, M.F. & **Weston, P.H.** (1991) *Correa* and *Crowea* (Rutaceae). Pp. 247-249, 254-255, in G. Harden (ed.) *op. cit.* [-, 0]

20. Crisp, M.D. & **Weston, P.H.** (1991) *Telopea*. Pp. 30-31, in G. Harden (ed.) *op. cit.* [0.6, 0]

21. Gross, C.L. & **Weston, P.H.** (1992) *Macadamia jansenii* (Proteaceae), a new species from central Queensland. *Australian Systematic Botany* 5: 725-28. [0.75, 8]

22. Crisp, M.D. & **Weston, P.H.** (1993) Geographic and ontogenetic variation in morphology of Australian waratahs (*Telopea*: Proteaceae). *Systematic Biology* 42: 49-76. [14.387, 76]

23. Gilmore, S., **Weston, P.H.**, & Thomson, J.A. (1993) A simple, rapid, inexpensive and widely applicable technique for purifying plant DNA. *Australian Systematic Botany* 6: 139-148. [0.75, 41]

24. **Weston, P.H.** (1993) Key to genera, *Cyrtostylis*, *Cryptostylis*, *Zeuxine*, *Cheirostylis*, *Pseudovanilla*, *Erythrorchis*, *Epipogium*, *Gastrodia*, *Oberonia*, *Liparis*, *Dendrobium*, *Calanthe*, *Phaius*, *Geodorum*, *Dipodium*, *Cymbidium*, *Sarcochilus*, *Rhinerrhiza*, *Peristeranthus*, *Papillilabium*, *Schistotylus*, *Plectorrhiza*, *Taeniophyllum* (Orchidaceae). Pp. 134-138, 218-219, 219-221, 221-233, 236-247, in G. Harden (ed.) *Flora of New South Wales* vol. 4 (New South Wales Univ. Press: Sydney). [-, 0]

25. **Weston, P.H.** & Hill, K.D. (1993) *Bulbophyllum* (Orchidaceae). Pp. 233-236, in G. Harden (ed.) *op. cit.* [-, 0]

26. **Weston, P.H.** & Crisp, M.D. (1994) Cladistic biogeography of Waratahs and their allies (Embothrieae: Proteaceae) across the Pacific. *Australian Systematic Botany* 7: 225-249. [0.75, 73]

27. **Weston, P.H.** (1994) The Western Australian species of subtribe Persooniinae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 6: 51-165. [0.6, 19]

28. **Weston, P.H.** & Johnson, L.A.S. (1994) Three new species of *Persoonia* (Proteaceae) from Queensland. *Telopea* 6: 31-37. [0.6, 1]

29. **Weston, P.H.** (1994) Methods for rooting cladistic trees. Pp. 125-155, in D.J. Siebert, R.W. Scotland and D.M. Williams (eds.) *Models in Phylogeny Reconstruction* (Oxford Univ. Press: Oxford). [-, 38]

30. Crisp, M.D. & **Weston, P.H.** (1995) Mirbelieae. Pp. 245-282, in J.J. Doyle and M.D. Crisp (eds.) *Advances in Legume Systematics Part 7: Phylogeny* (Royal Botanic Gardens: Kew). [-, 37]

31. Crisp, M.D. & **Weston, P.H.** (1995) Subtribe Embothriinae (Proteaceae). *Flora of Australia* 16: 382-390. [-, 0]

32. Crisp, M.D., Linder, H.P. & **Weston, P.H.** (1995) Cladistic biogeography of plants in Australia and New Guinea: congruent pattern reveals two endemic tropical tracks. *Systematic Biology* 44: 457-473. [8.917, 121]

33. Thomson, J.A., **Weston, P.H.** & Tan, M.K. (1995) A molecular approach to tracing the major lineages in *Pteridium*. Pp. 21-28, in R.T. Smith and J.A. Taylor (eds.) *Bracken: an Environmental Issue* (University of Leeds: Leeds). [-, 13]

34. **Weston, P.H.** (1995) Key to the genera of Proteaceae in Australia, Subfamily Persoonioideae, Subfamily Bellendenoideae, Subtribe Gevuininae, Subtribe Hicksbeachiinae. *Flora of Australia* 16: 41-46, 47-125, 125-127, 409-410. [-, 0]

35. Bernhardt, P. & **Weston, P.H.** (1996) The pollination ecology of *Persoonia* (Proteaceae) in eastern Australia. *Telopea* 6: 775-804. [0.6, 48]

36. **Weston, P.H.** & Crisp, M.D. (1996) Trans-Pacific biogeographic patterns in the Proteaceae. Pp. 215-232, in A. Keast & S.E. Miller (eds.) *The Origin and Evolution of Pacific Island Biotas, New Guinea to Eastern Polynesia: Patterns and Processes* (SPB Academic Publishing: Amsterdam). [-, 34]

37. **Weston, P.H.** & Johnson, L.A.S. (1997) *Persoonia hindii* (Proteaceae), a new species from the Newnes Plateau, New South Wales. *Telopea* 7: 199-203. [0.6, 6]

38. Jobson, P.C. & **Weston, P.H.** (1998) *Dillwynia glaucula* (Fabaceae: Mirbelieae), a new species from the Southern Tablelands, New South Wales. *Telopea* 8: 1-5. [0.6, 1]

39. **Weston, P.H.** (1999) *Persoonia pauciflora* (Proteaceae), a new species from the Hunter Valley, New South Wales. *Telopea* 8: 159-164. [0.6, 5]

40. Crisp, M.D., Gilmore, S.R. & **Weston, P.H.** (1999) The phylogenetic relationships of two anomalous species of *Pultenaea* (Fabaceae: Mirbelieae) from molecular and morphological data, and description of a new genus. *Taxon* 48: 701-714. [2.447, 21]

41. Jobson, P.C. & **Weston, P.H.** (1999) Two new species of *Dillwynia* (Fabaceae: Mirbelieae), from the Southern Tablelands of New South Wales. *Telopea* 8: 363-369. [0.6, 0]

42. Thomson, J.A., **Weston, P.H.** and Tan, M.K. (1999) A molecular approach to tracing major lineages in *Pteridium*: update and amendment. Pp. 35-36 in J.A. Taylor & R.T. Smith (eds.) *Bracken Fern: Toxicity, Biology and Control* (International Bracken Group: Aberystwyth). [-, 1]

43. **Weston, P.H.** (2000) Process morphology from a cladistic perspective. Pp. 124-144 in R. Scotland & T. Pennington (eds.) *Homology and Systematics: Coding Characters for Phylogenetic Analysis* (Taylor & Francis: Basingstoke). [-, 24]

44. Indsto, J. & **Weston, P.H.** (2000) Near-ultraviolet reflectance in *Dendrobium* (Orchidaceae). Pp. 326-334 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 5]

45. Kores, P.J., **Weston, P.H.**, Molvray, M., & Chase, M.W. (2000) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 449-456 in K.L. Wilson and D.A. Morrison (eds.) *Monocots: Systematics and Evolution*. (CSIRO: Melbourne). [-, 60]

46. Savolainen, V., Fay, M.F., Albach, D.C., Backlund, A., van der Bank, M., Cameron, K.M., Johnson, S.A., Lledo, M.D., Pintaud, J.-C., Powell, M., Sheahan, M.C., Soltis, D.E., Soltis, P.S., **Weston, P.H.**, Whitten, W.M., Wurdack, K.J., & Chase, M.W., (2000) Phylogeny of the eudicots: a nearly complete familial analysis based on *rbc*L gene sequences. *Kew Bulletin* 55: 257-309. [0.577, 467]

47. Crisp, M.D. & **Weston, P.H.** (2000) *Telopea* (Proteaceae) Pp. 115-117 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

48. **Weston, P.H.** (2000) *Persoonia* (Proteaceae) Pp. 89-105 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

49. **Weston, P.H.** & Crisp, M.D. (2000) *Alloxylon* (Proteaceae) P. 115 in G.J. Harden, D.W. Hardin & D.C. Godden (eds.) *Proteaceae of New South Wales* (New South Wales Univ. Press: Sydney). [-, 0]

50. Hill, R.S. & **Weston, P.H.** (2001) Southern (austral) ecosystems. Pp. 361-370 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* vol. 5 (Academic Press: San Diego). [-, 1]

51. Kores, P.J., Molvray, M., **Weston, P.H.**, Hopper, S.D., Brown, A., Cameron, K.M., and Chase, M.W (2001) A phylogenetic analysis of Diurideae (Orchidaceae) based on plastid DNA sequence data. *American Journal of Botany* 88: 1903-1914. [3.05, 135]

52. Jobson, P.C. & **Weston, P.H.** (2001) *Dillwynia rupestris* (Fabaceae: Mirbelieae), a new species from the New England Tableland of New South Wales. *Telopea* 9: 323-327. [0.6, 0]

53. Barker, N.P., **Weston, P.H.**, Rourke, J.P., & Reeves, G. (2002) The relationships of the southern African Proteaceae as elucidated by internal transcribed spacer (ITS) DNA sequence data. *Kew Bulletin* 57: 867-883. [0.577, 33]

54. Mant, J.G., Schiestl, F.P., Peakall, R., & **Weston, P.H.** (2002) A phylogenetic study of pollinator conservatism among sexually deceptive orchids. *Evolution* 56: 888-898. [4.201, 96]

55. **Weston, P.H.** (2002) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium* (Fabaceae), Pp. 3-20, 622-632 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

56. **Weston, P.H.** & Duretto, M.F. (2002) *Boronia* (Rutaceae). Pp. 265-276 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 3]

57. **Weston, P.H.** & Harden, G.J. (2002) *Correa, Philotheca*, *Eriostemon, Crowea, Phebalium, Nematolepis*, *Leionema* (Rutaceae) Pp. 289-310, in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 4]

58. **Weston, P.H.** & Jobson, P.C. (2002) *Dillwynia* (Fabaceae). Pp. 542-549 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 0]

59. **Weston, P.H.** & de Kok, R. (2002) *Pultenaea* (Fabaceae). Pp. 549-565 in G.J. Harden (ed.) *Flora of New South Wales* vol. 2, second, revised edition (New South Wales Univ. Press: Sydney). [-, 1]

60. **Weston, P.H.** & Kooyman, R.M. (2002) Systematics of *Eidothea* (Proteaceae), with the description of a new species, *E. hardeniana*, from the Nightcap Range, north-eastern New South Wales. *Telopea* 9: 821-832. [0.6, 15]

61. Bernhardt, P., Sage, T., **Weston, P.H.**, Azuma, H., Lam, M., Thien, L.B., & Bruhl, J. (2003) The pollination of *Trimenia moorei* (Trimeniaceae): floral volatiles, insect/wind pollen vectors, and stigmatic self-incompatibility in a basal angiosperm. *Annals of Botany* 92: 445-458. [4.041, 87]

62. Qiu, H. & **Weston, P.H.** (2003) Proteaceae. *Flora of China* 5: 192-199 (Science Press: Beijing and Missouri Botanical Garden Press: St Louis). [-, 0]

63. Thien, L.B., Sage, T.L., Jaffré, T., Bernhardt, P., Pontieri, V., **Weston, P.H.**, Malloch, D., Azuma, H., Graham, S.W., McPherson, M.A., Rai, H.S., Sage, R.F., & Duprey, J.-L. (2003) The population structure and floral biology of *Amborella trichopoda* Baillon (Amborellaceae). *Annals of the Missouri Botanical Garden* 90: 466-490. [2.838, 72]

64. Mill, R.R. & **Weston, P.** (2004). Proposals to reject the names *Polypodiopsis* and *Polypodiopsis muelleri* (*Plantae vasculares, incertae sedis*). *Taxon* 53: 203-205. [2.447, 2]

65. **Weston, P.H.** (2004) Proteaceae. Pp. 313-316 in N. Smith, S.A. Mori, A. Henderson, D.W. Stevenson & S.V. Heald (eds.) *Flowering Plants of the Neotropics* (The New York Botanical Garden and Princeton University Press: Princeton). [-, 0]

66. **Weston, P.H.** & Turton, M. (2004) *Phebalium bifidum* (Rutaceae), a new species from the Capertee Valley, New South Wales. *Telopea* 19: 787–792. [0.6, 2]

67. Entwisle, T.J. & **Weston, P.H.** (2005) Majority rules, when systematists disagree. *Australian Systematic Botany* 18: 1–6. [0.75, 29]

68. Indsto, J.O., **Weston, P.H.**, Clements, M.A. & Whelan, R.J. (2005) Highly sensitive DNA fingerprinting of orchid pollinia remnants using AFLP. *Australian Systematic Botany* 18: 207–213. [0.75, 9]

69. Jordan, G.J., Dillon, R.A. & **Weston, P.H.** (2005) Solar radiation as a factor in the evolution of scleromorphic leaf anatomy in Proteaceae. *American Journal of Botany* 92: 789–796. [3.05, 96]

70. Kurzweil, H., **Weston, P.H.** & Perkins, A.J. (2005) Morphological and ontogenetic studies on the gynostemium of some Australian members of Diurideae and Cranichideae (Orchidaceae). *Telopea* 11: 11–33. [0.6, 9]

71. Mant, J., Bower, C.C., **Weston, P.H.** & Peakall, R. (2005) Phylogeography of pollinator-specific sexually deceptive *Chiloglottis* taxa (Orchidaceae): evidence for sympatric divergence? *Molecular Ecology* 14: 3067–3076. [6.086, 26]

72. Mant, J., Peakall, R. & **Weston, P.H.** (2005) Specific pollinator attraction and the diversification of sexually deceptive *Chiloglottis* (Orchidaceae). *Plant Systematics and Evolution* 253: 185–200. [1.239, 33]

73. Mant, J., Brown, G.R. & **Weston, P.H.** (2005) Opportunistic pollinator shifts among sexually deceptive orchids indicated by a phylogeny of pollinating and non-pollinating thynnine wasps (Tiphiidae). *Biological Journal of the Linnean Society* 86: 381–395. [2.288, 16]

74. Rymer, P.D., Whelan, R.J., Ayre, D.J. & **Weston, P.H.** (2005) Reproductive success and pollinator effectiveness differ in common and rare *Persoonia* species (Proteaceae). *Biological Conservation* 123: 521–532. [4.022, 57]

75. **Weston, P.H.**, Perkins, A.J., & Entwisle, T.J. (2005) More than symbioses: orchid ecology, with examples from the Sydney Region. *Cunninghamia* 9: 1–15. [-, 34]

76. **Weston, P.H.** & Barker, N.P. (2006) A new suprageneric classification of the Proteaceae, with an annotated checklist of genera. *Telopea* 11(3): 314-344. [0.6, 86]

77. Indsto, J.O., **Weston, P.H.**, Clements, M.A., Dyer, A.G., Batley, M. & Whelan, R.J. (2006) Pollination of *Diuris maculata* (Orchidaceae) by male *Trichocolletes venustus* bees. *Australian Journal of Botany* 54: 669-679. [0.793, 37]

78. **Weston, P.H.** (2007) Proteaceae. Pp. 364-404 in K. Kubitzki (ed.) *Families and Genera of Vascular Plants* Volume IX (Springer Verlag: Berlin). [-, 26]

79. **Weston, P.H.** (2007) Proteaceae. Pp. 268-269 in V.H. Heywood, R.K. Brummitt, A. Culham & O. Seberg (eds.) *Flowering Plant Families of the World* (Royal Botanic Gardens, Kew: London). [-, 0]

80. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2007) Floral phyllotaxis and floral architecture in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 168: 285–306. [1.748, 36]

81. Indsto, J.O., **Weston, P.H.**, Clements, M., Dyer, A., Batley, M. & Whelan, R. (2007) Generalised pollination of *Diuris alba* R.Br. (Orchidaceae) by small bees and wasps. *Australian Journal of Botany* 55: 628-634. [0.793, 17]

82. Barker, N.P., **Weston, P.H.**, Rutschmann, F. & Sauquet, H. (2007) Molecular dating of the "Gondwanan" plant family Proteaceae is only partially congruent with the timing of Gondwanan break-up. *Journal of Biogeography* 34: 2012-2027. [4.248, 166]

83. Jordan, G.J., **Weston, P.H.**, Carpenter, R.J., Dillon, R.A. & Brodribb, T.J. (2008) The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae. *American Journal of Botany* 95:521-530. [3.05, 82]

84. Mast, A.R., Willis, C.L., Jones, E.H., Downs, K.M., & **Weston, P.H.** (2008) A smaller *Macadamia* from a more vagile tribe: Inference of phylogenetic relationships and divergence times in *Macadamia* and relatives (tribe Macadamieae; Proteaceae). *American Journal of Botany* 95: 843-870. [3.05, 55]

85. Sauquet, H., **Weston, P.H.**, Anderson, C.L., Barker, N.P. Cantrill, D.J., Mast, A.R., & Savolainen, V. (2009) Contrasted patterns of hyperdiversification in Mediterranean hotspots. *Proceedings of the National Academy of Sciences of the U.S.A.* 106: 221-225. [9.661, 169]

86. Staedler, Y.M., **Weston, P.H.** & Endress, P.K. (2009) Comparative gynoecium structure and development in Calycanthaceae (Laurales). *International Journal of Plant Sciences* 170: 21-41. [1.748, 25]

87. Sage, T.L., Hristova-Sarkovsi, K., Koehl, V., Lyew, J., Pontieri, V., Bernhardt, P., **Weston, P.**, Bagha, S., & Chiu, G. (2009) Transmitting tissue architecture in relictual-basal angiosperms: implications for transmitting tissue origins. *American Journal of Botany* 96: 183-206. [3.05, 34]

88. Crisp, M.D., Arroyo, M.T.K., Cook, L.G., Gandolfo, M.A., Jordan, G.J., McGlone, M.S., **Weston, P.H.**, Westoby, M., Wilf, P., & Linder, H.P. (2009) Phylogenetic biome conservatism on a global scale. *Nature* 458: 754-758. [40.137, 465]

89. Indsto, J.O., **Weston, P.H.**, & M.A. Clements (2009) A molecular phylogenetic analysis of *Diuris* (Orchidaceae) based on AFLP and ITS reveals three major clades and a basal species. *Australian Systematic Botany* 22: 1-15. [0.75, 7]

90. Sauquet, H., **Weston, P.H.**, Barker, N.P. Anderson, C.L., Cantrill, D.J. & Savolainen, V. (2009) Using fossils and molecular data to reveal the origins of the Cape proteas (subfamily Proteoideae). *Molecular Phylogenetics and Evolution* 51: 31-43. [4.419, 40]

91. Rossetto, M., Thurlby, K.A.G., Offord, C.A., Allen, C.B., & **Weston, P.H.** (2011) The impact of distance and a shifting temperature gradient on genetic connectivity across a heterogeneous landscape. *BMC Evolutionary Biology* 11(126):1-11. [3.221, 18]

92. Byrne, M., Steane, D., Joseph, L., Yeates, D., Jordan, G.J., Crayn, D., Aplin, K., Cantrill D., Cook, L.G., Crisp, M.D., Keogh, J.S., Melville, J., Moritz, C., Porch, N., Sniderman, J.M.K., Sunnucks P., & **Weston, P.H.** (2011) Decline of a biome: evolution, contraction, fragmentation, extinction and invasion of the Australian mesic zone biota. *Journal of Biogeography* 38: 1635–1656. [4.590, 216]

93. Mast, A.R., Milton, E.F., Jones, E.H., Barker, R.M., Barker, W.R., & **Weston, P.H.** (2012) Time-calibrated phylogeny of the woody Australian genus *Hakea* (Proteaceae) supports multiple origins of insect-pollination among bird-pollinated ancestors. *American Journal of Botany* 99: 472-487. [3.05, 32]

94. Stimpson, M.L., **Weston, P.H.**, Telford, I.R.H., & Bruhl, J.J. (2012) First instalment in resolution of the *Banksia spinulosa* complex (Proteaceae): *B. neoanglica*; a new species supported by phenetic analysis, ecology and geography. *Phytokeys* 14: 57–80. [0.686, 6]

95. Rossetto, M., Allen, C., Thurlby, K., **Weston, P.H.**, & Milner, M. (2012) Genetic structure and bio-climatic modelling support allopatric over parapatric speciation along a latitudinal gradient. *BMC Evolutionary Biology* 12:149. [3.221, 13]

96. Clark, V.R., Perera, S.J., Stiller, M., Stirton, C.H., **Weston, P.H.**, Stoev, P., Coombs, G., Morris, D., Ratnayake-Perera, D., Barker, N.P., & MacGregor, G.K. (2012) A rapid multi-disciplinary biodiversity assessment of the Kamdebooberge (Sneeuberg, Eastern Cape, South Africa): implications for conservation. *SpringerPlus* 1:56 [0.982, 5]

97. Milner, M.L., Rossetto, M., Crisp, M.D., & **Weston, P.H.** (2012) The impact of multiple biogeographic barriers and hybridization on species-level differentiation. *American Journal of Botany* 99: 2045–2057. [3.05, 17]

98. Ford, A.J. & **Weston, P.H.** (2012) A taxonomic revision of *Hollandaea* Anon. (Proteaceae). *Austrobaileya* 8: 670-687. [-, 0]

99. Hidayat, T., **Weston, P.H.**, Yukawa, T., Ito, M., & Rice, R. (2012) Phylogeny of subtribe Aeridinae (Orchidaceae) inferred from DNA sequences data: advanced analyses including Australasian genera. *Jurnal Teknologi (Sciences and Engineering)* 59 (suppl. 1): 87-95. [0.096, 4]

100. **Weston, P.H.** & Hill, R.S. (2013) Southern (austral) ecosystems. Pp. 612-619 in S.A. Levin (ed.) *Encyclopedia of Biodiversity* second edition, vol. 6 (Academic Press: Waltham, MA). [-, 9]

101. Jordan, G.J., Brodribb, T.J., Blackman, C.J., & **Weston, P.H.** (2013) Climate drives vein anatomy in Proteaceae. *American Journal of Botany* 100: 1483-1493. [3.05, 19]

102. **Weston, P.H.** & Woods, L.A. (2013) Correction of a typographical error in the protologue of *Banksia conferta* A.S.George var. *penicillata* A.S. George. *Telopea* 15: 67–69. [0.6, 0]

103. Milner, M.L., McIntosh, E.J., Crisp, M.D., **Weston, P.H.**, & Rossetto, M. (2013) Microsatellite variation for phylogenetic, phylogeography and population genetic studies in *Lomatia* (Proteaceae). *Australian Systematic Botany* 26: 186-195. [0.75, 2]

104. **Weston, P.H.** (2014) What has molecular systematics contributed to our knowledge of the Proteaceae? Pp. 365-397 in P. Besse (ed.) *Molecular Plant Taxonomy: Methods and Protocols*, *Methods in Molecular Biology*, vol. 1115 (Springer: New York). [-, 11]

105. McIntosh, E., Rossetto, M., **Weston, P.H.**, & Wardle, G. (2014) Maintenance of strong morphological differentiation despite ongoing natural hybridization between sympatric species of *Lomatia* (Proteaceae). *Annals of Botany* 113: 861-872. [4.041, 16]

106. Stimpson, M.L., Bruhl, J.J. & **Weston, P.H.** (2014) Could this be Australia's rarest *Banksia*? *Banksia vincentia* (Proteaceae), a new species known from fourteen plants from south-eastern New South Wales, Australia. *Phytotaxa* 163: 269–286. [1.24, 1]

107. Thomas, N., Bruhl, J.J., Ford, A., & **Weston, P.H.** (2014) Molecular dating of Winteraceae reveals a complex biogeographic history involving both ancient Gondwanan vicariance and long-distance dispersal. *Journal of Biogeography* 41: 894-904. [4.590, 28]

108. **Weston, P.H.**, Perkins, A.J., Indsto, J.O., & Clements, M.A. (2014) Phylogeny of Orchidaceae tribe Diurideae and its implications for the evolution of pollination systems. Pp. 91-154 in Edens-Meier, R. & P. Bernhardt (eds.) *Darwin's Orchids: Then and Now* (University of Chicago Press: Chicago). [-, 10]

109. Kooyman, R.M., Wilf, P., Barreda, V.D., Carpenter, R.J., Jordan, G.J., Sniderman, J.M.K., Allen, A., Brodribb, T.J., Crayn, D., Feild, T.S., Laffan, S.W., Lusk, C., Rossetto, M., & **Weston, P.H.** (2014) Paleo-Antarctic rainforest into the modern Old World tropics: the rich past and threatened future of the 'southern wet forest survivors'. *American Journal of Botany* 101: 2121 – 2135. [3.05, 36]

110. Lambers, H., Clode, P., Hawkins, H.-J., Laliberté, E., Oliveira, R., Reddell, P., Shane, M.W., Stitt, M., & **Weston, P.H.** (2015) Metabolic adaptations of the non-mycotrophic Proteaceae to soil with a low phosphorus availability. *Annual Plant Reviews* 48: 289–336 (Plaxton, W.C. & Lambers, H. (eds.) *Phosphorus Metabolism in Plants in the Post-genomic Era: From Gene to Ecosystem* (Wiley-Blackwell Publishing: Chichester, UK)). [-,34]

111. Mast, A.R., Olde, P., Makinson, R.O., Jones, E., Kubes, A., Miller, E. & **Weston, P.H.** (2015) Paraphyly changes understanding of timing and tempo of diversification in subtribe Hakeinae (Proteaceae), a giant Australian plant radiation. *American Journal of Botany* 102: 1634-1646. [3.05, 15]

112. Thiele, K.R., **Weston, P.H.** & Mast, A.M. (2015) Paraphyly, modern systematics and the transfer of *Dryandra* into *Banksia* (Proteaceae): a response to George. *Australian Systematic Botany* 28: 194–202 [0.75, 1]

113. Milner, M.L., **Weston, P.H.,** Rossetto, M., & Crisp, M.D., (2015) Biogeography of the Gondwanan genus *Lomatia* (Proteaceae): vicariance at continental and intercontinental scales. *Journal of Biogeography* 42: 2440–2451. [4.590, 9]

114. Stimpson, M.L., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (2016) A morphometric analysis of the *Banksia spinulosa* complex (Proteaceae) and its complex taxonomic implications. *Australian Systematic Botany* 29: 55-86. [0.75, 0]

115. Onstein, R.E., Jordan, G.J., Sauquet, H., **Weston, P.H.**, Bouchenak-Khelladi, Y., Carpenter, R.J., & Linder, H.P. (2016) Evolutionary radiations of Proteaceae are triggered by the interaction between traits and climates in open habitats. *Global Ecology and Biogeography* 25: 1239–1251. [6.045, 17].

116. van der Merwe, M., Crayn, D., Ford, A., Rossetto, M., & **Weston, P.H.** (2016) Evolution of Australian *Cryptocarya* (Lauraceae) based on nuclear and plastid phylogenetic trees: evidence of recent landscape-level disjunctions *Australian Systematic Botany* 29: 157–166. [0.75, 3]

117. Citerne, H., Reyes, E., Le Guilloux, M., Delannoy, E., Sannier, J., Simmonet, F., Sauquet, H., Nadot, S., **Weston, P.H.**, & Damerval, C. (2017) Characterisation of CYCLOIDEA-like genes in

Proteaceae, a basal eudicot family with multiple shifts in floral symmetry. *Annals of Botany* 119: 367-378. [4.041, 13]

118. **Weston, P.H.**, & Jordan, G.J. (2017) Evolutionary biogeography of the Australian flora in the Cenozoic Era. Pp. 40-62 in D.A. Keith (ed.) *Australian Vegetation*, 3rd edition (Cambridge University Press: Cambridge). [-, 1]

119. Cardillo, M., **Weston, P.H.**, Reynolds, Z., Olde, P.M., Mast, A.R., Lemmon, E., Lemmon, A. & Bromham, L. (2017) The phylogeny and biogeography of *Hakea* (Proteaceae) reveals the role of biome shifts in a continental plant radiation. *Evolution* 71: 1928–1943. [4.201, 10]

120. Holmes, G., **Weston, P.H.**, Murphy, D., Gardner, S., Connelly, C., & Cantrill, D.J. (2018) The genealogy of geebungs: phylogenetic analysis of *Persoonia* (Proteaceae) and related genera in subfamily Persoonioideae. *Australian Systematic Botany* 31: 166–189. [0.75, 0]

121. **Weston, P.H.** (in press) Proteaceae. *Flora of North America North of Mexico* 10-11 (Oxford University Press: New York and Oxford). [-,-]

122. Steenbeeke, G., Dowle, M., Laurence, M.H., Liew, E.C.Y., Newby, Z.-J., Renner, M., Sommerville, K., Weston, P.H., Ward, S. (in review) Phylogeny of selected *Microtis* (Orchidaceae) in south eastern Australia and its implications for taxonomy and conservation priorities. *Telopea* [0.6, -]

Papers in Preparation

1. Stimpson, M.L., Wright, B.R., **Weston, P.H.**, Whalley, R.D.B., & Bruhl, J.J. (in review) Seedling morphology helps unravel the taxonomic intricacies in the *Banksia spinulosa* complex (Proteaceae). *Botanical Journal of the Linnean Society* [2.523, -]

2. Jobson, P.C. & **Weston, P.H.** (in prep.) Recombinations in *Dillwynia* (Fabaceae: Faboideae: Mirbelieae) for Flora of South Australia.

3. Jordan, G.J. & **Weston, P.H.** (in prep.) Estimating the age of origin of functional traits.

4. **Weston, P.H.** & Garnock-Jones, P. (in prep.) A taxonomic revision of *Knightia* (Proteaceae).

Conference Abstracts

1. **Weston, P.H.** (1984) A reappraisal of Nelson's direct method of character analysis. P. 9, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

2. Wilson, P.G. & **Weston, P.H.** (1984) A preliminary cladistic analysis of the *Metrosideros* suballiance (Myrtaceae). P. 19, Programme and Abstracts, Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra.

3. **Weston, P.H.** (1984) Drifting waratahs or continents? P. 9, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

4. Crisp, M.D. & **Weston, P.H.** (1984) Waratahs – one species or two? P. 5, Abstracts, *Waratahs: Their Biology Cultivation and Conservation*, an Australian Flora Foundation Symposium, Canberra.

5. **Weston, P.H.** (1988) Problems with the statistical testing of panbiogeographic hypotheses. Abstracts, Symposium on *Panbiogeography of New Zealand*, Wellington.

6. **Weston, P.H.** (1989) Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae. P. 37, Program and Abstracts, Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney.

7. **Weston, P.H.** & Crisp, M.D. (1990) Transoceanic cladistic patterns in the Proteaceae. P. 51, Abstracts, *Systematics and Biogeography of the Austral Biota*, IXth meeting of the Willi Hennig Society, Canberra.

8. **Weston, P.H.** (1993) Direct methods for polarising character transformation series. P. 13, Programme and Abstracts, *Models in Phylogeny Reconstruction*, a joint conference of The Systematics Association and The Linnean Society, London.

9. Crisp, M.D., Linder, H.P., & **Weston, P.H.** (1994) Cladistic biogeography of Australia: is there more than one endemic tropical track? P. 14, Program and Abstracts, *Origin and Evolution of the Flora of the Monsoon Tropics*, a symposium of the Australian Systematic Botany Society, Kuranda.

10. **Weston, P.H.** (1996) ITS sequence variation in the Proteaceae and what it tells us about phylogeny. P. 49, Abstracts, *An International Symposium on the Biology of Proteaceae*, Melbourne.

11. **Weston, P.H.** (1997) Rolf Sattler's plant morphology and cladistic analysis. P. 54, Abstracts, *First Biennial International Conference of the Systematic Association*, Oxford, U.K..

12. **Weston, P.H.** & Crisp, M.D. (1997) Cladistic biogeography of a key woody group: Proteaceae. P. 5, Abstracts, *II Southern Connection Congress*, Valdivia, Chile.

13. Kores, P.J., Molvray, M., **Weston, P.H.**, & Chase, M.W. (1998) Phylogenetic relationships within the Diurideae (Orchidaceae); inferences from plastid *mat*K DNA sequences. Pp. 33-34, Abstracts. Monocots II Conference, Sydney.

14. **Weston, P.H.** (1999) Historical biogeography of Proteaceae. Abstracts, XVI International Botanical Congress, Saint Louis.

15. **Weston, P.H.** (2002) Proteaceae: Brown and now. P. 16, Abstracts, Robert Brown 200 Conference, Sydney.

16. Mant, J.G., **Weston, P.H.**, Peakall, R., & Schiestl, F.P. (2003) Coevolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators. P. 55, Abstracts, *Monocots III*, The Third International Conference on the Comparative Biology of the Monocotyledons, Ontario, U.S.A..

17. **Weston, P.H.,** Clements, M.A., Indsto, J.O., Mant, J., Peakall, R., & Perkins, A.J. (2005) Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae). XVII International Botanical Congress, Vienna.

18. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2006) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 39 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

19. **Weston, P.H.** (2006) A new suprageneric classification of the Proteaceae. P. 45 Conference Book, *Plant Diversity in the Tropics,* Australian Systematic Botany Society conference, Cairns, Australia.

20. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K.. (2006). Floral architecture and phyllotaxis in Calycanthaceae (Laurales). Abstract 192, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

21. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2006). A phylogenetic approach to the evolution of pollen morphology in Proteaceae (Proteales). Abstract 405, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

2. Milton, E.F., **Weston, P.H.**, Mast, A. (2006) The diversification of ecologically significant traits in the species-rich Australian genus *Hakea* (Proteaceae). Abstract 324, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

23. Mast, A., **Weston, P.H.**, Jones, E., Sauquet, H., Cantrill, D., Jordan, G., & Barker, N. . (2006) The timing of disjunctions in the southern hemisphere family Proteaceae: Sensitivity analysis with 6 genes, multiple calibration points, and 70+ genera. Abstract 327, Botany 2006 (Botanical Society of America conference, Chico, U.S.A).

24. Willis, C.L., **Weston, P.H.**, & Mast, A. (2007) Inference of phylogenetic relationships in *Macadamia* and relatives (tribe Macadamieae; Proteaceae) using three chloroplast and three nuclear DNA regions. Abstract 1677, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

25. Staedler, Y.M., **Weston, P.H.**, & Endress, P.K. (2007) Structure and development of the gynoecium in Calycanthaceae (Laurales). Abstract 1121, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

26. Sauquet, H., Cantrill, D.J., **Weston, P.H.**, Barker, N., Mast, A., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). Abstract 1593, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

27. Milton, E.F., **Weston, P.H.**, Barker, W., Barker, R., & Mast, A. (2007) Inference of phylogenetic relationships in *Hakea* (Proteaceae) using morphology and four chloroplast and three nuclear DNA regions. Abstract 1712, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

28. Kubes, A., **Weston, P.H.**, Makinson, R.O., Olde, P., & Mast, A.R. (2007) Resolving relationships in *Grevillea* (Proteaceae), the third largest Australian plant genus. Abstract 1814, Botany & Plant Biology 2007 (Botanical Society of America conference, Chicago).

29. **Weston, P.H.**, Barker, N.P., Rutschmann, F., & Sauquet, H. (2007) 'I'm not dead yet' – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation). P. 76, Conference Program, 5th International Southern Connection Congress, Adelaide.

30. Sauquet, H., **Weston, P.H.**, Cantrill, D.J., & Savolainen, V. (2007) Bringing together the living and the dead: integrating extant and fossil biodiversity in evolutionary studies of Proteaceae (Proteales). P. 58, Conference Program, 5th International Southern Connection Congress, Adelaide.

31. Mast, A., Jones, E., Barker, R., Barker, W., **Weston, P.H.** (2009) The phylogeny and age of the woody Australian genus *Hakea* (Proteaceae) and the evolution of its leaf and fire persistence features. Abstract 335, Botany & Mycology 2009 (Botanical Society of America conference, Snowbird, Utah)

32. Holmes, G.D., Porter, C., Murphy, D.J., **Weston, P.H.** and Cantrill, D.J. (2009) What are the relationships among Snottygobbles and Geebungs? A preliminary phylogeny of *Persoonia* (Proteaceae). P 45, Conference Booklet, *Systematic Botany: from Science to Society*, a conference of the Australian Systematic Botany Society, Armidale.

33. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests. P. 29, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

34. **Weston, P.H.**, Sauquet, H., Mast, A.R., & Barker, N.P. (2010) Cladistic biogeography, molecular dating, fossils and the Proteaceae. P. 18, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

35. Baum, M., Crisp, M., Rossetto, M. & **Weston, P.** (2010) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 20, Program, *Gondwana Reunited: a Southern Perspective for a Changing World*, VI Southern Connection Congress, Bariloche.

36. **Weston, P.H.** (2010) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 68, *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*, a conference of the Australian Systematic Botany Society, Lincoln University, New Zealand.

37. **Weston, P.H.** (2011) Cenozoic environmental change and the systematics of southern hemisphere plants. P. 34, Abstracts 2nd Book, *Plants in a Changing World*, (37th annual conference of the South African Association of Botanists, Rhodes University, South Africa).

38. **Weston, P.H.**, Indsto, J.O., Perkins, A.J., Clements, M.A., & Peakall, R. (2011) Total evidence phylogenetic analysis of the orchid tribe Diurideae and what it tells us about the evolution of pollination systems. P. 152, Abstract Book, XVIII International Botanical Congress, Melbourne.

39. **Weston, P.H.**, Wilson, P.G., Conn, B.J., Rymer, P.D. (2011) Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations. P. 266, Abstract Book, XVIII International Botanical Congress, Melbourne.

40. Nguyen, C.H., Beattie, G.A.C., Holford, P., Mabberley, D.J., & **Weston, P.H.** (2011) Determining the origin and diversification of *Murraya paniculata*: one or more species? P. 354, Abstract Book, XVIII International Botanical Congress, Melbourne.

41. Milner, M., Crisp, M.D., Rossetto, M., & **Weston, P.H.** (2011) Speciation and phylogeography of *Telopea* and *Lomatia* (Proteaceae). P. 281, Abstract Book, XVIII International Botanical Congress, Melbourne.

42. **Weston, P.H.** (2012) Contested, uncontested and potentially controversial taxonomic changes in the Proteaceae: how do they differ? P. 49, Program and Abstracts, *Local Knowledge, Global Delivery* (Australasian Systematic Botany Society 2012 Perth Conference Committee: Perth).

43. **Weston, P.H.,** Jones, E.H., Olde, P.M., Makinson, R.O., & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 101, *Genetics in the Harbour City* (Program and abstracts of the annual conference of the Genetics Society of Australasia, Sydney).

44. Onstein, R., Jordan, G., Bouchenak-Khelladi, Y., Xing, Y., Wright, I., Sauquet, H., Carpenter, R., **Weston, P.** & Linder, P. (2013) Leaf trait evolution in the Proteaceae. P. 11, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

45. Cantrill, D.J., Lewis, E., Murphy, D.J. & **Weston, P.H.** (2013) Variation in pollen morphology within *Persoonia* (Proteaceae) supports clades revealed by molecular data. P. 19, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

46. **Weston, P.H.**, Jones, E.H., Olde, P.M., Makinson, R.O. & Mast, A.R. (2013) Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications. P. 20, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

47. Schulte, K., Micheneau, C., Simpson, L., **Weston, P.**, Crayn, D. & Clements, M. (2013) The *Dendrobium* alliance revisited: A molecular phylogenetic approach towards reconciling taxonomic concepts in Dendrobiinae (Orchidaceae). P. 32, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

48. Stimpson, M.L., Prychid, C.J., **Weston, P.H.** Whalley, R.D.B. & Bruhl, J.J. (2013) Structure and function of the cotyledonary node in the *Banksia spinulosa* complex (Proteaceae). P. 68, *Systematics Without Borders* (Program and abstracts of the combined conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney).

49. **Weston, P.H.** (2014) Problems and progress in plant systematics since Nancy Burbidge. P. 17, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

50. Thomas, N., Bruhl, J., Ford, A. & **Weston, P.** (2014) Molecular dating of Winteraceae reveals a complex biogeographical history involving both ancient Gondwanan vicariance and long-distance dispersal. P. 28, *Next Generation Systematics* (Program and abstracts of the conference of the Australasian Systematic Botany Society, Massey University, Palmerston North, New Zealand).

51. **Weston, P.H.** Reyes, E. & Sauquet, H. (2015) A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution. P. 35, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

52. Schulte, K., Micheneau, C., Field, A., **Weston, P.**, Crayn, D. & Clements, M. (2015) The *Dendrobium* alliance revisited: examining macroevolutionary patterns in Dendrobiinae (Orchidaceae). P. 30, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

53. Thiele, K., Barker, W.R., Crayn, D.M., Waycott, M., Holland, A., Breitwieser, I., Lockhart, P., Bayly, M., **Weston, P.H.**, & Schulte, K. (2015) Progress towards a decadal plan for Australasian biodiversity science – an update. P. 33, *Building Our Botanical Capital* (Program and abstracts of the conference of the Australasian Systematic Botany Society, CSIRO Discovery Centre, Canberra).

Articles in Magazines, Newsletters, etc.

1. Weston, P.H. (1988c) Proteaceae. Australian Plants 14: 259.

2. Weston, P.H. (1988d) The flower - part 2. *Australian Plants* 14: 262-263.

3. Weston, P.H. (1992) A special tree [an article about *Idiospermum australiense*]. *Friends of the Royal Botanic Gardens Newsletter* 14: 4.

4. Weston, P.H. & Crisp, M.D. (1995) Phylogenetic analysis. *Australasian Biotechnology* 5(5): 291-293.

5. Weston, P.H. (1998) Lust, lies and fungus flies. *The Gardens* 39: 8-9.

6. Weston, P.H. (2000) Flower wasps and bird orchids. *The Gardens* 44: 5.

7. Weston, P.H. (2000) An intriguing case of snottygobbles. *The Gardens* 44: 11.

8. Weston, P.H. (2001) The Nightcap Oak comes out of the bush and into the spotlight. *The Gardens* 50: 6.

9. Weston, P.H. (2001) New tree species discovered in Australia. *Forest Genetic Resources* 29: 26.

10. Weston, P.H. & Kooyman, R.M. (2002) *Eidothea hardeniana*: botany and ecology of the 'Nightcap Oak'. *Australian Plants* 21: 339-342, 344.

11. Weston, P.H. (2003) Proteaceae subfamily Persoonioideae: botany of the geebungs, snottygobbles and their relatives. *Australian Plants* 22: 62-78, 91.

12. Weston, P.H. (2005) Sex and Death in the Sydney Tropical Centre. *The Gardens* 65: 6-7, republished in re-edited form in *Australian Orchid Review* 70(5): 32-33.

14. Weston, P.H. (2009) From the President. *ASBS Newsletter* 141: 1-3.

15. Weston, P.H. (2010) Madagascar: a world of botanical wonders. *The Gardens* 84: 10-11.

16. Weston, P.H. (2010) From the President. *ASBS Newsletter* 142: 1.

17. Weston, P.H. (2010) From the President. *ASBS Newsletter* 143: 1-3.

18. Weston, P.H. (2010) From the President. *ASBS Newsletter* 144-145: 1.

19. Weston, P.H. (2010) ASBS President's Report 2009–2010. *ASBS Newsletter* 144-145: 4-6.

20. Weston, P.H. (2010) Life Membership awarded to John Clarkson. *ASBS Newsletter* 144-145: 16.

21. Weston, P.H. (2010) ASBS 2010 Conference Report, Lincoln, Canterbury, New Zealand. *ASBS Newsletter* 144-145: 17-21.

22. Weston, P.H. (2011) From the President. *ASBS Newsletter* 146: 1-2.

23. Weston, P.H. (2011) From the President. *ASBS Newsletter* 147-148: 1-3.

24. Weston, P.H. (2011) Award of Nancy T. Burbidge Medals to Professors Pauline Ladiges and Michael Crisp. *ASBS Newsletter* 147-148: 3-8.

25. Weston, P.H. (2011) The ARC-ERA journal ranking project has been aborted. *ASBS Newsletter* 147-148: 11-12.

26. Weston, P.H. (2011) Recent advances and new developments in biogeographical reconstruction methods. *ASBS Newsletter* 147-148: 14.

27. Weston, P.H. (2011) [Book review of] The Flowering of Australia's Rainforests: A Plant and Pollination Miscellany. By Geoff Williams and Paul Adam. *ASBS Newsletter* 147-148: 21-23.

28. Weston, P.H. (2011) From the President. *ASBS Newsletter* 149: 1-2.

29. Weston, P.H. (2011). ASBS President's Report 2010-2011. *ASBS Newsletter* 149: 4-7.

30. Weston, P.H. (2012) From the President. *ASBS Newsletter* 150: 1-2.

31. Weston, P.H. (2012) New proposals to change ASBS rules. *ASBS Newsletter* 150: 4-10.

32. Weston, P.H. (2012) From the President. *ASBS Newsletter* 151: 1-2.

33. Weston, P.H. (2012) A remarkable botanical find: the double discovery of *Danhatchia australis* in Australia. *The Gardens* 94: 27.

34. Weston, P.H. (2012) From the President. *ASBS Newsletter* 152: 1-2.

35. Weston, P.H. (2013) Exploring southern Africa. *The Gardens* 96: 18-19.

36. Weston, P.H. (2013) ASBS President's Report 2011-2012. *ASBS Newsletter* 153: 7-10.

37. Weston, P. (2013) Not an exact science. *Sydney Morning Herald,* 19 June 2013: 19.

38. Weston, P.H. (2015) Funding research. *The Gardens* 103:33.

39. Weston, P.H. (2016) Building a database of floral characters for researching the iconic Australian plant family Proteaceae. Report to the Winston Churchill Memorial Trust

(https://www.churchilltrust.com.au/media/fellows/Weston_P_2014_Building_a_database_of_floral_characters_of_Proteaceae.pdf).

40. Weston, P.H. (2016) Hunting Proteaceae from European dungeons to the wilds of the Western Cape. *The Gardens* 109: 16-17.

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document D – Trend analysis

Supporting document D – Contents

Trend analysis report – summary

25 July 2019

The purpose of this paper is to summarise the trend analysis final report prepared by Ascelin Gordon and Isaac Peterson of RMIT University.

INTRODUCTION

The trend analysis is a modelling project undertaken as part of the Western Sydney strategic assessment to model long-term changes in native vegetation extent and condition across the Cumberland subregion under various scenarios that approximate the development impacts of the Growth Areas and the conservation benefits of the offset areas under the Plan.

The trend analysis is not a requirement of the Cth EPBC Act/Terms of Reference (ToR) or NSW BC Act/BAM.

It was undertaken by Dr Ascelin Gordon who is a senior research fellow at RMIT University, by Dr Isaac Peterson who is a research fellow at RMIT University Melbourne. Open Lines oversaw the project, including helping to define the development and offset scenarios.

PURPOSE OF TREND ANALYSIS

The purpose of the trend analysis is to better understand:

- Underlying trends in native vegetation condition in the subregion
- Influence of landscape level threats on native vegetation condition, including relative to urban development
- Potential benefits to native vegetation condition of securing offsets early relative to late in program implementation
- Outcomes of different management regimes on native vegetation condition in offset areas in different existing condition states, including the potential benefits of restoring low condition vegetation through high intensity management

USE AND LIMITATIONS

The trend analysis is a high-level modelling exercise. By necessity, it incorporates a range of assumptions, and has a number of limitations uncertainties associated with the results. It will be used only to provide context, or to inform at a general level, the strategic assessment.

It will mainly be used to:

- Inform the evaluation of the adequacy of the Plan under the ToR and the draft OEH *Guidelines for planning authorities for proposing conservation measures in strategic applications for biodiversity certification*
- Inform high level decisions on Plan implementation, such as the timing and management of offset areas

The trend analysis provides a general indication of the adequacy of the conservation package under the Plan. However, due to the significant uncertainties and assumptions underlying the analysis, it does not provide a complete understanding of the adequacy of the package and will not be used as the primary basis for evaluating the Plan.

SCOPE

The trend analysis modelled how the extent and condition of one PCT – PCT 849 (one of the PCTs that comprise Cumberland Plain Woodland) changes over time under various scenarios. Only one PCT was modelled due to the time and resources needed for the expert elicitation process to model condition change through time.

Care should be taken in extrapolating the results to other PCTs. However, the overall findings are likely to have relevance and provide useful context to a discussion of long-term trends in native vegetation generally in the Cumberland subregion.

The project modelled various scenarios that approximate the development within the Growth Areas and the offset areas proposed under the Plan over the implementation period for the Plan (37 years). Development and offset areas were based on draft development footprint and Conservation Investigation Area (CIAs) boundaries at November 2018.

The scenarios modelled were:

1. Do nothing – assumes no development or offsetting and continuation of typical land use activities
2. Development only – assumes development occurs in the Growth Areas without offsets
3. Development with offsets secured early and subject to low intensity management
4. Development with offsets secured incrementally and subject to low intensity management
5. Development with offsets secured early and subject to high intensity management
6. Development with offsets secured incrementally and subject to high intensity management

As part of scenarios 3-6, two sets of sub-scenarios were modelled:

- All PCT 849 was secured in the CIAs (assumes 100% of landholders willing to secure offsets)
- Half of all PCT 849 was secured in the CIAs (assumes 50% of landholders willing to secure offsets)

It is recognised that these assumptions about offset timing, low intensity management and landholder willingness may not be realistic and represent the outer bounds of what is likely to occur in practice. However, this is considered appropriate because it allows clear differences in the results of the modelling to be identified, making the results more useful. As the outputs of the modelling are subject to significant uncertainty and assumptions, it is not meaningful to distinguish between a large number of scenarios that could be considered more realistic, but that all have results that are not significantly different.

PROCESS AND METHODS

The trend analysis involved three key steps:

- An expert elicitation process comprising two workshops to derive data on how native vegetation condition (using PCT 849) is predicted to change over time under different management scenarios, including a do nothing scenario
- Development of a spatial simulation model based on data derived from the expert elicitation process to predict how native vegetation (using PCT 849) changes over time under different development and offset scenarios
- Preparation of a report on the methods and results

Data was elicited from the experts so a simplified approximation of the BAM vegetation integrity score over time could be derived. Data was elicited on four plant growth form groups (trees, grass & grass-like, forbs and shrubs) and experts were asked to provide estimates for how two ecological attributes (plant species richness and plant cover) change over time (20, 40, and 60 year periods) for vegetation zones within PCT 849 within four different condition states.

The following eight experts participated in two expert elicitation workshops:

- David Keith (University of NSW)
- Charles Morris (University of Western Sydney)
- Peter Ridgeway (Local Land Services)
- David Kirkland (Western Sydney Parklands Trust)
- Jonathan Sanders (former National Parks and Wildlife Service)
- Paul Price (Biosis)
- Greg Steenbeeke (on secondment to DPIE from OEH)

A number of these experts, particularly David Keith, provided significant input and guidance on the expert elicitation process and the methods and assumptions used as part of the process.

RESULTS

The main results of the trend analysis are presented in **Error! Reference source not found.**3 to 15 in the final trend report.

Results are discussed in terms of 'outcomes' and 'impacts', and at two scales:

- Landscape scale – this covers changes on PCT 849 over the entire Cumberland subregion
- Program scale – this covers changes in PCT 849 over the program area only (Growth Areas and CIAs)

‘OUTCOMES’ RESULTS

The ‘outcomes’ results are shown in Figures 13 and 14. These show changes in native vegetation extent and condition over time under each scenario relative to the current situation, taking into account ongoing decline from landscape scale threats.

Figures 13 and 14 indicate whether an offset scenario compensates for the impacts of both the development and ongoing decline from landscape scale threats. A vegetation integrity score for a scenario that is higher than the starting point indicates that scenario has compensated for both the development impacts and landscape threats at that point in time.

Figure 13 shows outcomes at the landscape scale and Figure 14 shows outcomes at the program scale.

‘IMPACTS’ RESULTS

‘Impacts’ results are shown in Figure 15. This shows changes in native vegetation extent and condition over time under each scenario relative to the ongoing decline from landscape scale threats under the do-nothing scenario.

The impacts results indicate whether an offset scenario compensates for the impacts of the development only (not including the ongoing decline from landscape scale threats). A vegetation integrity score for a scenario that is greater than zero indicates that scenario has compensated for the development impacts at that point in time.

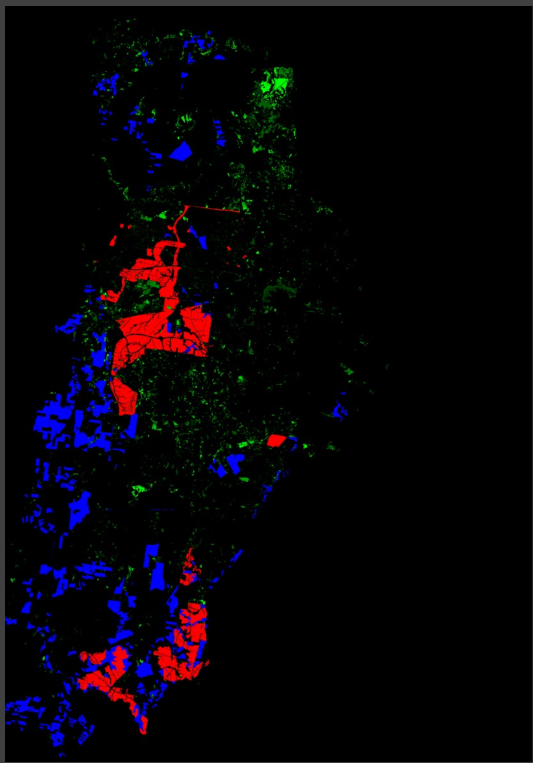
KEY FINDINGS

The key findings of the trend analysis for PCT 849 suggest that:

- Landscape scale threats across the Cumberland subregion, such as weed invasion, illegal activities, rubbish dumping, disturbance from recreational activities, are causing substantial declines
- The impacts of the Growth Areas are of a similar scale to ongoing declines from landscape scale threats across the entire subregion over 37 years. Both result in a reduction in total vegetation integrity score (summed over all CPW in the subregion) of about 6%
- In terms of whether the Plan may compensate for the Growth Areas within the program area, the analysis suggests:
    - Three of the four offset scenarios compensate for development impacts (all except scenario 4) when 100% of the CPW known to be available in the offset area is secured as an offset
    - Two of the four offset scenarios provide adequate compensation for development impacts when 50% of the CPW known to be available in the offset area is secured as an offset
- In terms of whether the Plan may compensate for the Growth Areas as well as ongoing declines from landscape scale threats within the program area, the analysis suggests:
    - Three of the four offset scenarios compensate for development impacts and landscape scale threats when 100% of the CPW known to be available in the strategic offset area is secured
    - None of the offset scenarios compensate for development impacts and landscape scale threats when only 50% of the CPW known to be available in the strategic offset area is secured
- The timing of offset implementation and the level of management intensity make a significant difference to the gains able to be achieved by offsets, with early implementation/high intensity management always performing best
- While possible under scenario 5, the Plan is generally unlikely to be able to reverse declines from both the Growth Areas and landscape scale threats across the entire subregion. This is because the magnitude of landscape scale threats is substantial and the Plan can only influence a relatively small proportion of the subregion
- The relative benefit of early implementation compared to high intensity management depends on the time period over which gains are evaluated. The results suggest that:
    - Early implementation with low or high intensity management delivers greater gains in the short term (1 to 2 decades)
    - Early implementation with high intensity management delivers the greatest gains in the long term
- Results of the expert elicitation indicates that high intensity management provides significant potential for providing restoration gains for CPW, even when starting from a low initial condition. However, low intensity management has limited capacity to provide restore gains for CPW over time, especially when starting from a low initial condition

It is important to note that the results of the trend analysis are based 1,605 ha of PCT 849 being available in the offset areas. The current target in the draft Plan for securing PCT 849 is greater than this – securing larger amounts of this PCT would change the results of the analysis and improve the outcomes of the offset scenarios.

Cumberland Subregion Conservation Plan – Vegetation Trend Analysis



Ascelin Gordon, Isaac Peterson

RMIT University

PREPARED FOR THE NSW DEPARTMENT OF

PLANNING, INDUSTRY AND ENVIRONMENT,

OPEN LINES, AND BIOSIS

Suggested citation:

Gordon A., Peterson I. (2019) Cumberland Subregion Conservation Plan — Vegetation Trend Analysis. RMIT University, Melbourne, Victoria. 49 pages.

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Isaac Peterson is a research fellow at RMIT University with who specializes on statistical approaches to ecological modelling and undertakes research that focusses on modelling the outcomes of biodiversity offsetting.

Acknowledgments

A range of people have been invaluable in pulling together the data required for this study and providing input into the expert elicitation. In particular we would like to thank: Tom Holden (Open Lines), Peter Hemphill (Open Lines), Rebecca Dwyer (Biosis), Darren James (DAJ Environmental), and James Shephard (Biosis), and in addition Jonathan Sanders, Greg Steenbeeke, Charles Morris, Paul Price, Peter Ridgeway, David Kirkland and David Keith, who contributed their time and knowledge to the expert elicitation process reported here.

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SUMMARY

The NSW Government has identified four urban Growth Areas, a new rail line and a series of road and rail Transport Corridors to support planned future growth in Western Sydney over the next 37 years.

As part of this process, the NSW Department of Planning, Industry and Environment (DPIE) is preparing the Cumberland Plain Conservation Plan (the Plan) to support two separate statutory approvals processes under State and Commonwealth laws to address the impacts of the proposed development on biodiversity values.

The Plan describes the proposed urban and transport development and a set of commitments and actions to achieve the Plan's objective and offset the impacts of the proposed development on biodiversity values.

This report presents the results of a trend analysis examining long-term changes in the extent and condition of a native vegetation community in the Cumberland subregion under various scenarios that approximate the development impacts of the Growth Areas and the conservation benefits of the offsets under the Plan.

The native vegetation community examined is Plant Community Type (PCT) 849 *Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion*. This is one of two PCTs that make up the threatened ecological community *Cumberland Plain Woodland in the Sydney Basin Bioregion* as defined under the Biodiversity Conservation Act (the other being PCT 850). PCT 849 is also part of the threatened ecological community *Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest* under the EPBC Act, although size and condition thresholds apply to the definition of the community under this Act.

PCT 849 is referred to in this report as 'CPW' hereafter.

The purpose of the trend analysis is to better understand, in relation to CPW extent and condition:

- Underlying trends in the subregion
- The significance of existing landscape scale threats relative to urban development
- Potential benefits of securing offsets early relative to late in program implementation
- The outcomes of different management regimes in offset areas in different existing condition states, including the potential benefits of restoring low condition sites through high intensity management

In this report, the condition of CPW is characterized using an approximation of the vegetation integrity score defined in the NSW Biodiversity Assessment Method (BAM).

The report consists of two major outputs: (i) a formal expert elicitation to gather quantitative knowledge regarding how the condition of CPW will change over time under high or low intensity management, and where subject to typical ongoing private land activities; and (ii) quantitative modelling to simulate the urban development within the Growth Areas, compensation via managing areas as offsets in a strategically defined offset region, and the ecological response of CPW.

The modelling includes 10 scenarios, with 8 of these exploring different options for implementing biodiversity offsets. These 8 scenarios vary the timing of when the offsets are implemented, the total area of offsets implemented, and the type of management implemented for the offsets (low or high intensity). The 10 scenarios examined were:

1. Do nothing — continuation of typical private land activities, with no development or offsetting.
2. Development only — development in Growth Areas, with no offsets. All subsequent scenarios use the same development model.
3. Development in Growth Areas with strategic offsets secured early, subject to low intensity management. Offsets are all implemented in the first time-step of the simulation.

4. Development in Growth Areas with strategic offsets secured incrementally, subject to low intensity management. Offsets are implemented at an approximately constant rate, such that all parcels are offset by the end of the 37 years of simulation.
5. Development in Growth Areas with strategic offsets secured early, subject to high intensity management. This is the same as Scenario 3, but with offsets subject to high intensity management.
6. Development in Growth Areas with strategic offsets secured incrementally, subject to high intensity management. This is the same as Scenario 4, but with offsets subject to high intensity management.

Four additional scenarios were also defined: scenarios 3A, 4A, 5A, and 6A. These are identical to scenarios 3-6, respectively, except that only half the parcels (randomly selected) in the strategic offset area are implemented as offsets.

The key findings of this trend analysis for CPW can be summarized as follows:

- Landscape-scale threats across the Cumberland subregion, such as weed invasion, grazing, rubbish dumping, and disturbance from recreational activities are causing significant declines.
- The negative impact of development in the Growth Areas is of a similar scale to ongoing declines from landscape scale threats across the whole Cumberland subregion over 37 years. Landscape scale threats are projected to result in a 5.8 % drop in summed vegetation integrity score over 37 years. The additional impact of development adds further losses of almost the same magnitude (another 5.78 %).
- The Plan is generally unlikely to reverse declines from landscape scale threats across the whole Cumberland subregion because the magnitude of these threats is large and the Plan only influences a proportion of the subregion. The only scenario where declines were always reversed at the landscape scale was scenario 5, where it was assumed that: (i) all parcels in the strategic offset area are implemented as offsets, (ii) all offsets were implemented immediately; and (iii) all offsets had high-intensity management. This comprises the outer bound of the best-case scenario, and may not be feasible to implement.
- In terms of whether the Plan addresses the impacts of development in the Growth Areas alone within the program area (ignoring declines from landscape scale threats), two of the four offset scenarios (scenarios 5 and 6) provided adequate compensation irrespective of whether 100% or 50% of the CPW was secured as offsets in the strategic offset area. When 100% of the CPW available in the strategic offset area is secured as an offset, three of the four offset scenarios compensate for development impacts (all except scenario 4). When 50% of the CPW available in the strategic offset area is secured as an offset, only two of the four offset scenarios provide adequate compensation.
- In terms of whether the Plan addresses the impacts of development in the Growth Areas as well as declines from landscape scale threats within the program area, three of the four offset scenarios (scenarios 3, 5, and 6) compensate for both these impact types when 100% of the CPW in the strategic offset area is secured. However, none of the offset scenarios can compensate for both these impact types in the program area if only 50% of the CPW in the strategic offset area is secured.
- The timing of offset implementation and the level of management intensity make a significant difference to the gains able to be achieved by offsets, with early implementation/high intensity management always performing best.
- The relative benefit of early implementation compared to high intensity management depends on the time period over which gains are evaluated. The results suggest that:
    - Early implementation with low or high intensity management delivers greater gains in the short term (1 to 2 decades).
    - Early implementation with high intensity management delivers the greatest gains in the long term.
- Results of expert elicitation indicate that high intensity management provides significant potential for providing restoration gains for CPW, even when starting from a low initial condition. However, low intensity management has limited capacity to improve the ecological condition of CPW, especially when starting from a low initial condition.

INTRODUCTION

BACKGROUND AND CONTEXT

The NSW Government has identified four Growth Areas, a new rail line – the Sydney Metro Stage 1 Western Sydney Airport Stage 1 (Sydney Metro Stage 1), and a series of road and rail Transport Corridors to support planned future growth in Western Sydney for the next 37 years (Figure 1). These initiatives are identified under two key planning strategies:

- *A Metropolis of Three Cities - The Greater Sydney Region Plan* (Greater Sydney Commission, 2017)
- *Future Transport 2056* (Transport NSW, 2017)

The Growth Areas program represents the strategic prioritisation and delivery of new development as part of the long-term growth of Greater Sydney provided under the Greater Sydney Region Plan. The Growth Areas are the key focus for development over the coming 37 years and will be the centres of economic activity in Western Sydney. The Growth Areas occur largely within the Cumberland subregion and are:

- Wilton
- Greater Macarthur (GMAC)
- Western Sydney Aerotropolis (WSAGA)
- Greater Penrith to Eastern Creek Urban Release Investigation Area (GPEC)

the NSW Department of Planning, Industry and Environment (DPIE) is progressing the planning and environmental approvals required for the proposed development. As part of the biodiversity approvals required, DPIE is preparing the Cumberland Plain Conservation Plan (the Plan) to provide long-term certainty for biodiversity and development in Western Sydney.

The Plan will support two separate statutory approvals processes under State and Commonwealth laws required to address the impacts of the proposed development on biodiversity values:

- Strategic biodiversity certification under Part 8 of NSW Biodiversity Conservation Act 2016 (BC Act)
- Strategic assessment under Part 10 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The objective of the Plan is to:

> *Deliver biodiversity outcomes and support the ecological function of the Cumberland Plain, improving liveability and facilitating urban development in Western Sydney*

The Plan describes the proposed urban and transport development and a set of commitments and actions to achieve the Plan's objective and offset the impacts of the proposed development on biodiversity values. This includes identifying Conservation Investigation Areas within which offsets will be strategically secured through several mechanisms, including reservation of land and Biodiversity Stewardship Agreements. These Conservation Investigation Areas are referred to hereafter as the 'strategic offset area'.

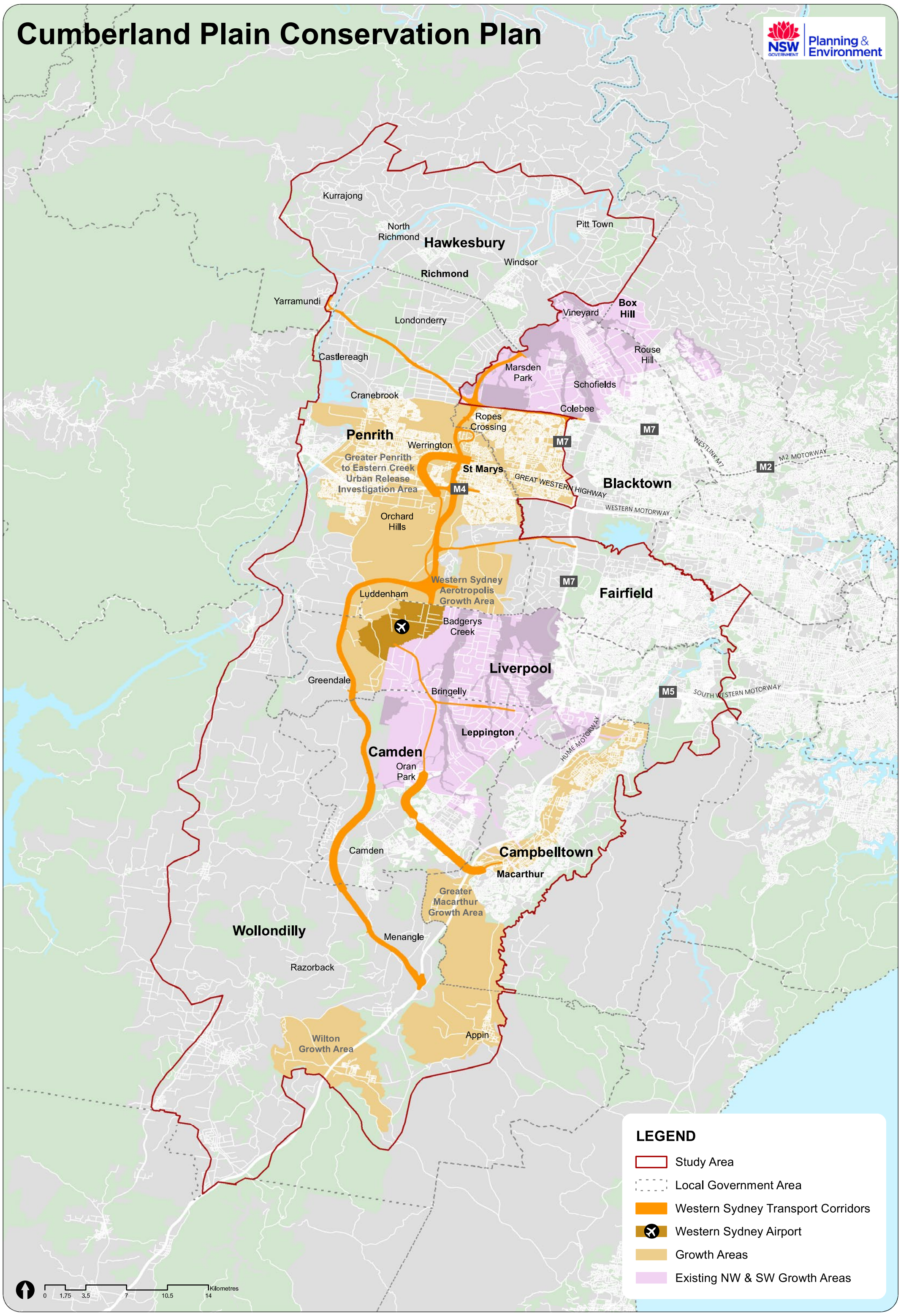

Figure 1. Map of depicting the Growth Areas and transport corridors in the Cumberland subregion.

AIMS OF THIS RESEARCH

This report presents the results of a trend analysis examining long-term changes in the extent and condition of a native vegetation community in the Cumberland subregion under various scenarios that approximate the development impacts of the Growth Areas and the conservation benefits of the offsets under the Plan.

The native vegetation community examined is PCT 849 *Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion*. This is one of two PCTs that make up the threatened ecological community *Cumberland Plain Woodland in the Sydney Basin Bioregion* as defined under the BC Act (the other being PCT 850). PCT 849 is also part of the threatened ecological community *Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest* under the EPBC Act, although size and condition thresholds apply to the definition of the community under this Act.

This community is referred to in this report hereafter as CPW.

The purpose of the trend analysis is to better understand, in relation to CPW extent and condition:

- Underlying trends in the subregion
- The significance of existing landscape scale threats relative to urban development
- Potential benefits of securing offsets early relative to late in program implementation
- The outcomes of different management regimes in offset areas in different existing condition states, including the potential benefits of restoring low condition sites through high intensity management

This information can be used to support key decisions in developing the Plan, as well as inform the evaluation of the adequacy of the Plan in accordance with the requirements of the BC Act and EPBC Act.

The trend analysis builds on work already undertaken for other development projects that models the impact of development and mitigation in the form of biodiversity offsets on native vegetation (Gordon, 2015; Gordon et al., 2011a, Gordon et al., 2011b). This present work extends these existing approaches to model changes in the condition of CPW using more sophisticated metrics of ecological condition, that are an approximation of the metrics specified for vegetation integrity in the BAM (BAM; OEH, 2017).

The report consists of two major outputs: (i) a formal expert elicitation to gather quantitative knowledge regarding how the condition of CPW will change over time, under high or low intensity management, and under the case where CPW is exposed to typical ongoing private land activities; and (ii) quantitative modelling to simulate the urban development within the Growth Areas, compensation via managing areas as offsets in a strategically defined offset region, and the ecological response of CPW.

BACKGROUND THEORY

The aim of a biodiversity offset is to counterbalance a specified biodiversity loss (usually after appropriate avoidance measures have been considered (Bull et al., 2013)). When the gains attributed to the offset fully mitigate the losses attributed to the development, the offset is considered to have achieved 'No Net Loss' of biodiversity (Bull et al., 2014). However, it is important to note that there are multiple ways in which the gains and losses can be calculated and No Net Loss defined. This potentially has a large influence on whether No Net Loss can be said to have been achieved (Maron et al., 2018), or equivalently, it also has a large influence on the offset requirements needed to achieve No Net Loss.

It is important to note that the offset scheme under the NSW BC Act defines the term No Net Loss of biodiversity and establishes a process to determine whether this has been achieved, which involves the calculation of biodiversity credits under the BAM. In relation to biodiversity certification, the BC Act does not require that the value of offsets be calculated in terms of credits, or require the number of credits needed to achieve No Net Loss be secured (OEH, 2017). The objective of the Plan is to deliver biodiversity outcomes and support the ecological function of the Cumberland Plain rather than to specifically achieve 'No Net Loss' as defined under the BAM. However, here we start by introducing what is required to be able assess whether offsets have achieved No Net Loss and the relevant background theory for this.

To understand if No Net Loss is achieved, it is necessary to measure and compare the change attributable to the development actions with the change attributable to the offset actions associated with that development. Here we use terminology from impact evaluation and refer to this change as the *impact* (which can be either negative due to development or positive due to offsets).

To determine the impact, it is necessary to measure the difference between what happened on-ground subsequent to the development and offset interventions (the *outcome*) compared to what would have happened in the absence of the intervention (the *counterfactual*) (Baylis et al., 2016; Ferraro, 2009).

In traditional *ex-post* impact evaluation, the outcome is measured after the intervention, and the counterfactual is estimated (using a range of approaches depending on context) to provide the estimate of impact. In this case we undertake an *ex-ante* analysis to examine the impacts of different scenarios by estimating the outcome (via simulation) and comparing that to the estimated "do nothing" case where landscape scale threats and typical private land activities continue (the counterfactual).

The modelling presented in this report can be used to estimate the net impact of development and offsetting in the Cumberland subregion on CPW. The modelling incorporates three processes: (i) development which is assumed to remove all CPW on developed parcels; (ii) offsetting, for which offset parcels are assumed be managed in a way that improves the condition of CPW on the site; and (iii) the trajectory of the vegetation on parcels that are neither developed or offset, which is assumed to be a slow decline in condition due to landscape scale threats and typical private land activities such as grazing, and minimal weed and pest management, etc (excepting existing conservation areas—which are assumed to be managed). This is consistent with the expectations of Section 13.5 of the BAM (OEH, 2017). It is important to note that this modelling exercise involved an expert elicitation process to inform how CPW responds to management as an offset and to landscape scale threats in areas that are not developed or offset.

In this case the typical private land activities are assumed to be the counterfactual, i.e. what would have occurred without development or offsetting. This is schematically depicted in Figure 2, which shows the trajectory of the development parcel (in yellow, which goes to zero when development occurs), the offset parcel (in green, which gradually improves due to management), and the assumed counterfactual of slow ongoing decline without offsetting or development. The thick black dotted line shows the net outcome of the combined offset and development action. In this example, we use the definition of No Net Loss as relative to the counterfactual of ongoing decline (Maron et al., 2018). Under this definition, No Net Loss is achieved when the combined outcomes of the offset and development results in what would have happened without either offsetting or development (shown at t_2 in Figure 2). However, it is important to note that with this definition of No Net Loss, even when it has occurred, there has still been a loss of biodiversity relative to what was there before the development and impact occurred. We could also use a more stringent definition of No Let Loss which would require the offset to both compensated for loss due to development, and for the ongoing declines due to landscape scale threats. This would result in the net outcome being the same as what was present before the development and offset were implemented. In this case, the dashed line representing the net outcome would need to reach the level at which it started, shown at t_1.

In this report we use the former definition of No Net Loss, depicted in Figure 2, which involves the development and offset together achieving the same outcome as the ongoing background declines that would have occurred without them. Under this definition of No Net Loss, achieving the same outcome as what was present before the offset and development would be referred to as a Net Positive Impact (Maron et al., 2018).

The results of impacts and outcomes in this report are shown at two different scales: the ***program scale*** and the ***landscape scale***. Each scale is important and provides different information.

The ***program scale*** results are obtained by summing the vegetation integrity score multiplied by the area of CPW in ***all the developed and offset parcels only*** (this is equivalent to what is shown in Figure 2 with the loss and gain curves being assumed to come from multiple parcels). At this scale, the outcomes show the net ecological condition of all parcels developed and offset. This can be used to determine the extent to which the offsets have compensated for the development losses due to the program (but not ongoing declines that would have still occurred). If a net impact of zero is achieved, this means the development and offset(s) have together resulted in the same background decline that would have occurred with only typical private land activities occurring on the development and offset parcels. It can also be used to examine the extent to which it has averted the losses (or delivered additional gains) relative to what would have occurred without the development (in this case due to typical private land activities) on the program parcels. This only occurs if a net positive impact is generated so both development losses and the background declines can be compensated for. If the net result is the same or better than the biodiversity value before the interventions, then it is clear that both degrading processes (development and typical private land activities) have been compensated for.

The ***landscape scale*** results are obtained by summing the vegetation integrity score multiplied by the area of CPW in all parcels in the whole Cumberland subregion. This includes the parcels that are not part of the program and subject to ongoing declines due to typical private land activities. For the modelling results presented here, it also includes all the conservation areas outside the program that are assumed to be managed. Thus, if the net outcome at this scale achieves a value equal or greater than the starting value, the offset impacts have compensated not only for the development, but also for the ongoing declines of all the parcels that are not part of the program.

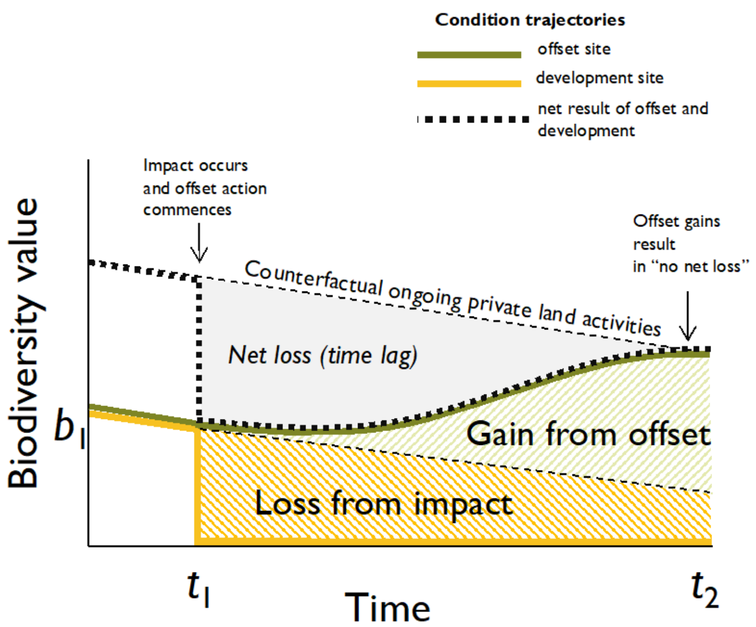

Figure 2. Schematic depiction of the biodiversity trajectory at the development site (yellow line), the offset site (green line) and net result of the offset and development (black dotted line). The counterfactual of ongoing decline is shown with the thin black dashed line. Where the net outcome is the same as the counterfactual (at t_2), no net loss can be said to occur. However, this still represents an absolute loss relative to the biodiversity value at t_1, and achieving the same outcome as what was present at t_2 would be referred to as a Net Positive Impact.

METHODS

OVERVIEW

For the modelling results presented in this report, we use the open source *R* package OffsetSim (see https://github.com/isaacpeterson/offset_simulator), developed by Isaac Peterson and Ascelin Gordon at RMIT University. This is used to simulate development, offsetting and the resulting ecological dynamics for CPW.

OffsetSim works using raster layers as one set of inputs and requires a land parcel layer, and layers showing which parcels can be developed and offset. It can also use one or more ecological features. The ecological value of a particular location is determined using a user-specified metric that can be defined over a set of one or more feature layers (e.g. using a multiple-component metric of vegetation community condition or an aggregated metric such as the BAM (OEH, 2017) or other individual features such as species-occupancy or species-abundance (Bull et al., 2016, 2013; Maron et al., 2012; Quétier and Lavorel, 2011)). Raster layers depicting the initial value of each ecological component are required, and then OffsetSim provides a model that needs to be parameterised to evolve each feature over time based on whether it is developed, managed as an offset, or not subject to any intervention. In this case, we used CPW as the ecological community of interest.

Below, we provide details of the expert elicitation used to develop the condition-change model which allows the condition (measured via an "ecological integrity score"—see below) of CPW to change over time, under each of two different management regimes, or under no management. This requires use of ecological feature layers for the richness and cover of different plant growth form groups, as specified within section 5.3.4.10 of the BAM (OEH, 2017; Oliver et al., 2019).

While OffsetSim has the capacity to select offsets for a given development such that the offsets are determined to deliver appropriate gains within some time horizon to compensate for the development losses, we do not use that feature here. Instead, the development and offset areas are pre-specified, and developments and offsets are implemented at a fixed rate throughout the simulation as described in detail below. We then use OffsetSim to evaluate the ecological impacts of these scenarios.

VEGETATION DATA

Data on the extent and condition of CPW in the Cumberland subregion was used from multiple sources. Within the Growth Areas this was based on detailed mapping of native vegetation that was informed by field surveys undertaken by Biosis in 2018 in accordance with the BAM. Within the Cumberland subregion but outside the Growth Areas, the mapping was based on existing native vegetation maps prepared by OEH, which are described in detail in Table 1.

The condition of CPW in the mapping was captured using the following categories: Intact, Thinned, Scattered Trees, Derived Native Grassland, and Urban native/Exotic. Below, these categories are explained with notes about how they were applied as part of the Biosis mapping of the Growth Areas.

- **Intact:** This condition type was assigned to areas of wooded vegetation, including regrowth, displaying a range of structural layers and likely to have fauna habitat features present (e.g. tree hollows, fallen timber, leaf litter). The canopy density is largely unmodified with a range of age classes and species present. This condition type was assigned during the desktop mapping to areas where Nearmap imagery indicated significant patches of continuous canopy and the Canopy Height Model (from LiDAR) indicated vegetation in both the upper and mid storeys.
- **Thinned:** This condition type was assigned to native vegetation in various states of modification and included: 1) wooded vegetation with a partly cleared canopy resulting in a more open structure than the

intact category of the same PCT; 2) areas of wooded vegetation that has been under-scrubbed; 3) areas of regrowth. This condition type was assigned during the desktop mapping to areas where the Nearmap imagery indicated patches of reduced density. This was typically where the Canopy Height Model indicated canopy and visible ground only, with no discernible shrub layer or structural complexity.

- **Scattered trees:** This condition type includes a single tree or small group of trees surrounded by native or exotic grassland or areas of cultivation. Typically, other structural components of the vegetation have been removed. This condition type was assigned during the desktop mapping to areas where the Nearmap imagery and LiDAR canopy polygons indicated one or a few likely native trees surrounded by cleared land.
- **Derived Native Grasslands** Areas of potential Derived Native Grassland (DNG) were identified from the Nearmap imagery and later verified in the field.
- **Urban native/exotic:** Urban native/exotic areas were areas within built up zones and residential areas that consisted of street trees, urban parks and other patches of planted vegetation that could provide habitat for native species.

There were no patches of vegetation categorized as grasslands or urban native/exotic for CPW.

Table 1. Existing native vegetation maps of the Cumberland Plain

Native vegetation dataset	Description (from VIS)
Remnant Vegetation of the Western Cumberland Subregion 2013 Update (OEH 2013)	A 2013 update to the western parts of the Remnant Vegetation of the Cumberland subregion GIS data layers (VIS_IDs 2221, 2222 and 3785) using 2011 and 2012 imagery. Update focused on removing large areas of clearing at 1:10,000-1:15,000 scale. Those areas within the Sydney Metro Catchment Management Authority boundary, which were covered by the Sydney Metro Veg V2 2013 vegetation map (VIS_ID 3817), were not updated. Provides data on native vegetation extent, type (PCTs) and condition Note: Previous update completed by the Scientific Committee and Simpson 2008 (VIS_ID 3785) was integrated into this update. Txu (<10% canopy cover of urban land) vegetation (VIS_ID 2223) is excluded from the update and this layer. Areas of significant regrowth were added.
The Native Vegetation of the Sydney Metropolitan Area Version 3.0 (OEH 2016)	Provides data on native vegetation extent, PCTs and condition for the eastern part of the Cumberland subregion. The purpose of the data is to provide a single detailed coverage of native vegetation communities in the Sydney metropolitan area using standardised vegetation classification. This classification is designed to relate to the objectives of the OEH vegetation information systems and to assist users with the assessment of threatened ecological communities listed under the NSW TSC Act and Commonwealth EPBC Act This update replaces version 2.0 (VIS_ID 3817) and creates a seamless alignment between the GIS layer and the Plant Community and Biometric Vegetation Types in the Biodiversity Assessment Method tool.

EXPERT ELICITATION

BACKGROUND

This section provides a summary of the expert elicitation process carried out to develop the ecological condition change model. This model allows the components that make up the vegetation integrity score that is defined in the BAM (OEH, 2017) to be modelled as changing through time for CPW, based on a given initial condition and a specified type of management. The expert elicitation was undertaken in two separate workshops in 2018, at the Biosis offices in Sydney.

Information was elicited from experts in a structured way such that best estimates and confidence intervals were obtained, with an opportunity for experts to refine their estimates through structured discussion. This involved using a modified Delphi procedure called "the IDEA protocol" (Investigate, Discuss, Estimate, and Aggregate) to elicit the expert judgments, in a way that has been shown to minimize contextual biases (Burgman et al., 2011; Hemming et al., 2017). This involves initially eliciting the information from the experts, and these judgments are then compiled and shown to the group anonymously, where they are discussed and visually summarised. In a second round of the elicitation, the experts then have the option to revise their estimates and update the comments on their estimates. They also have the option not to change their estimates.

The expert elicitation was led by Dr Ascelin Gordon, with Dr Isaac Peterson providing technical support. Tom Holden (Open Lines) and Rebecca Dwyer (Biosis) provided logistical support for the workshops.

SELECTION OF EXPERTS

Participants were invited to take part in the elicitation if they worked in an area that requires ecological expertise of the Cumberland subregion and had been identified as an expert by peers. Participants were sought mainly from local or state government agencies and universities.

Participants were identified by contacting an initial group of people identified by Ascelin Gordon, Tom Holden (Open Lines) and Rebecca Dwyer (Biosis). These experts were then asked to suggest additional suitably qualified experts. This process generated a list of 10 potential participants, 7 of which were available to participate in the initial workshop. The experts who participated in the first workshop were:

- David Keith (University of NSW)
- Charles Morris (University of Western Sydney)
- Peter Ridgeway (Local Land Services)
- David Kirkland (Western Sydney Parklands Trust)
- Jonathan Sanders (formerly NSW National Parks and Wildlife Service)
- Paul Price (Biosis)
- Greg Steenbeeke (on secondment to DPIE from OEH)

In a follow up workshop to finalize the elicitation, two experts were unable to attend (Peter Ridgeway and Paul Price). So, the full elicitation was only able to be completed with five experts.

In the run up to the workshop, information was compiled to brief the experts on the background of the project and provide them with details of what they would be asked to provide during the elicitation.

DETAILS OF ELICITATION

The elicitation focused on CPW, and specifically three growth form groups (*Trees*; *Grass & grass-like*; and *Forbs*) and two ecological attributes (*species richness*; and *cover* of the plant growth form type). The elicitation also used four initial conditions, and three management regimes (see below).

Information was elicited such that an approximation of the vegetation integrity score defined in the BAM (OEH, 2017; see below) could be derived, along with how it will change through time under different management regimes.

The experts were asked to provide estimates for how the ecological attributes Species Richness and a simplified value for Projected Cover changed over time for a 'vegetation zone' within CPW. The attributes are defined as follows:

- ***Plant species richness***: the mean species richness of the growth form group recorded (observed) from all the plots in the vegetation zone. This is used to calculate a 'composition condition score' in the BAM.
- ***Plant cover***: the mean cover for the growth form group recorded (observed) from all plots/transects in the vegetation zone. This is used to calculate the structure condition score of the BAM. Note that the elicitation used a simplified version of cover, being the percentage of the plot covered by the growth form group, compared to the BAM, which uses a more complex measure of cover (the sum of the individual cover values for each species in the growth form group, which can therefore be greater than 100%).

The BAM defines a *vegetation zone* as "an area of native vegetation on the subject land that is the same PCT and has a similar broad condition state" (OEH, 2017). Within a zone, the BAM specifies a plot area to be $400m^2$ (generally a standard 20m x 20m, but geometry can be varied though area remains the same), and the number of plots required for a survey varies from 1-8 depending on the overall area represented in all polygons of the vegetation zone.

The default benchmark values for each ecological component for the plant type (as drawn from the VIS-C database that informs the process) were provided as part of the elicitation. As a subset of the full canopy cover measure is being used compared to what is specified in the BAM, the experts were asked to provide estimates of what the benchmark value should be for the definition of cover we used.

The experts were asked to provide information for CPW that was in one of four initial conditions. The assumption regarding the initial conditions determined the initial value for richness or cover. After being giving an initial value for each measure, the experts were asked to provide estimates for the values of the richness and cover at 20, 40, and 60 years into the future under each of 3 different management regimes.

The initial condition states were:

- ***Low site quality:*** These are sites that were historically cleared and used for farming. They have a largely exotic ground cover and/or midstorey, and a sparse woody component. This type of site has mostly weedy grasses and a few opportunistic native forbs and grasses in the understorey. It has less than 5% cover of large old hollow-bearing trees with some canopy dieback and flowering in some years. It often includes the presence of African olives (Olea europaea subsp. cuspidata).

- ***Medium quality 1:*** This state is of similar history to *Low* but may have had less clearing of trees and less intensity of farming, and there is more resilience is clearly evident in the native groundcover clearly evident. It has a native/exotic ground layer with no dominant species, and the site has had grazing and limited fertiliser. There is some presence of perennial grass weeds (not at high density and not transformer species). There is approximately a 10% canopy cover of regrowth trees (large enough to flower but without hollows) with no presence of African Olives. It is assumed that no superphosphate or nitrogen fertilizers have been used on these sites.

- ***Medium quality 2:*** This state has been more intensively farmed and it has had the application of superphosphate. It has a greater amount of canopy regeneration and the understory has a greater presence of weeds. African olives or blackberries (*Rubus fruticosus* species complex) have a foothold and often dominate the understorey. Some native ground cover observed but limited due to the high presence of woody weeds (African olive and/or blackberry). Woody components are present and due to regrowth, often comprise a cover level greater than the benchmark for the plant community type but are not mature.

- ***High quality:*** Here the ground cover is mostly native; the site has been free of fertilizer and has had no grazing or grazing only at light to moderate intensity. The woody component is mostly native and there is little presence of African olives.

These categories were chosen as to be generally representative of current condition states that CPW would be found in within the Cumberland subregion, while being limited to no more than four condition states, due to constraints on the amount of information that could be elicited over the workshops. Figure 3 shows example photographs of CPW in each of the initial condition states.

The 3 management regimes were:

- ***Typical private land activities:*** Under this management regime, it is assumed that ongoing declines in CPW condition are expected due to a range of threatening processes. It is also assumed that there is a continuation of the typical practices as currently employed by most landholders. This includes grazing, often at high intensities; minimal weed management for agricultural weeds; and minimal pest management for agricultural pests.
- ***Low-intensity management:*** This primarily comprises threat management that focuses on control of aggressive weeds and exclusion or restriction of grazing, i.e. managing issues that change the structural and functional composition of the community. It is assumed that this management is consistent with the 'required management actions' for a biodiversity stewardship site under the BAM.
- ***High-intensity management:*** This involves the same threat management as low-intensity management, but also includes regenerative weed control, active planting of the site (via direct seeding or by using tubestock) and other techniques to increase diversity (e.g. fire, creating habitat, fauna reintroduction). It is assumed that this management is consistent with what is required for 'active restoration management' at a biodiversity stewardship site under the BAM, what are in addition to the actions required under low-intensity management.

The required management actions specified in the BAM for low-intensity management are given in Table 2 and in Table 3 for high-intensity management (OEH 2017).

Table 2. Required management actions and types of management activities for improving vegetation integrity and threatened species habitat at a biodiversity stewardship site. Source: OEH (2017).

Required management action	Types of management activities that may be undertaken as part of the required management action for ecosystem credits and species credits
Preparation of a management plan	Preparation of a management plan for the biodiversity stewardship agreement for the site
Fire management	Undertake ecological burning activities, including where identified, the prevention of fire
Grazing management	Fencing to exclude stock, or strategic grazing of stock
Native vegetation management	Restore/rehabilitate native vegetation Retain and manage regrowth Undertake nutrient control Threatened species habitat management activities related to native vegetation
Threatened species habitat management	Protection of breeding habitat features or sites Undertake any other required management action identified in the Threatened Biodiversity Data Collection to create species credits or ecosystem credits required for that threatened species
Integrated pest animal control	Undertake feral pest management including control of foxes, cats, pigs, goats, avian pests, horses and any other miscellaneous species as required
Integrated weed management and control of high threat weeds	Undertake weed management and activities to control high threat exotic and other exotic vegetation Fine-scale intensive removal of high threat exotic and other exotic vegetation
Management of human disturbance	Exclude development and clearing activities except those listed as permissible in the biodiversity stewardship agreement Identify sensitive locations and protect from disturbance Undertake rubbish removal Implement measures to restrict access to the site where necessary (vehicles, etc.)
Monitoring	Monitoring for evidence of disease Assessment of the management plan and activities against the performance measures Establishment of permanent plots to provide a baseline for assessing biodiversity outcomes Establishment of 360° photo points Review of the management plan and management activities

Table 3. Active restoration management actions that may be undertaken to improve or manage native vegetation or threatened species habitat at a biodiversity stewardship site. Source: OEH (2017).

Types of active restoration management actions	Types of management activities that may be undertaken as part of the active restoration management actions for ecosystem credits and species credits
Habitat enhancement	Inclusion of artificial nesting boxes and if the management plan specifies ongoing management, replacement and maintenance Relocation of fallen logs onto biodiversity stewardship site from appropriate sources Addition of rocks from appropriate sources Relocation and securing of dead hollow-bearing stag trees from appropriate sources
Native vegetation and habitat management and augmentation	Undertake targeted supplementary planting to: • increase native plant richness and cover above the level determined for management gain • restore or enhance the condition and species composition of recognisable PCTs • improve habitat suitability for specific threatened species • restoration of PCTs through changed hydrological flows
Integrated weed management and control of high threat exotic vegetation	Removal of high threat exotic vegetation through appropriate methods (e.g. scalping) and replacement with native vegetation Other approved methods to reduce cover of high threat exotic vegetation
Hydrology management	Create artificial frog ponds or wetlands Manage drainage Install sediment trap(s) Manage debris Undertake nutrient control
Monitoring	Assessment of performance measures of outcomes related to the active restoration components such as: • evidence of occupation of and condition of artificial hollows or relocated logs and stags • persistence and abundance of species targeted by supplementary plantings or sowings

To elicit the trends over time, each expert was asked to fill a spreadsheet (via a Google sheets link) containing information as to how each ecological attribute will change over time for each plant growth form group. Given all the combinations of the growth form groups; initial conditions; and management actions, experts were required to provide data to inform the shape of 50 curves, as detailed in Table 4.

For each curve, the experts were requested to provide their best estimate; upper; and lower bounds, for the component being elicited, at a notional time points 20, 40, and 60 years into the future.

An example of the spreadsheets used for the elicitation is available here: https://docs.google.com/spreadsheets/d/1rFkq80R3orUgCRv_rbFW6crgTZN1-1rc5Wi-J6AhU7Y/edit?usp=sharing. The spreadsheet asks the experts to provide upper and lower bounds first (in any order), and then to provide a best estimate, and additionally to provide an estimate of their confidence that the true value falls within the bounds they have provided. Curves were generated as participants enter the data to show how their bounds and best estimate change over time. The spreadsheet automatically extrapolated bounds to show the 90 percent confidence intervals based on the estimate of confidence given by the participant.

Ethics approval for undertaking this component of the research involving human participants was obtained from RMIT University (approval number CHEAN A 21472-04/18).

High quality (foreground only - olive in the gully behind is Medium quality 2)	***Medium quality 1*** **(foreground only - olive in the gully behind is medium 2)**
	
Medium quality 2	**Low quality**
	

Figure 3. Examples of CPW in each of the initial condition class categories (photograph credits: Greg Steenbeeke).

Table 4. The spreadsheets components to be filled in by each expert during the elicitation process — a total of 50 curves needed to be elicited.

Tab no.	Plant growth form group	Ecological attribute	Initial condition	Management actions	No. of curves
1	Tree	Richness	Low	all 3	3
2	Tree	Richness	Med 1	all 3	3
3	Tree	Richness	Med 2	all 3	3
4	Tree	Richness	High	Typical private land activities only	1
5	Grass & grass-like	Richness	Low	all 3	3
6	Grass & grass-like	Richness	Med 1	all 3	3
7	Grass & grass-like	Richness	Med 2	all 3	3
8	Grass & grass-like	Richness	High	Typical private land activities only	1
9	Forbs	Richness	Low	all 3	3
10	Forbs	Richness	Med 1	all 3	3
11	Forbs	Richness	Med 2	all 3	3
12	Forbs	Richness	High	Typical private land activities	1
13	Tree	Cover	Low	all 3	3
14	Tree	Cover	Med 1	all 3	3
15	Tree	Cover	Med 2	all 3	3
16	Tree	Cover	High	Typical private land activities	1
17	Grass & grass-like	Cover	Low	all 3	3
18	Grass & grass-like	Cover	Med 1	all 3	3
19	Grass & grass-like	Cover	Med 2	all 3	3
20	Grass & grass-like	Cover	High	Typical private land activities	1
				Total	**50**

CONVERTING MAPPED VEGETATION CONDITION TO EXPERT ELICITATION CONDITION CLASSES

As described above in the section on Vegetation Data, the condition information in the available spatial data on native vegetation does not match the initial conditions that were required by the experts to elicit the response of richness and cover for the relevant plant growth-form groups.

The following scheme was used to convert the condition categories used in the mapping, to the condition classes used in the expert-elicited condition change model. While the correspondence between each category is not perfect, they are approximating the same kinds of condition states for native woodlands.

- ***Scattered paddock trees*** was determined to equate to ***low site quality***, as it contains a single tree or small group of trees surrounded by low-condition native or exotic grassland, or areas of cultivation. One or more structural layers may be absent (e.g. shrubs and/or grasses/forbs).

- ***Derived Native Grasslands*** (DNG) was determined to equate to ***medium quality 1*** given it contains a grassland community where the cover of native species is 50% or more, and has some presence of perennial grass weeds but not at high density.

- ***Thinned*** was determined to equate to ***medium quality 2*** given it contains:
    - Woodlands that have a partly cleared canopy resulting in a more open structure than intact vegetation.
    - Vegetation that has been under-scrubbed (shrub layer removed).
    - Some areas of regrown woodland that would otherwise approach the intact condition.

- ***Intact*** was determined to equate to ***high quality*** native woodland or open forest that is in good condition, including good DNG within short distances (distance (typically under 30 metres) of intact canopy cover. Intact CPW displays a diversity of vegetation layers and habitat features (such as tree hollows, fallen timber, groundcover, leaf litter). Tree density is close to natural, and a range of ages is present including established mature trees. Regrowth may be included if it meets the above criteria.

CALCULATING THE VEGETATION INTEGRITY SCORE

Once all the richness and cover estimates were elicited, they were converted to the vegetation integrity score via the following approach, derived from BAM (OEH, 2017).

First the *unweighted richness condition score* is calculated via

$$URC_i = 100.68\,(1 - e^{-5\left(\frac{\bar{x}_i}{B_i}\right)^{2.5}}),$$

Where $\bar{x}_i$ is the mean of species richness of the i^{th} growth form group and B_i is the benchmark richness value for the i^{th} growth form group. Weights are then calculated as follows:

$$w_i = \frac{B_i}{\sum_{j=1}^{n} B_j}$$

where w_i is the weight for the i^{th} growth form group, B_i is the benchmark richness value of the attribute for the i^{th} growth form group, and n is the number of growth form groups.

The final *richness condition score* is then given by

$$RC = \sum_{i=1}^{n} URC_i \times w_i$$

An identical procedure was undertaken to calculate the final cover condition score (*CC*), replacing the richness terms (and benchmarks) in the above equations with the cover terms (and benchmarks). Given we do not include the function condition scores which are a component in the full BAM vegetation integrity score, we calculated the final vegetation integrity score as

$$VI = \sqrt{RC \times CC}$$

This is consistent with the vegetation integrity score using only richness and cover. This vegetation integrity score is then used as the metric to evaluate how the condition of CPW changes under management regimes, and to evaluate the different development and offsetting scenarios.

The additional components that make up the BAM vegetation integrity score were excluded due to the constraints the amount of information that could be elicited from the experts.

SIMULATING DEVELOPMENT, OFFSETTING AND CONDITION CHANGE OVER TIME

The OffsetSim model has three components:

1. A ***development model***, which in this case simulates development in the Growth Areas within development footprints (see below);
2. An ***offset model***, that implements offsets with either high or low intensity management in the strategically-defined offset areas (see below); and
3. A ***vegetation condition change model*** to simulate change in the condition of CPW over time under management types of different intensity, including no management.

The simulation works by running for a specified number of time steps. In each time step the following processes occur:

1. ***Develop parcels:*** Parcels are randomly selected from the development footprint area, with the number developed at each time step set so that all parcels in the development footprint area are developed within 37 years at an approximately even rate of development.
2. ***Offset parcels:*** Depending on the scenario (see below), offsetting is done in two ways. In one case parcels are randomly selected to be offsets in the strategic offset area, at a rate such that all or half of the parcels (depending on the scenario) are offset after 37 years, with offsetting occurring at an approximately constant rate. For other scenarios all or half (depending on the scenario) of the parcels in the strategic offset area are implemented as advanced offsets in the first time step.
3. ***Update ecological condition:*** The condition of CPW in each pixel is updated based on the relevant scenario occurring on the parcel where the CPW occurs: (i) for developed parcels, the condition of CPW is set to zero; (ii) for parcels managed as offsets, the condition of CPW improves based on the expert elicited curves depending on whether high or low intensity management is being used for the offsets; (iii) for parcels that are not offset or developed, the CPW will slowly decline in condition based on the expert elicited do nothing curves, which assumes typical private land activities continue.

These three processes are repeated every time step till the simulation is finished, and the condition of every pixel of CPW is retained for every time step. This allows the generation of the trends in condition over time, where condition scores are aggregated over either the whole Cumberland subregion, or the program area.

SPATIAL DATA INPUTS

All data was rasterized to a resolution of 20 m x 20 m, as the BAM specifies 20 m x 20 m survey plots are to be used to assess the composition and structure attributes (OEH, 2017). Thus, a vegetation integrity score consistent with the BAM can be modelled for each pixel in the vegetation raster layers without any additional transformation as each pixel is the size of standard BAM survey plot.

The required spatial inputs to the OffsetSim model comprise spatial raster layers depicting the development footprints and the set of locations where strategic offsets can occur, and the package allows these to be specified in any way, including having these areas overlapping.

The development footprints and strategic offset area are shown in Figure 4. It is important to note that these areas are based on preliminary boundaries as at November 2018, and are likely to change under the final Plan. It is also important to note that the strategic offset area at November 2018 contains approximately 1,605 ha of offsets for PCT 849 (CPW). However, the current draft target for PCT 849 under the Plan is 2,802 ha. Securing this larger amount of PCT 849 would change the results of the trend analysis.

OffsetSim also requires raster layers depicting the conservation features of interest, which in this case is the extent and condition of CPW. The extent of CPW is shown in Figure 5, overlaid on the development footprints and strategic offset area for reference. This layer includes the two existing vegetation data sets described above in the section on Vegetation Data, along with the data resulting from the Biosis field surveys in the Growth Areas. Figure 6 and Figure 7 show the condition classes of the CPW, with Figure 7 showing a close up that enables more of the vegetation patches and condition classes to be visible (see the Vegetation Data section above for a description of the condition classes in Figure 6 and Figure 7).

The land parcels for the Cumberland subregion are shown in Figure 8. These were sourced from the NSW Spatial Services Digital Cadastral Database (see http://spatialservices.finance.nsw.gov.au/mapping_and_imagery/cadastral_data), and rasterized to the same 20m pixel resolution as the other data. The parcels are the objects the simulation operates upon by selecting parcels to develop that are within the development region, and parcels to offset within the offset region. For this study, land parcels less than 1 ha were excluded from the analysis, as these are predominantly urban areas with very little CPW. Including these parcels creates significant challenges in running the simulation.

The simulation included existing conservation areas in the Cumberland subregion, including Biobank areas. This data is shown in Figure 9. Biobank sites are shown in pink to differentiate them from other conservation areas (shown in green). The spatial data for this information was provided by OEH in 2018. In the simulation it was assumed that Biobank sites were managed with *high intensity management,* while other conservation areas were managed with *low intensity management* (see Expert Elicitation section, above).

Table 5 shows the total area and the proportion of CPW that occurs in each of the spatial regions defined for the analysis. Of the 14,293.9 ha of CPW in the Cumberland subregion, 5.8% of it occurs in the development footprint area, 11.2% occurs within the strategic offset area, and 10.8 % occurs in existing Biobank and other conservation areas (Table 5).

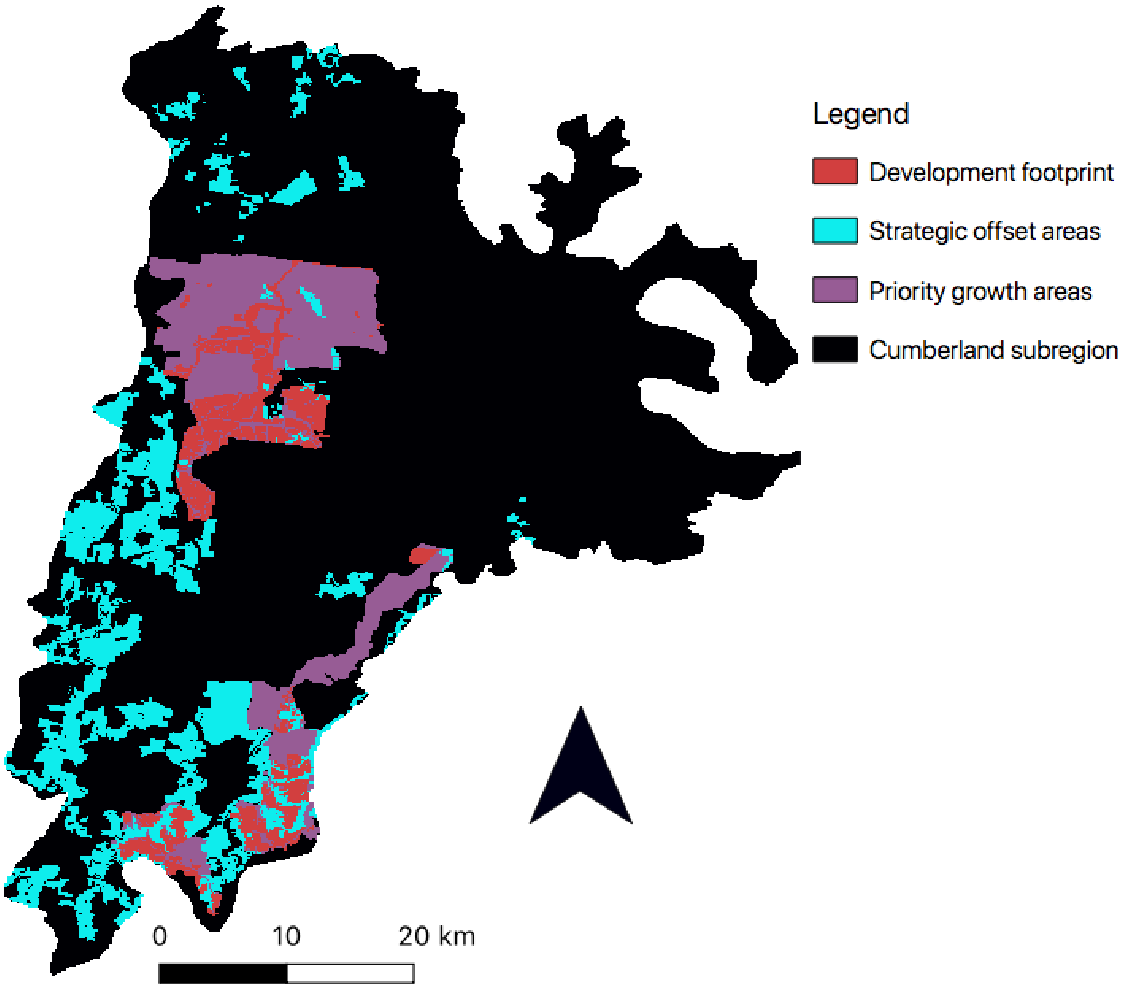

Figure 4. Map depicting the Growth Areas and the development footprint within them, and strategic offset locations within the Cumberland subregion.

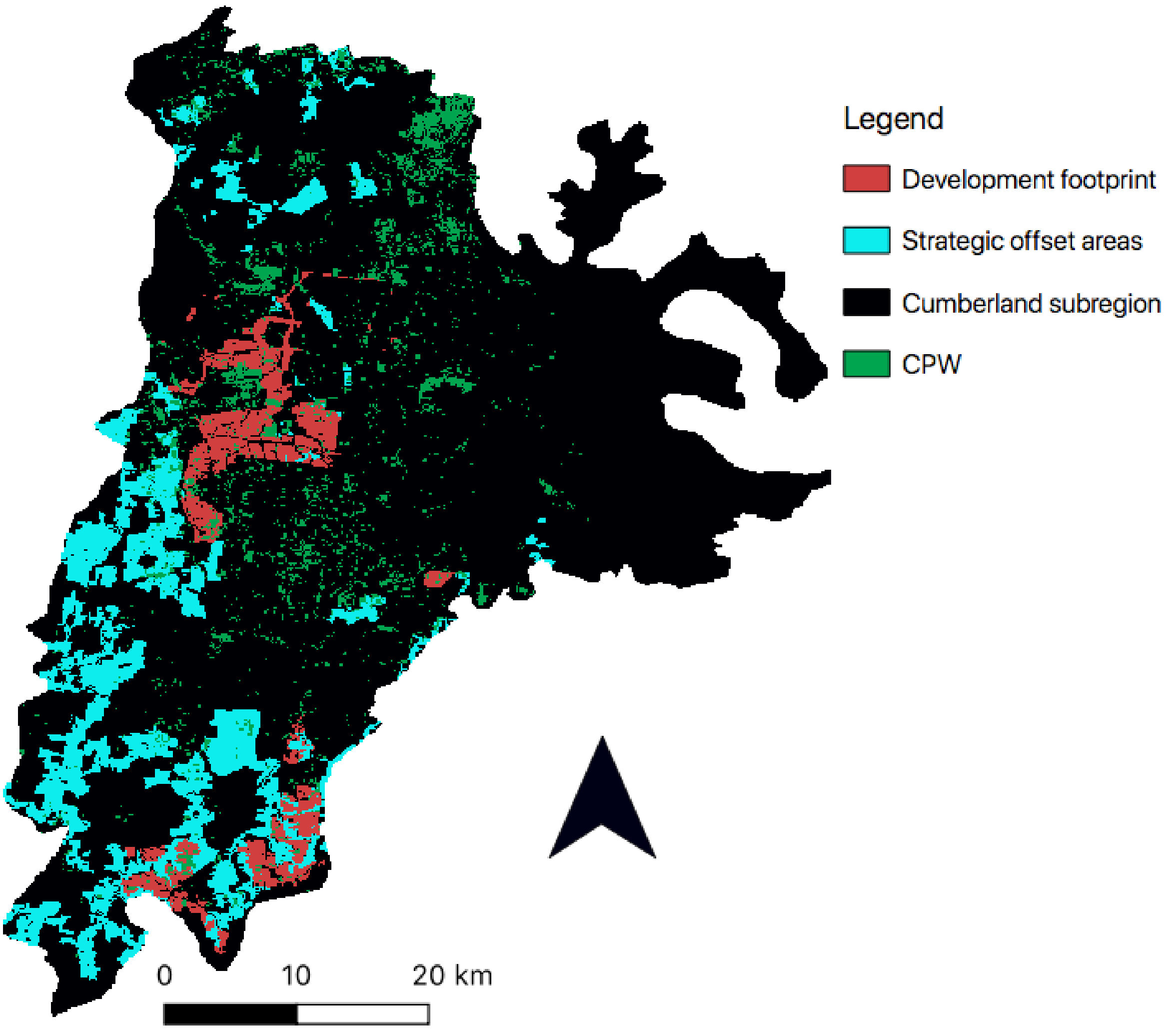

Figure 5. Map depicting the development footprint and strategic offset area, with distribution of CPW shown overlaid in green.

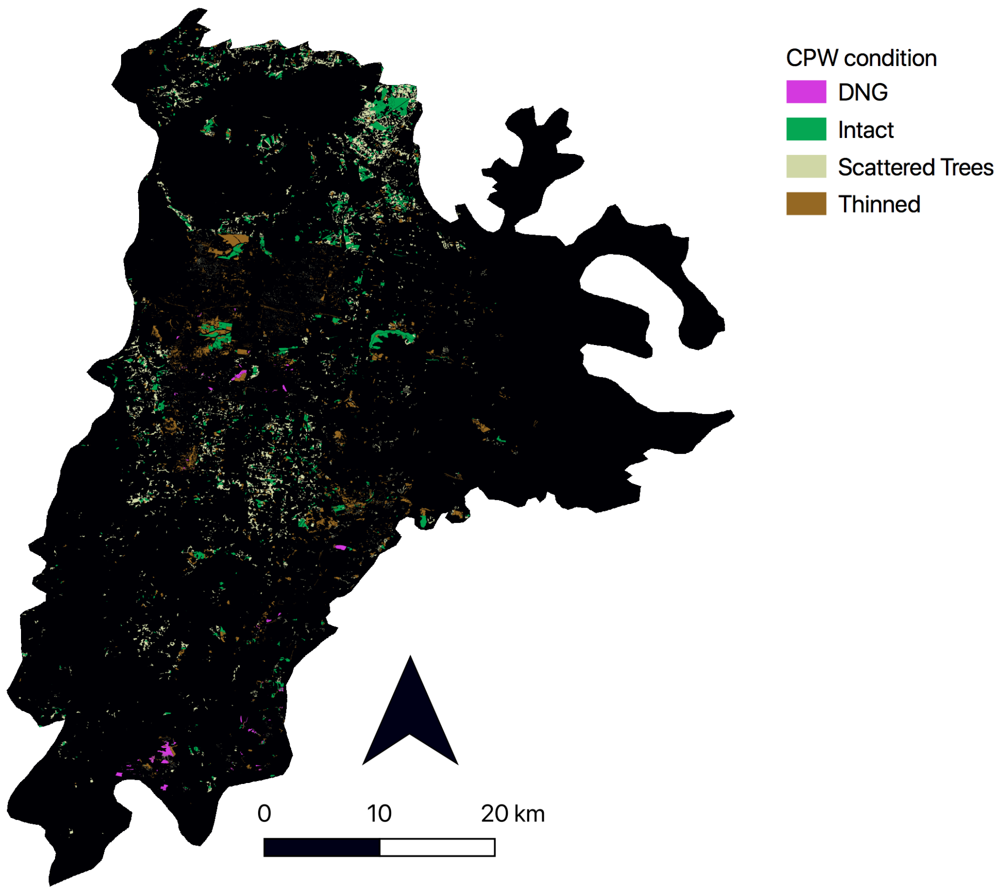

Figure 6. The distribution of CPW in the study area, showing the condition class of the vegetation.

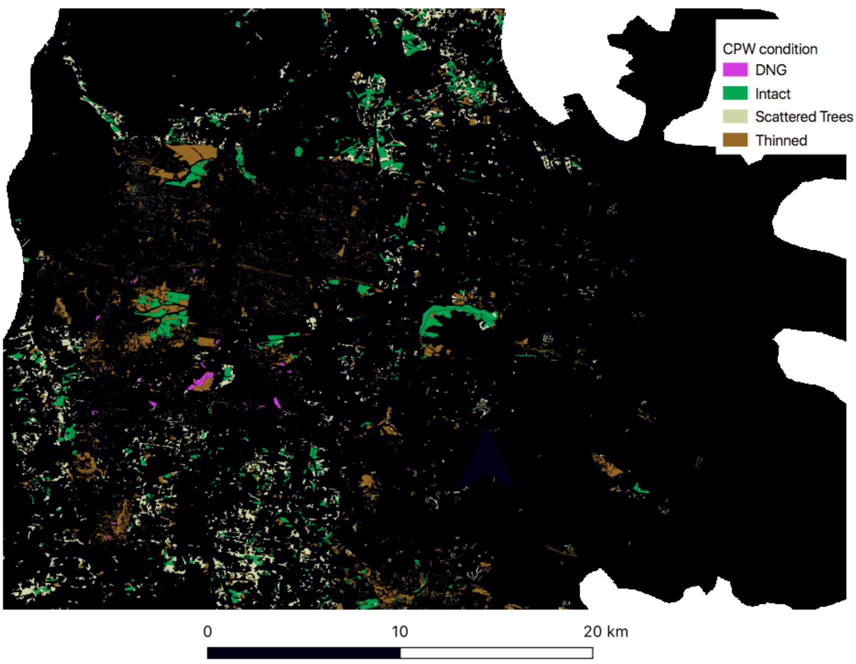

Figure 7. Close up of the layer showing the patches of CPW and their condition classes in the northern part of the Cumberland study area.

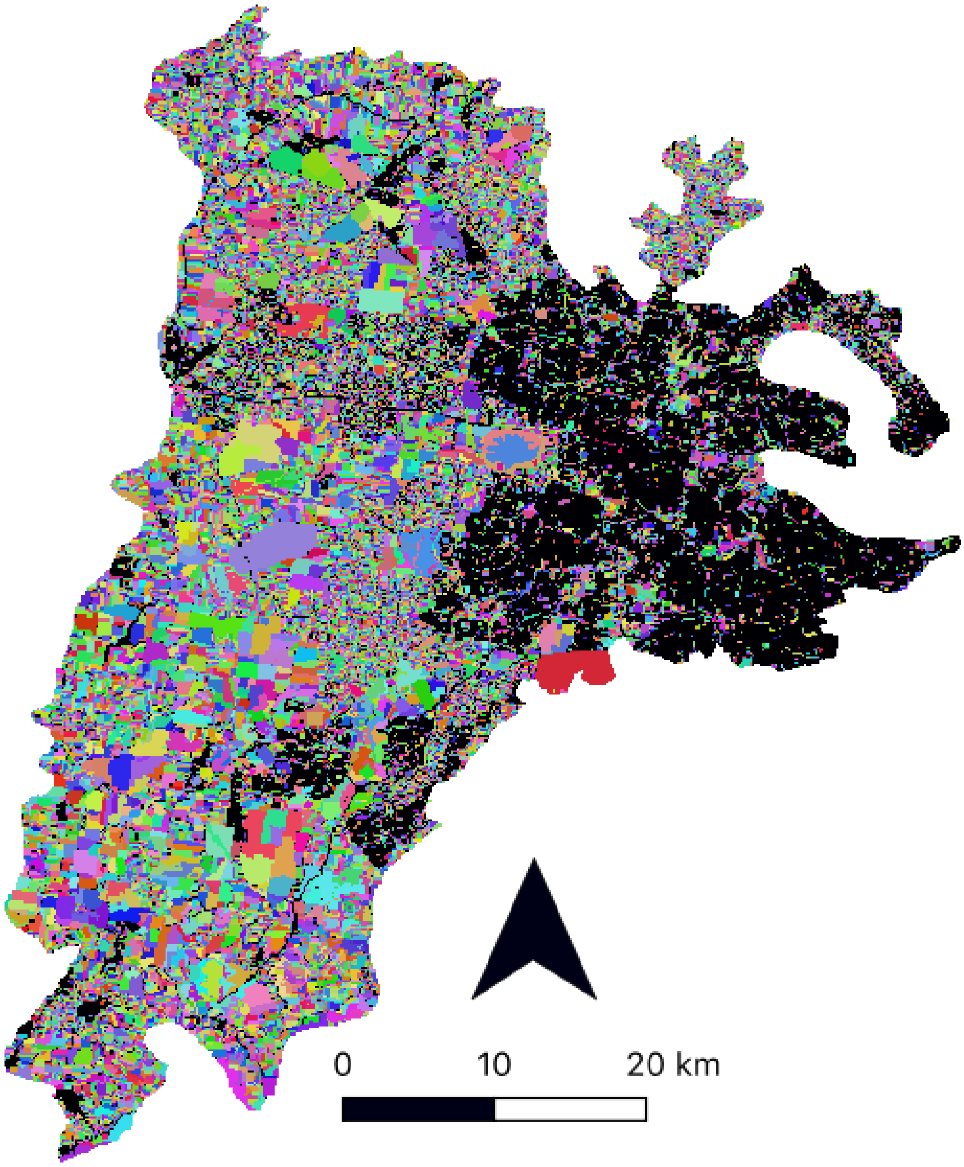

Figure 8. Map depicting the land parcels in the Cumberland subregion. Note that parcels less than 1 ha were excluded from the analysis, as these areas consisted primarily of urban areas, and contained very little CPW. Ares with excluded parcels are shown in black.

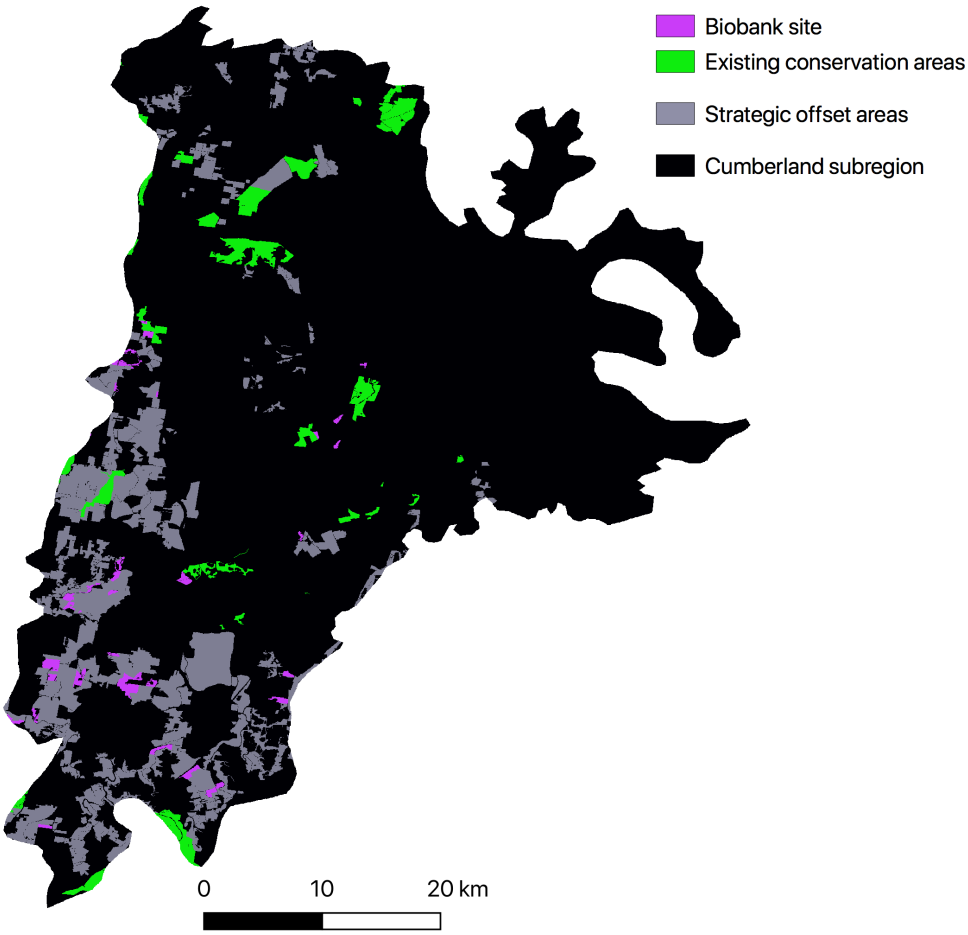

Figure 9. Existing conservation areas in the Cumberland subregion. Purple locations show existing Biobank sites, green areas show other existing conservation areas. For reference, the strategic offset areas are shown in grey.

Table 5. The total area and proportion of CPW in each of the regions used in the analysis.

Analysis feature	Area of CPW (ha)	Percentage of CPW in study area
Cumberland subregion	14,293.9	100 %
Growth Areas	3,083.7	21.6 %
Development footprint	827.0	5.8 %
Strategic offset area	1,605.3	11.2 %
Biobank sites	120.5	0.8 %
Other existing conservation areas	1,424.5	10.0 %
Phase zero areas (excluding offsets, overlaps with development region)	8,908.1	62.3 %

MODELLING CONDITION CHANGE OVER TIME

Modelling condition change involved three key steps:

- Setting the initial condition of each parcel of CPW – this was done differently depending on whether the parcel of CPW was within or outside the Growth Areas
- Applying the expert elicited curves to each parcel of CPW to predict how the initial condition changes under the scenarios (managed as an offset, developed, or subject to typical private land activities)
- Combining all the plant growth form richness and cover values into a vegetation integrity score

Firstly, the initial condition of every parcel of CPW was set to one of four condition classes used in the expert elicitation (*low*, *medium 1*, *medium 2*, or *high*, see above).

For CPW within the Growth Areas, this was done by directly converting the mapped condition classes determined during surveys undertaken by Biosis to the expert elicitation condition classes described above. Based on information from the experts during the elicitation, the mapped condition classes for CPW outside the Growth Areas is less accurate. Thus, the following approach was used to assign the initial condition classes outside the Growth Areas. First, the statistical distribution of the areas of CPW patches was determined for each of the condition classes in the Growth Areas. This characterises how likely a patch of CPW of a given size will be in a given condition class. These resulting distributions were used to undertake statistical sampling to assign an initial condition class to CPW patches outside the Growth Areas. While this means there is some randomness to the condition class assigned to these patches, it will result in the distribution of CPW patch sizes for each condition class being approximately the same for patches both within and outside the Growth Areas. The two fundamental assumptions underpinning this approach are: (i) patch area is the most important factor in determining the condition class of a patch of CPW, and (ii) that the relationship between patch area and condition is the same both inside the outside the Growth Areas. While neither of these assumptions will fully hold all the time, they are likely to provide a reasonable approximation.

Once the initial condition of each patch was determined, the initial values for richness and cover for the different plant growth form types were then determined (see the Expert Elicitation section, above). Next, the model updates the richness and cover values for each plant growth form type based on the curves provided by the experts (see Appendix A). In this analysis, the curves ***used were the means across all experts*** (see Figures A1-A5) and the particular curve applied to any given pixel of CPW depends on the scenario (i.e. managed as an offset; developed; or subject to typical private land activities).

The complexity of the condition change process comes in when a parcel moves from one state to another. For example, CPW in a given parcel might be slowly declining from some initial condition, and then at some point in the simulation the parcel is selected as an offset and management starts. From that point onwards, the trajectory of the CPW changes and starts improving based on the curve for either *high* or *low intensity management* (and it is assumed once a parcel is offset, management continues for the remaining duration of the simulation). The other change that can occur is when a parcel is developed, but in this case is it a simple transition as it goes straight to zero and then remains at zero for the duration of the simulation.

Thirdly, the plant growth form richness and cover values were combined into a vegetation integrity score, based on the equations given in the section “Calculating the Vegetation Integrity Score”, above. The vegetation integrity scores of each pixel of CPW were then summed, and it is the change of summed vegetation integrity score over time that provides the *trends* for extent and condition of CPW.

SCENARIOS

To address the purpose of the trend analysis, the following scenarios were modelled:

1. Do nothing — continuation of typical private land activities, with no development or offsetting.
2. Development only — development in Growth Areas, with no offsets. Development occurs at an approximately constant rate such that all parcels in the development region are developed by the end of the 37 years of simulation. All subsequent scenarios use the same development model.
3. Development in Growth Areas with strategic offsets secured early, subject to low intensity management. In the simulation, offsets are all implemented in the first time-step of the model.
4. Development in Growth Areas with strategic offsets secured incrementally, subject to low intensity management. In the simulation, offsets are implemented at an approximately constant rate, such that all parcels are offset by the end of the 37 years of simulation.
5. Development in Growth Areas with strategic offsets secured early, subject to high intensity management. This is the same as Scenario 3, but with offsets subject to high intensity management.
6. Development in Growth Areas with strategic offsets secured incrementally, subject to high intensity management. This is the same as Scenario 4, but with offsets subject to high intensity management.

Four additional scenarios were also defined: scenarios 3A, 4A, 5A, and 6A. These are identical to scenarios 3-6, respectively, except that only half the parcels in the strategic offset area are implemented as offsets. This models the case where not all landholders in the strategic offset area are willing to secure biodiversity offsets on their land. The parcels that are selected as offsets are randomly chosen, meaning that the total area of vegetation offset differs slightly for each model realization of scenarios 3A, 4A, 5A, and 6A.

While it is recognised that the assumptions under some of the scenarios may not be realistic, the scenarios represent a set of outer bounds for what is likely to occur in practice. This is appropriate because it is more likely to allow clear differences in the scenarios to be identified, making the results of the analysis more useful. As the outputs of the modelling are subject to significant uncertainty, it is not meaningful to distinguish between a larger number of potentially more realistic, but more similar scenarios. This is due to the range of underlying uncertainties, and the variation inherent in multiple model realizations due to random processes (such as the selection of parcels to develop or offset in a given time step) may mean there is very little to distinguish difference in performance between the scenarios.

RESULTS

EXPERT ELICITATION

The expert elicitation resulted in predictions that could be used from five experts (see 'Expert Elicitation' section above) regarding how CPW changes under the three management regimes.

Appendix A shows how the expert estimates of the different components that make up the BAM vegetation integrity score are predicted to change over time under the three different management regimes. As described above, for each management regime, predictions are made for four different initial condition states of CPW. The components of the BAM vegetation integrity score for which estimates were made were tree; grass (and grass-like); and forb richness; as well as cover of trees; and cover of grass and grass-like. The curves resulting from each expert, along with the mean over all experts, are shown for each component in Figures A1- A5 (Appendix A).

In some cases, there can be considerable variation among the expert's predictions, such as how tree richness is predicted to change under high intensity management when CPW is initially in *low condition* (Figure A1), or how tree cover is predicted to change under high intensity management starting from the *medium 1 condition* (Figure A4). In other cases, the expert's predictions were much more similar, such as how forb richness will change under high intensity management, starting in the *medium 1* condition (Figure A3). These results in general can be used to determine the likely outcomes of restoration under low or high intensity management (as defined in the BAM), or to predict declines under no management.

As described above, the components elicited can be combined by transforming, weighting and adding together to produce a vegetation integrity score similar to that defined in the BAM (OEH, 2017). This was done for all the elicited components and combined into a single curve, representing how the vegetation integrity score varies with time for each initial condition, and management combination. As noted above, the vegetation integrity score presented here is only an approximation of the vegetation integrity score defined in the BAM, as there are additional components in the BAM version that were not included in the elicitation (OEH, 2017).

Figure 3 shows how the vegetation integrity score is predicted to change under management, based on the mean values elicited across all experts. The way the vegetation integrity score is calculated (see above), results in a vegetation community in its pristine benchmark state having a vegetation integrity score 100. This benchmark value is shown with a horizontal green line in Figure 3. For each initial condition state, undertaking no management results in approximately linear declines due to ongoing threats from typical private landholder activities. High intensity management delivered significantly greater gains in vegetation integrity over time, compared to low intensity management. In most cases, high intensity management resulted in the vegetation integrity score plateauing, as components approached their benchmark values. In some cases, the experts predicted that richness or cover values for some growth form groups could exceed their benchmark values (see Appendix A), resulting in vegetation integrity scores greater than 100. This is most prominent for high management applied to CPW initially in the *medium 1* condition (top right plot; Figure 3). This suggests that high intensity management is predicted to deliver significant restoration gains from a low or medium initial condition. This is not the case for low intensity management, which provides much smaller gains, especially if the starting condition is low.

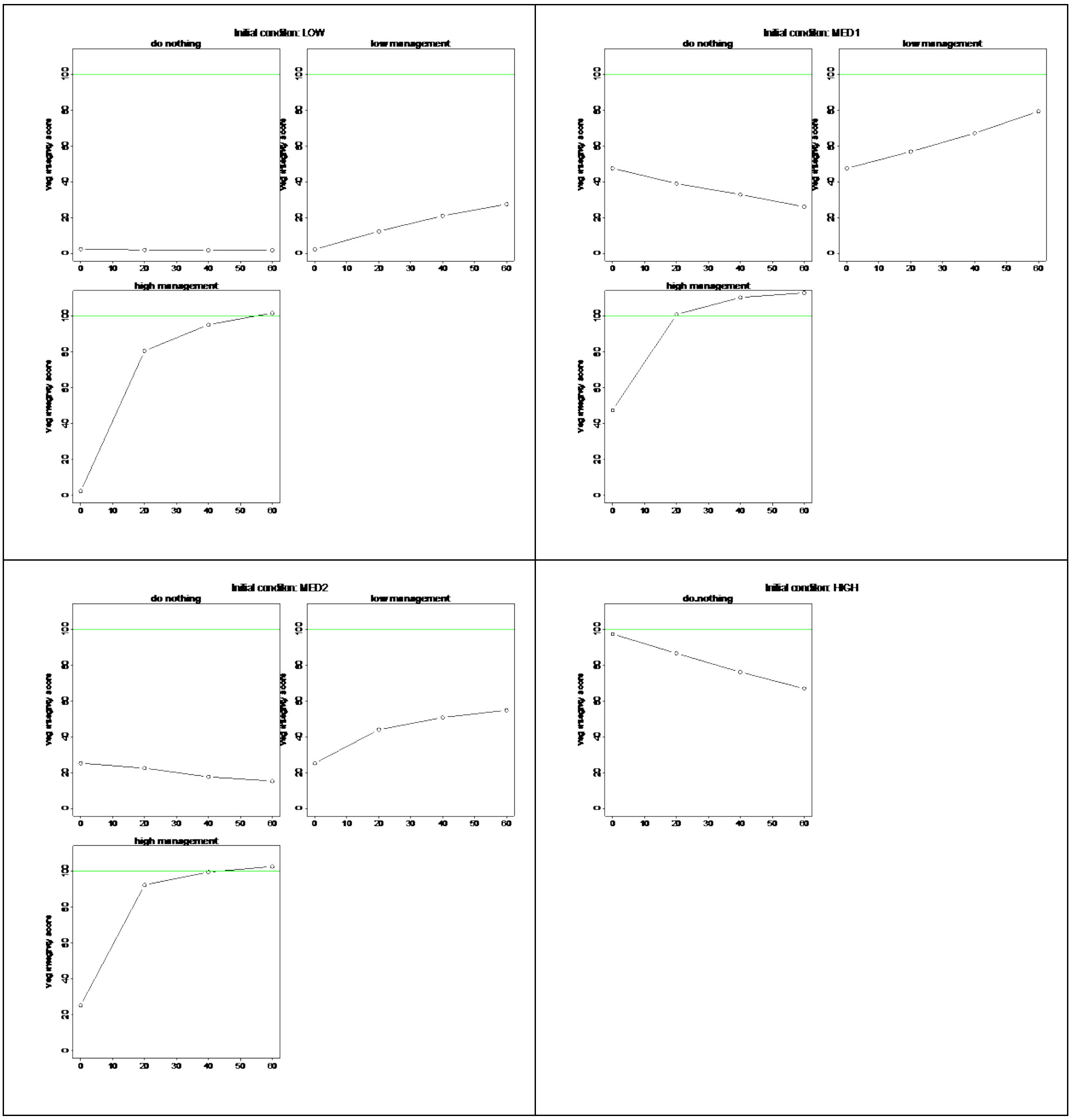

Figure 10. Results of the expert elicitation showing how the modelled version of the BAM vegetation integrity score (y-axis) changes with time (x-axis), for different management regimes and different initial conditions. Each plot shows the vegetation integrity score calculated by taking the mean value across all experts for each component that makes up the score. The top left plots show results for CPW starting in *low condition*, while the remaining plots show results for starting in *medium 1*, *medium 2* and *high conditions* (clockwise from top left). Note that for vegetation in high condition, only the do nothing scenario was elicited, as it was assumed that any management would retain the vegetation in high condition. The green horizontal line in the plots indicate the vegetation integrity score that CPW would have its pristine benchmark state (a value of 100.0).

SIMULATION OF DEVELOPMENT AND OFFSETTING

The main metric used to evaluate performance of the different scenarios is the summed BAM vegetation integrity score over the region of interest as a function of time.

The model produces a map at each time step, showing the condition of each patch of CPW, as well as the locations where development has occurred (where it is assumed that all CPW is removed) and where offsets were implemented (where it is assumed that CPW is managed under high or low intensity management).

Figure 11 shows the final maps generated by the simulation on the last time step for scenario 1 (on the left) and scenario 2 (on the right), where the condition of CPW is depicted by the shade of green (representing the modelled vegetation integrity score), and development is shown in red.

Figure 12 shows maps generated on the last time step for scenarios 3-6, after all development and offsetting has been applied. These plots show the offset regions in blue, where all parcels with CPW in the strategic offset area are implemented as offsets (left plot in Figure 12) and where only half the parcels (randomly selected) are implemented as offsets (right plot).

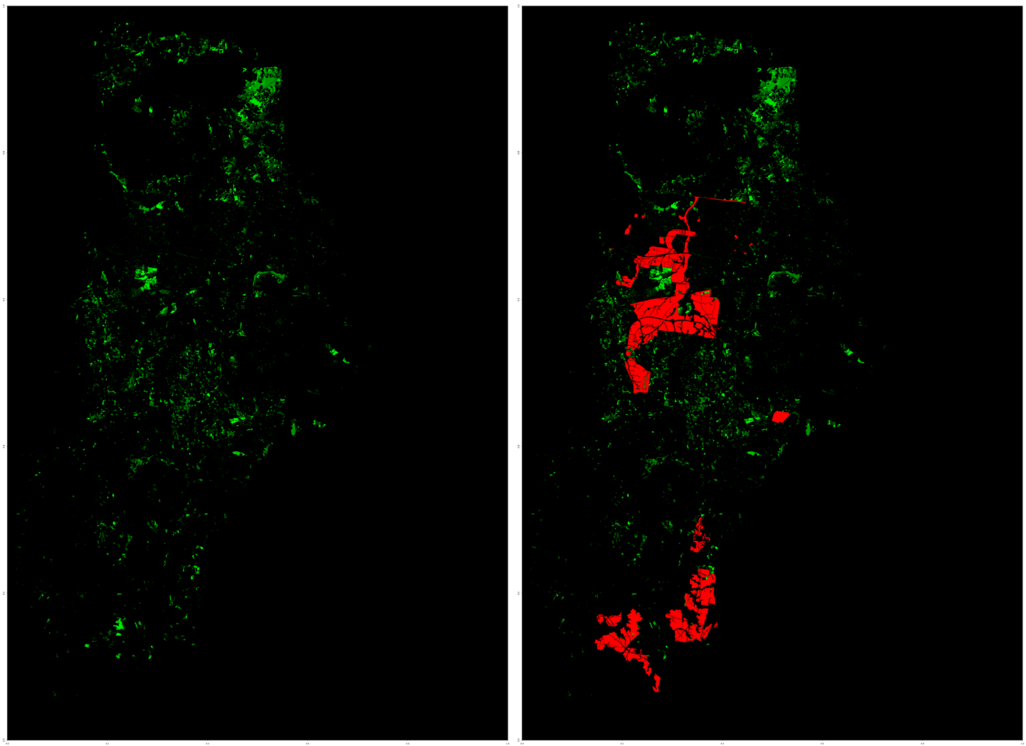

Figure 11. Maps showing modelling outputs for scenario 1 (S1: no development), and scenario 2 (S2: development only). CPW is shown in green with the lighter colour representing a higher vegetation integrity score. Developed parcels are shown in red. Maps show the results at the last time step when all development has been implemented.

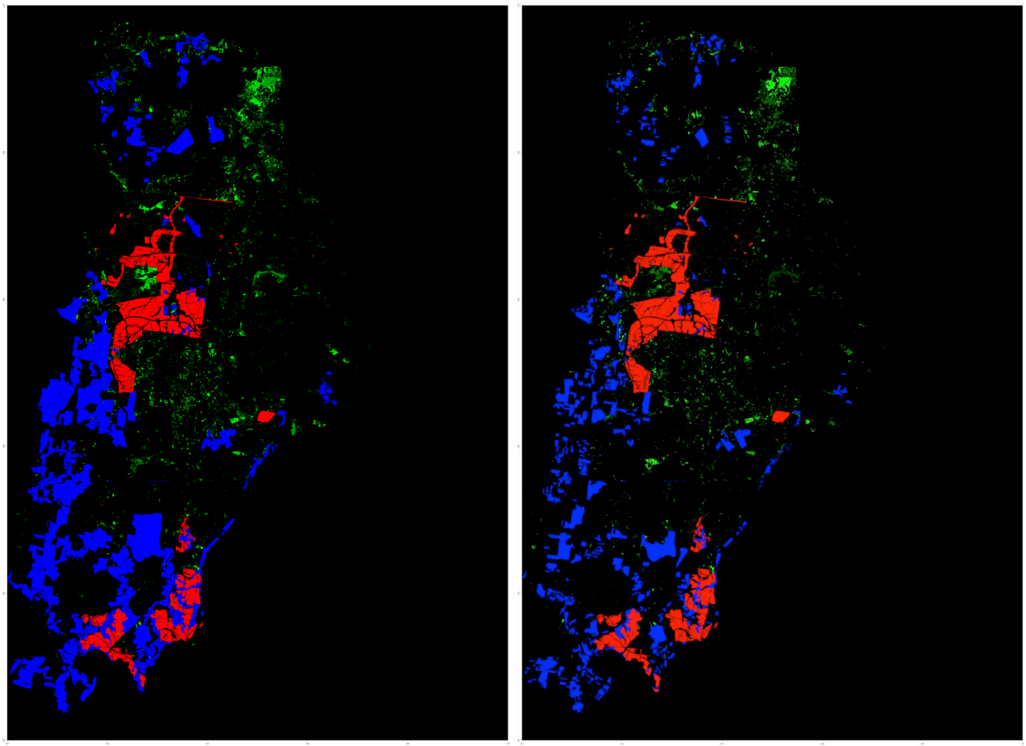

Figure 12. Maps showing outputs for scenarios with both offsetting and development. CPW is shown in green with the lighter colour representing a higher vegetation integrity score. Developed parcels are shown in red, and offset parcels are shown in blue. The map on the left shows the result when all parcels in the strategic offset area are implemented as offsets (scenarios 3-6), and the plot on the right shows one realization of the case where only half the parcels in strategic offsets area are implemented as offsets (scenarios 3A-6A). Maps show the results at the last time step when all development and offsetting has been implemented.

The predicted changes to the summed ecological integrity scores under each of the scenarios are shown in Figures 13-15 in relation to 'landscape scale and 'program scale' results.

The ***landscape scale*** results show the summed vegetation integrity score for the whole Cumberland subregion, including development and offset areas, other conservation areas and existing Biobank sites, as well as remaining areas on private and public land where the vegetation is assumed to be unmanaged.

The ***program scale*** results show the summed vegetation integrity score just for the parcels developed and offset.

The ***landscape scale*** results allow the contribution of development and offsetting to be evaluated relative to overall trends in the Cumberland subregion, while the ***program scale*** results allow an evaluation of the impacts on CPW just in the regions where development and offsetting is occurring (the program area).

Program scale results in Figures 14 and 15 are shown in terms of 'outcomes' and 'impacts'. The outcome plots show the absolute trajectory of the summed vegetation integrity score over time, starting from its initial (current) value and indicating how this value changes with time. The end point of each line shows the final summed vegetation integrity score predicted to occur under a given scenario (incorporating development losses and background declines due to ongoing typical private land activities).

The impact plots show the ***difference of each scenario relative to the counterfactual of S1*** (do nothing—ongoing private land impacts). Thus, for impact plots, values greater than zero indicate better performance relative to S1, and a value less than zero indicates worse performance than S1.

Assessing whether a scenario ***achieves No Net Loss in terms of mitigating the impacts of the development is done by determining when a scenario has an impact greater than zero on the impact plots***. Determining whether a scenario ***mitigates both development impacts and ongoing background declines is done by comparing the trajectory relative to the starting point on the outcome plots***. Where the trajectory is below the starting point, this indicates that both development and background declines have not been compensated for.

While outcome plots are provided at the landscape and program scale, the impact of the scenarios is the same at these scales. This is because the impact is the difference between a given scenario and S1 (i.e. *SX – S1*, for some scenario *X*). Everything occurring outside the program area (offset and development regions) is the same for S1 and all other scenarios, comprising management of Biobank and other conservation sites as well as ongoing decline for vegetation in other areas (i.e. SX – S1 = 0 outside the program areas). Thus, taking the difference of any given scenario, (SX) with S1 just provides the difference between what is occurring in the program area, as the summed vegetation integrity score outside the program area is the same in both scenarios. In other words, ***the impact of all scenarios at the program and landscape scale is the same***.

For all the results presented below it was assumed that existing protected areas had low intensity management and Biobank sites had high intensity management, and everywhere else outside development and offset footprints had no management. Each scenario was run 10 times (10 ***realizations***), and due to the random process in which parcels are selected for offsetting and development in a given time step, each realization has some variation in the summed vegetation integrity score over time due to different parcels being selected in different time steps. The plots show each realization as a fine line and the mean over all realizations for a given scenario as a thick line. Each scenario is shown in a different colour.

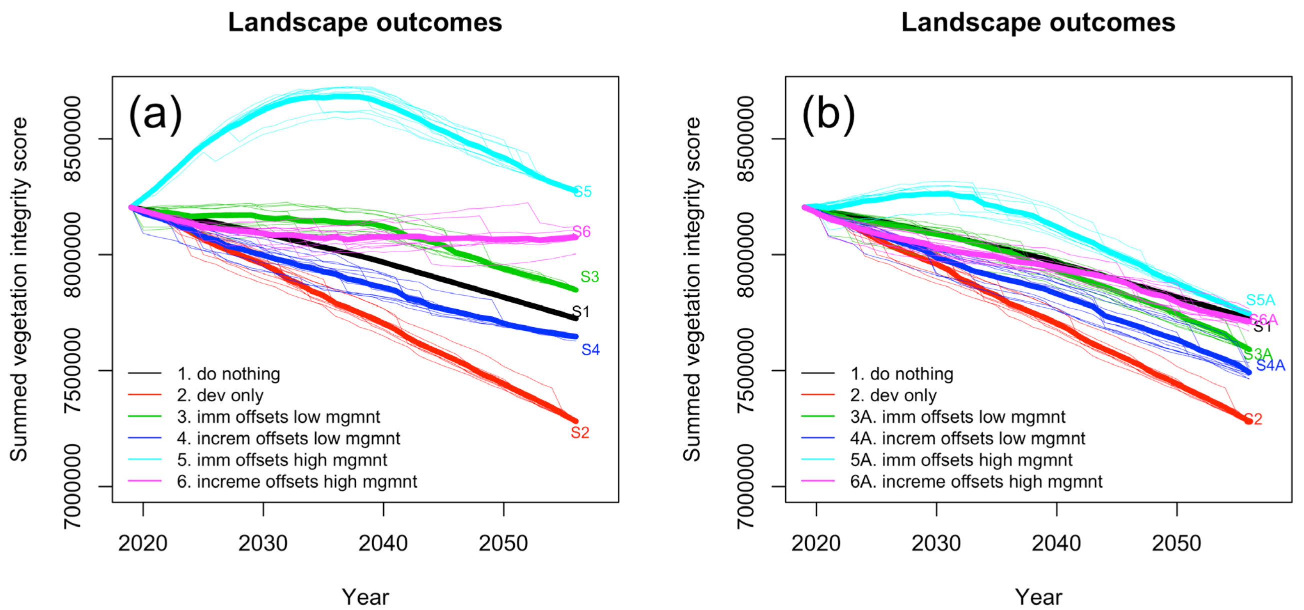

Figure 13. Landscape scale outcomes for 10 realisations of each scenario. The mean of each scenario is shown as the bold line and each individual realization is shown as a thin line. (a) depicts the case where all parcels in the strategic offset region are implemented as offsets, while (b) shows the case where only half of the parcels (randomly selected) in the strategic offset region are implemented as offsets.

Landscape scale ***outcomes*** are shown in Figure 13. When all parcels in the strategic offset area are implemented (Figure 13(a)), all scenarios except S5 result in losses in summed vegetation integrity relative to the initial state. The high intensity management of offsets and their early implementation mean S5 results in initial improvements, however once these gains stop accruing, the ongoing losses in the rest of the landscape result in S5 declining after about 2037, finishing slightly above the initial starting condition. S3 initially outperforms S6, but the high intensity management means that eventually S6 overtakes S3 resulting in a higher summed vegetation integrity score at 2055. The relative ranking of the scenarios is the same for the scenarios where only half the offsets are implemented (Figure 13(b)). However, in this case all scenarios result in ongoing landscape losses except S5A which has small initial gains, which then decline after approximately 2035. In this case, all scenarios end with summed ecological integrity below the current starting state.

Figure 14 shows program scale ***outcomes*** when the vegetation integrity score is summed over the program area (development and offset areas). For the scenarios where only half the parcels in the strategic offset area are implemented (Figure 14(b)), the offset program area is reduced compared to when all parcels in the offset area are implemented as offsets (Figure 14(a)), resulting the plots starting from a lower initial value. Note that in Figure 14(b) there are different starting values for each realization, due to the fact the offset parcels are randomly selected and will have different total area for each realization. When all offsets are implemented (Figure 14(a)), the relative performance of all scenario outcomes at the program scale is similar to the landscape scale outcomes (Figure 13). However, in this case S5 and S6 result in gains relative to the initial starting state, and S3 results in a small gain which eventually declines to approximately the stating state by the end of the simulation, while S4 results in declines relative to the initial state for the duration of the simulation. When half the offsets are implemented (Figure 14(b)), all scenarios result in losses by the end of the simulation relative to the starting state. S5A provides some initial gains but eventually drops below the initial state by the end of the simulation. The difference between each scenario is much more reduced compared to Figure 14(a), with the variation between model realizations providing significant overlaps between the scenarios.

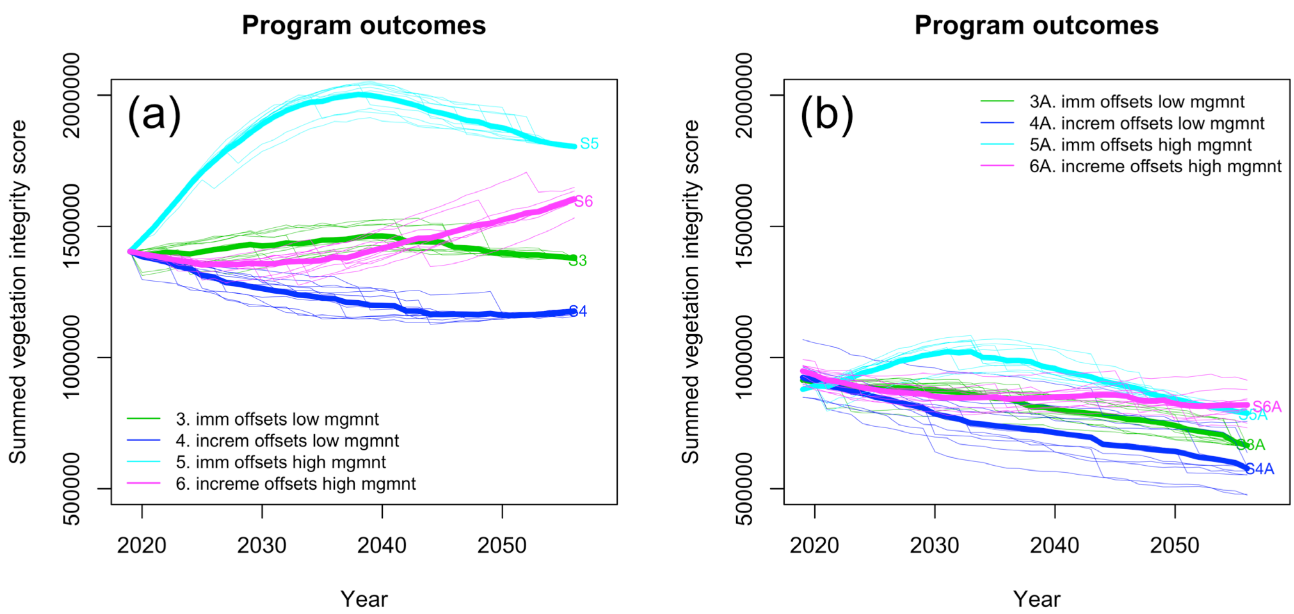

Figure 14. Program scale outcomes for 10 realisations of each scenario, with the mean of each scenario shown as a bold line and each individual realization shown as a thin line. (a) depicts the case where all parcels in the strategic offset region are implemented as offsets, while (b) shows the case where only half of the parcels (randomly selected) in the strategic offset region are implemented as offsets. Note that scenarios 1 and 2 are not shown as these scenarios do not have offsets and thus the 'program scale' (consisting of the offset and development area) is do not have offset areas defined.

The ***impact*** of each scenario is shown in Figure 15, depicting how each scenario performs relative to S1 without any offsets or development. As discussed above, this shows ***the extent to which the development impacts alone are compensated***. When all parcels in the strategic offset area are implemented (Figure 15(a)), S3, S5 and S6 always result in positive impacts, with S6 resulting in initial losses for the first 8 years or so. S3 initially outperforms S6, but the high intensity management of S6 means it eventually overtakes S3. S4 results in initial losses, which then improve but remain negative for the duration of the simulation meaning that low intensity management with offsets implemented incrementally is likely to result in losses relative to no development or offsets (S1). When only half the parcels in the offset area are implemented (Figure 15(b)), gains are significantly reduced for all offset scenarios, with only S6A ending with a value slightly higher than zero but S5A is also very close to zero. This means that when only half the parcels in the strategic offsets area are implemented as offsets, only scenarios with high intensity management (S5A and S6A) compensate for development losses.

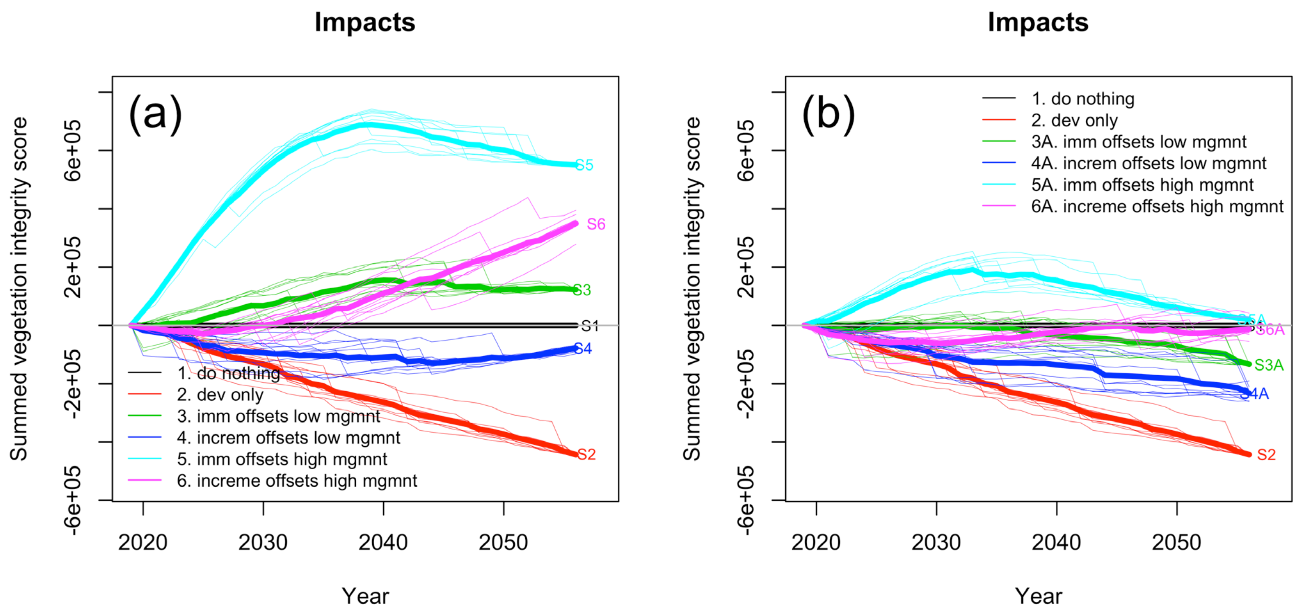

Figure 15. Impacts of the offset and development scenarios, relative to the counterfactual baseline of S1. This shows the performance of each scenario in terms of compensating for development losses alone. Ten realizations of each scenario are shown, with the mean of each scenario depicted as a bold line and each individual realization shown as a thin line. S1 is shown as a horizontal line with impact of zero (a) depicts the case where all parcels in the strategic offset region are implemented as offsets, while (b) shows the case where only half of the parcels (randomly selected) in the strategic offset region are implemented as offsets.

Table 6 summarizes all the results, showing the final summed vegetation integrity score for each scenario at the end of the simulation (year 2056). It also shows the percentage change of each scenario relative to summed vegetation integrity score of S1 on the last time step (middle column) as well as the percentage change relative to initial starting condition of all scenarios at the landscape scale (last column).

Table 6 indicates that under S1, there is a 5.8 % drop in summed vegetation integrity score at the landscape scale due to ongoing private land activities and other degrading process. When development is included, this adds an additional impact of almost the same magnitude (5.78 %) (seen by comparing the percentage change between S1 and S2). Thus, we see the impact of development is almost the same as the projected declines under S1 at the scale of Cumberland subregion from landscape scale threats.

From Table 6 it can also be seen that by the year 2056, only S5 and S6 provide gains at the landscape scale relative to the starting condition, and that S3, S5, S6, S5A and (almost) S6A provide gains, or achieve No Net Loss of summed vegetation integrity relative to do nothing (S1).

Table 6. The percentage change of each scenario relative to Scenario 1 (do nothing) on the last time step of the simulation.

Scenario	Mean summed vegetation integrity score on the last time step and landscape scale	Percentage change relative to value of Scenario 1 on the last time step	Percentage drop relative to starting condition
S1 – Do nothing	7,724,857	0 %	-5.8 %
S2 – Development only	7,281,680	- 5.7 %	-11.2 %
Offsets implemented in all of the parcels in the strategic offset area			
S3 – Imm offsets low management	7,847,765	+ 1.6 %	-4.3 %
S4 – Increm offsets low management	7,646,977	- 1.0 %	-6.8 %
S5 – Imm offsets high management	8,275,312	+7.1 %	+0.86 %
S6 – Increm offsets high management	8,074,270	+ 4.5 %	-1.6 %
Offsets implemented in half of the parcels in the strategic offset area			
S3A – Imm offsets low management	7,591,975	-1.7 %	-7.5 %
S4A – increm offsets low management	7,491,923	-3.0 %	-8.7 %
S5A – Imm offsets high management	7,745,532	+0.27 %	-5.6 %
S6A – Increm offsets high management	7,712,384	-0.16 %	-6.0 %

DISCUSSION

This report presents the results of a trend analysis examining the potential impacts of development and offsetting in the Cumberland subregion on the native vegetation community *Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion* (PCT 849; referred to here as CPW). It consisted of two parts: a formal expert elicitation to gather quantitative knowledge regarding how CPW will change over time under different management scenarios; and quantitative modelling to simulate the urban development within designated Growth Areas, compensation via managing areas as biodiversity offsets in a strategically defined offset region, and the ecological response of CPW over the whole Cumberland subregion. The main points that can be concluded from the trend analysis results are discussed below.

The landscape scale accounts for all parcels in the whole Cumberland subregion, including the parcels that are not part of the program and subject to ongoing declines due to typical private land activities. At this scale, only one scenario results in a gain of summed vegetation integrity of CPW relative to the current state over the whole Cumberland subregion (Figure 13). The gain occurs when offsets are implemented immediately with high intensity management and all parcels in the strategic offsets area are assumed to be secured. In this scenario, there are initial gains, but by the end of the 37-year time period, scenario 5 has dropped to be just above the initial value of the summed vegetation integrity score.

All other scenarios at the landscape scale result in losses of summed vegetation integrity over the whole Cumberland subregion, right from the start. This is due to the predicted large and ongoing condition declines of all the vegetation left unmanaged on private land, as the Plan only influences a proportion of the subregion. The predicted declines in vegetation integrity for unmanaged areas subject to typical private landholder activities can be seen in Figure 13, with scenario 1 line (black line in figure) showing how this plays out relative to the offset and development scenarios. By comparing Figure 13(a) and 13(b) it is clear that if only 50 % of the parcels in the strategic offset area can be implemented as offsets, CPW declines relative to its current condition will be notably larger by the end of the simulation.

The program scale accounts for only the parcels of land where development and offsetting occurs. At this scale, it is only possible to maintain the current state (or better) if all parcels in the strategic offset area are managed, *and* high intensity management *or* immediate offsets are implemented (scenarios 3, 5 and 6; Figure 14). If only half the offsets in the strategic offset area are implemented, all scenarios eventually fall below the current state (Figure 14(b)).

If all offsets in the strategic offset area are implemented, scenarios 3, 5, and 6 also offer the potential of achieving No Net Loss relative to the do nothing scenario (S1: no offsets or development; Figure 15). However, only scenario 5 can reliably deliver no let loss relative to scenario 1 where only half of the parcels in the offset area are secured (Figure 15(b)). In the case where only half the parcels are secured as offsets, all other scenarios result in losses relative to scenario 1, meaning that, in this case, the net impact of development and offsets results in a net loss.

From these results it is clear that high intensity management and implementing offsets as early as possible are both factors in ensuring offsets deliver the greatest gains. However, the importance of high intensity management relative to implementing offsetting early depends on the time horizon over which gains are evaluated. Implementing all offsets immediately with low intensity management delivers greater gains in the short term (1-2 decades), but the simulations show that implementing offsets incrementally with high intensity management eventually delivers greater gains. Clearly, the best conservation outcomes occur with high intensity management and immediate offsets (scenario 5), which results in notably better performance compared to all other scenarios.

The negative impact of development can be seen by comparing scenarios 1 and 2 in Figure 13 (the black and red lines, respectively) which shows the landscape outcomes of CPW of the whole Cumberland subregion. The only difference between these scenarios is the loss of vegetation due to development. Comparison of these two lines in Figure 13 indicates that development in the Growth Areas is having a large negative impact on CPW, and this impact is of similar in magnitude to the declines occurring over the whole Cumberland subregion (a decline of 5.7% in the summed vegetation integrity score (Table 6)).

The results of the expert elicitation reveal there is significant potential for restoring CPW if high intensity management (as defined in Table 3) is implemented. As shown in Figure 10, the expert elicitation revealed that the vegetation integrity score can be significantly improved under the high intensity management regime, even when starting from the low initial condition state. However, if low intensity management is implemented (as described in Table 2), then the gains are significantly reduced and do not reach the point of plateauing within the 60-year time horizon of the elicitation.

It should be noted that the effects of climate change were *not* included in this analysis. While this was discussed in some detail during the expert elicitation workshop, it was agreed that the other degrading processes considered in the elicitation are likely to have a greater determinantal effect than climate change over shorter time frames. In addition, there is a much greater ability control these processes compared to climate change. These factors, along with the significant uncertainties around the impacts of climate change, led to excluding climate change as a degrading process in the modelling.

There are many uncertainties and assumptions in a modelling exercise such as presented here, which have been detailed throughout the report. They include uncertainties in the model inputs, such as the spatial data characterizing the location and initial condition of CPW, and the expert predictions of how ecological factors of CPW will change over time (which varied considerably between experts in some cases). There are also uncertainties in the assumptions of the structure of the model, for example around management being constant and continuous and equally effective over all parcels being managed. Finally, there are many assumptions built into the scenario definitions, which, as discussed above, represent outer bounds of different realistic options for offsetting. While these assumptions and uncertainties may limit the actual predictive ability of a modelling exercise such as this, it is impossible to model so far into the future and on such as large scale without making a wide range of assumptions.

The utility of an exercise such as this is that it allows the relative performance of different scenarios to explored with respect to a clearly-articulated system model, including its uncertainties and assumptions. Thus, scenarios can at least be evaluated with respect to these system models, providing a transparent set of assumptions as how the evidence underlying mitigation decisions were generated. For evaluating mitigation strategies over such large spatial and temporal scales, there is no other alternative.

OVERALL KEY MESSAGES

The key findings of this analysis for CPW are summarized below.

- Landscape-scale threats across the Cumberland subregion, such as weed invasion, grazing, rubbish dumping, and disturbance from recreational activities are causing significant declines.
- The negative impact of development in the Growth Areas is of a similar scale to ongoing declines from landscape scale threats across the whole Cumberland subregion over 37 years. Landscape scale threats across the subregion are projected to result in a 5.8 % drop in summed vegetation integrity score over 37 years (scenario 1, Table 6). The additional impact of development adds further losses of almost the same magnitude (another 5.78 %; Table 6).
- The Plan is generally unlikely to reverse declines from landscape scale threats across the whole Cumberland subregion because the magnitude of these threats is large and the Plan only influences a proportion of the subregion. The only scenario where declines were always reversed at the landscape scale was scenario 5 (Figure 13, Table 6), where it was assumed that: (i) all parcels in the strategic offset area are implemented as offsets, (ii) all offsets were implemented immediately; and (iii) all offsets had high-intensity management. This comprises the outer bound of the best-case scenario, and may not be feasible to implement.
- In terms of whether the Plan addresses the impacts of development in the Growth Areas alone within the program area (ignoring declines from landscape scale threats), two of the four offset scenarios (scenarios 5 and 6) provided adequate compensation irrespective of whether 100% or 50% of the CPW was secured as offsets in the strategic offset area (Figure 15, S5 and 5A, S6 and 6A). When 100% of the CPW available in the strategic offset area is secured as an offset, three of the four offset scenarios compensate for development impacts (all except scenario 4). When 50% of the CPW available in the strategic offset area is secured as an offset, only two of the four offset scenarios (S5 and S6) provide adequate compensation.
- In terms of whether the Plan addresses the impacts of development in the Growth Areas as well as declines from landscape scale threats within the program area, three of the four offset scenarios (scenarios 3, 5, and 6) compensate for both these impact types when 100% of the CPW in the strategic offset area is secured (Figure 14(a)). However, none of the offset scenarios can compensate for both these impact types in the program area if only 50% of the CPW in the strategic offset area is secured (Figure 14(b)).

- The timing of offset implementation and the level of management intensity make a significant difference to the gains able to be achieved by offsets, with early implementation/high intensity management always performing best.
- The relative benefit of early implementation compared to high intensity management depends on the time period over which gains are evaluated. The results suggest that (Figure 15):
    - Early implementation with low or high intensity management delivers greater gains in the short term (1 to 2 decades).
    - Early implementation with high intensity management delivers the greatest gains in the long term.
- Results of expert elicitation (Figure 10) indicate that high intensity management provides significant potential for providing restoration gains for CPW, even when starting from a low initial condition. However, low intensity management has limited capacity to improve the ecological condition of CPW, especially when starting from a low initial condition.

Care will need to be taken in extrapolating these results to other PCTs. However, it is likely that the overall findings will have relevance and will provide useful context to the discussion of long-term trends in native vegetation change within the Cumberland subregion.

REFERENCES

Baylis, K., Honey-Rosés, J., Börner, J., Corbera, E., Ezzine-de-Blas, D., Ferraro, P.J., Lapeyre, R., Persson, U.M., Pfaff, A., Wunder, S. (2016) Mainstreaming Impact Evaluation in Nature Conservation: Mainstreaming impact evaluation. *Conservation Letters*. 9, 58–64. https://doi.org/10.1111/conl.12180.

Bull, J.W., Gordon, A., Watson, J.E.M., Maron, M. (2016) Seeking convergence on the key concepts in 'no net loss' policy. *Journal of Applied Ecology*. 53, 1686–1693. https://doi.org/10.1111/1365-2664.12726.

Bull, J.W., Gordon, A., Law, E., Suttle, K.B., Milner-Gulland, E.J. (2014) Importance of Baseline Specification in Evaluating Conservation Interventions and Achieving No Net Loss of Biodiversity. *Conservation Biology*. 28, 799–809. https://doi.org/10.1111/cobi.12243.

Bull, J.W., Suttle, K.B., Gordon, A., Singh, N.J., Milner-Gulland, E.J. (2013) Biodiversity offsets in theory and practice. *Oryx*. 47, 369-380. https://doi.org/10.1017/s003060531200172x.

Burgman, M.A., McBride, M., Ashton, R., Speirs-Bridge, A., Flander, L., Wintle, B., Fidler, F., Rumpff, L. & Twardy, C. (2011) Expert status and performance. *PLoS One*. 6, 1-7.

Ferraro, P.J., 2009. Counterfactual thinking and impact evaluation in environmental policy. *New Directions in Evaluation*. 2009, 75–84.

Gordon, A. (2015) Implementing backcasting for conservation: determining multiple policy pathways for retaining future targets of endangered woodlands in Sydney, Australia. *Biological Conservation*. 181, 182–189. https://doi.org/10.1016/j.biocon.2014.10.025.

Gordon A., Langford W.T., Bekessy S.A. (2011a) *Modelling the growth of Sydney and the impacts on the Cumberland Plain Woodland*. Report prepared for the Australian Government's Department of Sustainability, Environment, Water, Population and Communities. RMIT University, Melbourne, Victoria. 22 pages.

Gordon, A., Langford, W.T., Todd, J.A., White, M.D., Mullerworth, D.W, Bekessy, S.A. (2011b) Assessing the impacts of biodiversity offset policies. *Environmental Modelling and Software*. 26, 1481–1488. https://doi.org/10.1016/j.envsoft.2011.07.021.

Greater Sydney Commission. (2017) *A metropolis of three cities – The Greater Sydney Region Plan*. Available at https://gsc-public-1.s3.amazonaws.com/s3fs-public/gsrp_oct_2017.pdf

Hemming, V., Burgman, M. A., Hanea, A. M., McBride, M. F., Wintle, B. C. (2018) A Practical Guide to Structured Expert Elicitation Using the IDEA Protocol. *Methods in Ecology and Evolution*. 1, 169–80. https://doi.org/10.1111/2041-210X.12857

Holden, T., Hemphill P. (2019) *Cumberland Plain Assessment Report*. Open Lines, Canberra, ACT.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B., McAlpine, C.A. (2012) Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation*. 155, 141–148. https://doi.org/10.1016/j.biocon.2012.06.003.

Maron, M., Brownlie, S., Bull, J.W., Evans, M.C., von Hase, A., Quétier, F., Watson, J.E.M., Gordon, A. (2018) The many meanings of No Net Loss in environmental policy. *Nature Sustainability*. 1: 19-27. doi: 10.1038/s41893-017-0007-7.

OEH (2013) Remnant Vegetation of the western Cumberland subregion, 2013 Update. Available at https://data.nsw.gov.au/data/dataset/remnant-vegetation-of-the-western-cumberland-subregion-2013-update-vis_id-4207fd1f4.

OEH (2016) The Native Vegetation of the Sydney Metropolitan Area Version 3. Available at https://www.environment.nsw.gov.au/surveys/VegetationSydMetro.htm.

OEH (2017) Biodiversity Assessment Method. 2017 State of NSW. Available at https://www.environment.nsw.gov.au/biodiversity/assessmentmethod.htm.

OEH (2017) Guidelines for planning authorities for proposing conservation measures in strategic applications for biodiversity certification. Draft Version 7, State of NSW (unpublished)

Oliver I., McNellie M.J., Steenbeeke G., Copeland L., Porteners M.F., Wall J. (in press) Expert allocation of primary growth form to the NSW flora underpins the Biodiversity Assessment Method. *Australasian Journal of Environmental Management*.

Quétier, F., Lavorel, S. (2011) Assessing ecological equivalence in biodiversity offset schemes: Key issues and solutions. Biological Conservation. 144, 2991–2999. https://doi.org/10.1016/j.biocon.2011.09.002.

Transport NSW (2017) *Future Transport Strategy 2056*. Available at https://future.transport.nsw.gov.au/sites/default/files/media/documents/2018/Future_Transport_2056_Strategy.pdf.

APPENDICES

APPENDIX A – DETAILED RESULTS OF THE EXPERT ELICITATION

Below, the key results of the expert elicitation are summarized. They show the *best estimates* of each expert for how tree richness (Figure A1), grass richness (Figure A2), forb richness (Figure A3), tree cover (Figure A4), and grass cover (Figure A5) change over time. This is presented using four different starting conditions (low; medium 1; medium 2; high) and three management regimes (do nothing; low; and high management)— see main text for details of starting conditions and management. In each of the plots below, the results for each individual expert is shown with a thin, coloured line. The mean over all experts for is shown with a dashed black line. For the results presented in the main report, the mean value is across all experts is used for calculating the vegetation integrity score, as described above.

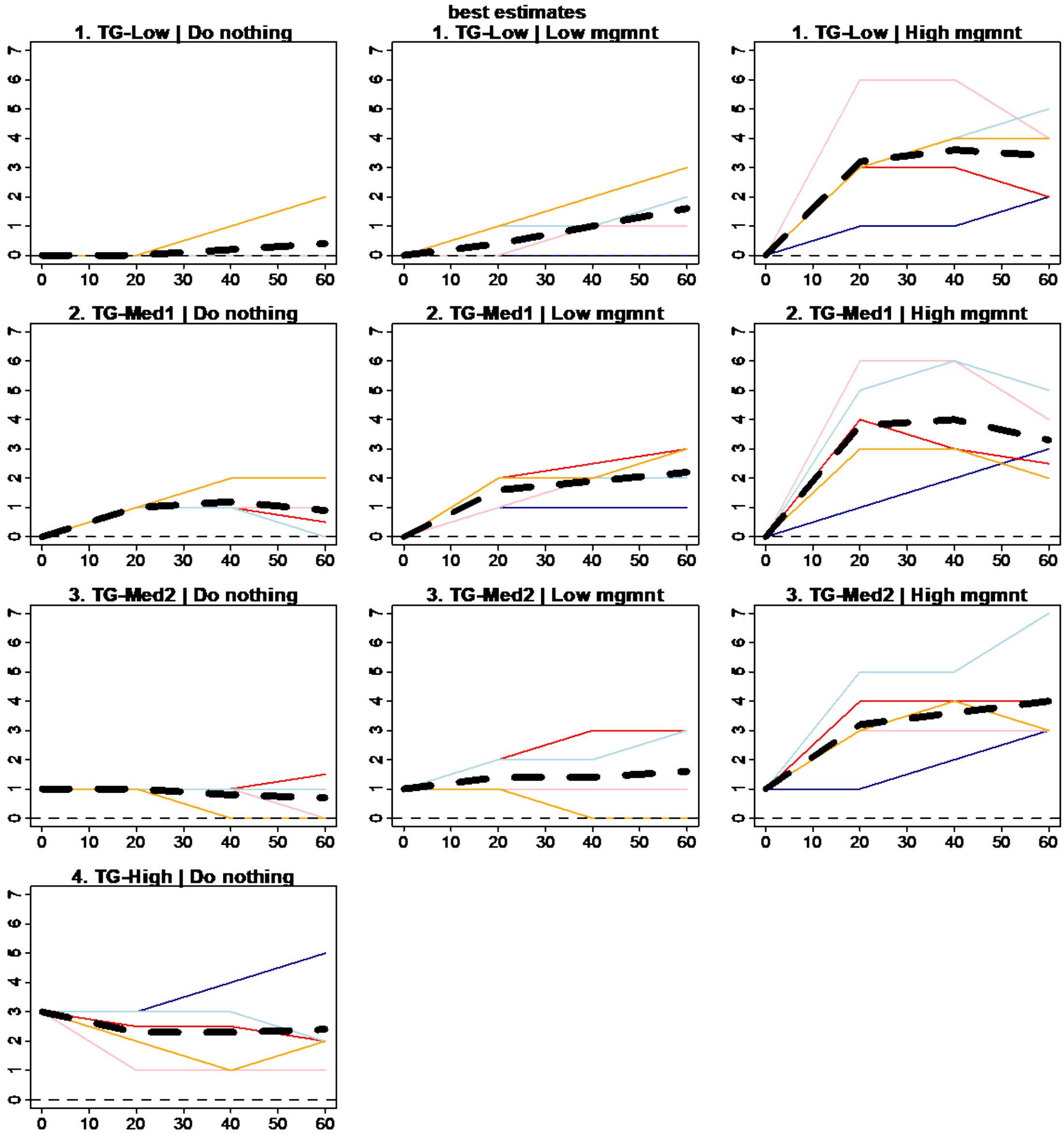

Figure A1. Results of the expert elicitation showing how <u>tree richness</u> (y-axis) for CPW is predicted to change over time (x-axis) for different initial conditions and management regimes in 20-year increments. The left column shows results for the do-nothing management scenario, while the middle and right columns show results for the low and high management regimes, respectively. The top row shows results for vegetation starting in the low condition, the second and third rows show results for vegetation starting in the medium 1 and medium 2 condition, respectively. The bottom plot shows results for vegetation starting in the high condition under do-nothing. Note, results were not elicited for vegetation starting in the high condition under high or low management, as it was assumed that with management, it would retain its richness score. Y-axis value on all plots is the count of species of trees in a notional 20 m x 20 m plot. X-axis (time) values were identified at t=0, t=20, t=40 and t=60.

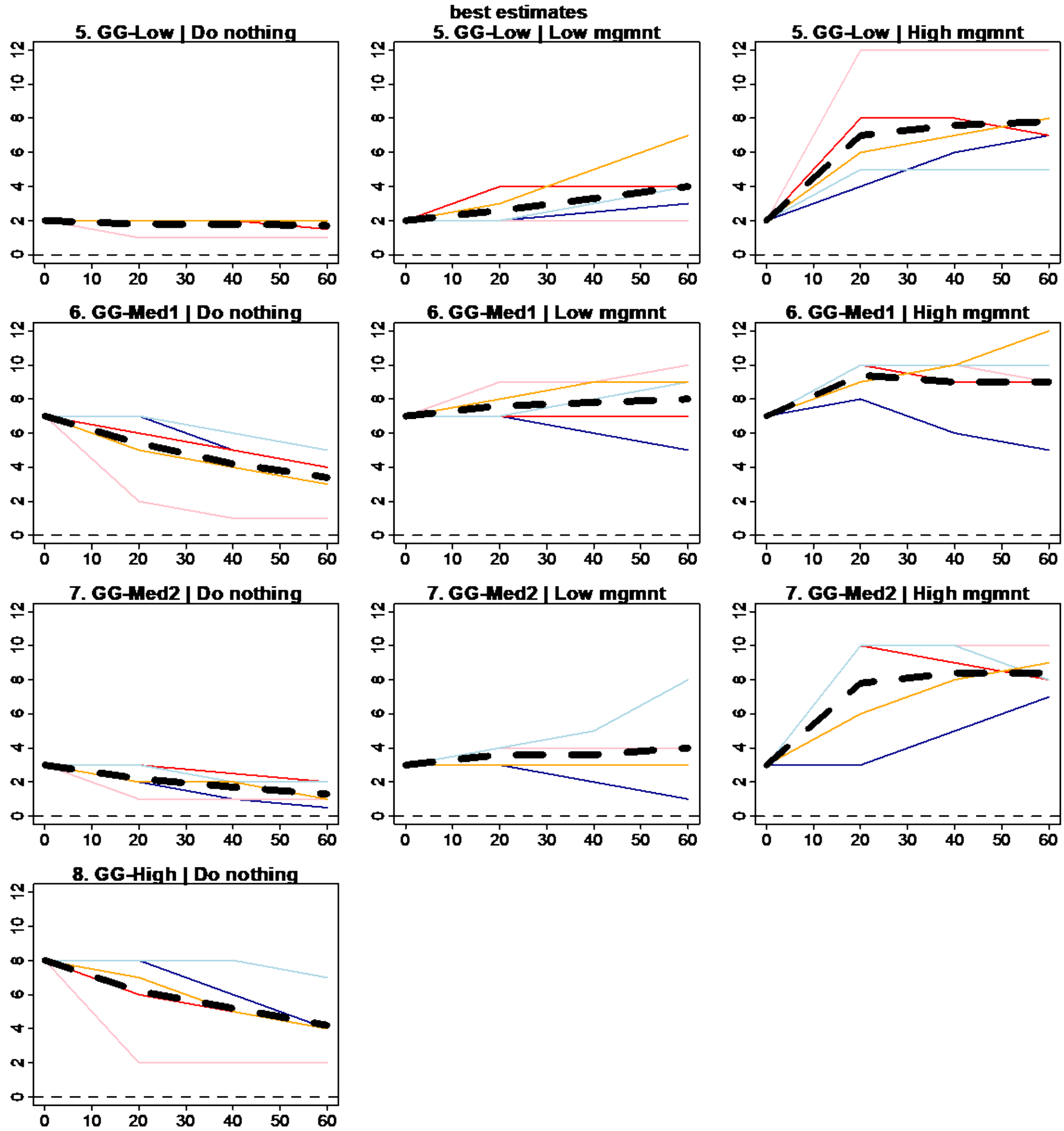

Figure A2. Results of the expert elicitation showing how grass-growth-form-group species richness (y-axis) for CPW is predicted to change over time (x-axis) for different initial conditions and management regimes in 20-year increments. The left column shows results for the do-nothing management scenario, while the middle and right columns show results for the low and high management regimes, respectively. The top row shows results for vegetation starting in the low condition, the second and third rows show results for vegetation starting in the medium 1 and medium 2 condition, respectively. The bottom plot shows results for vegetation starting in the high condition under do-nothing. Note, results were not elicited for vegetation starting in the high condition under high or low management, as it was assumed that with management, it would retain its richness score.

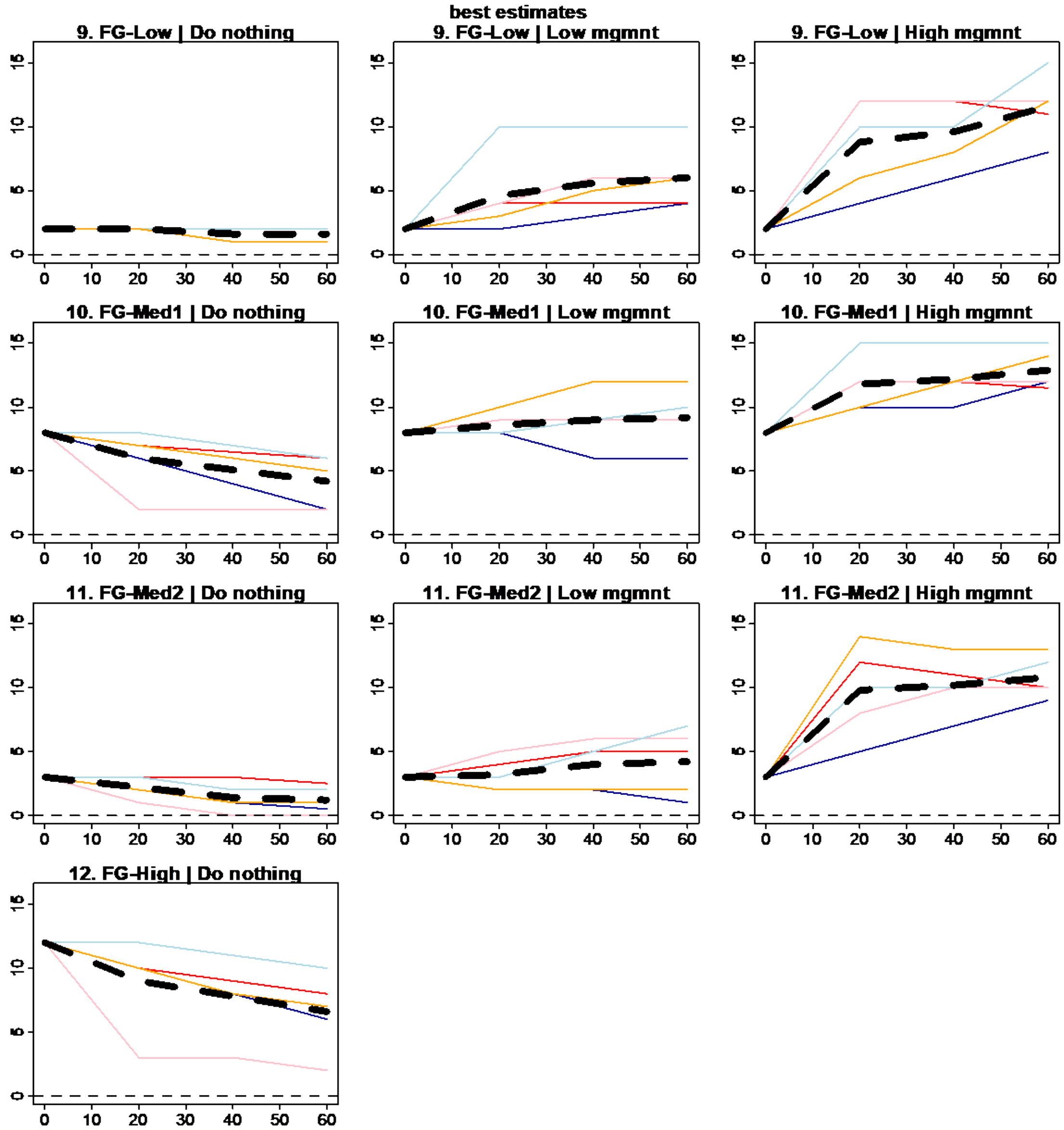

Figure A3. Results of the expert elicitation showing how <u>forb species richness</u> (y-axis) for CPW is predicted to change over time (x-axis) for different initial conditions and management regimes in increments of t=20. The left column shows results for the do-nothing management scenario, while the middle and right columns show results for the low and high management regimes, respectively. The top row shows results for vegetation starting in the low condition, the second and third rows show results for vegetation starting in the medium 1 and medium 2 condition, respectively. The bottom plot shows results for vegetation starting in the high condition under do-nothing. Note, results were not elicited for vegetation starting in the high condition under high or low management, as it was assumed that with management, it would retain its richness score.

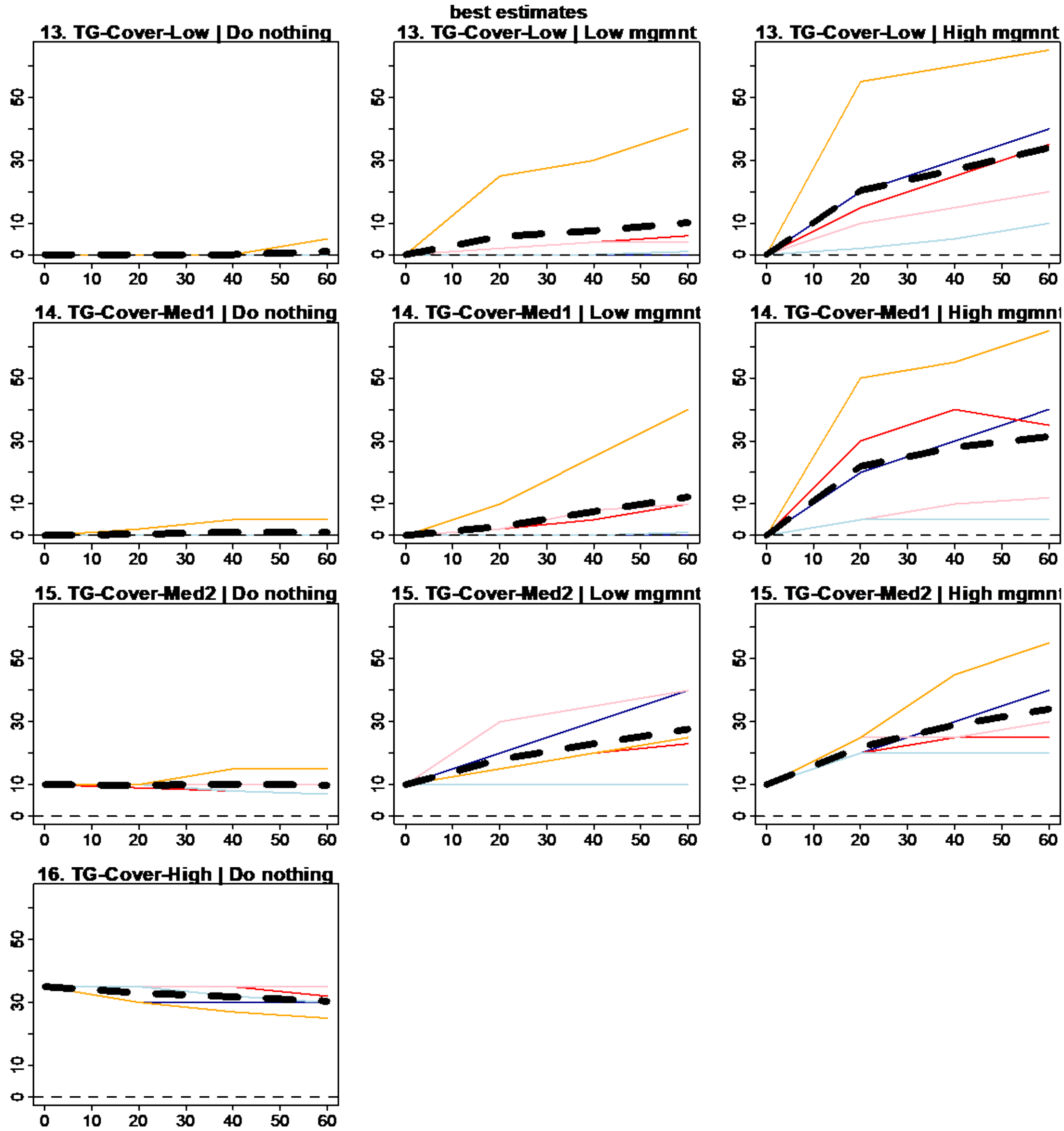

Figure A4. Results of the expert elicitation showing how <u>tree crown cover</u> (y-axis) for CPW is predicted to change over time (x-axis) for different initial conditions and management regimes in increments of t=20. The left column shows results for the do-nothing management scenario, while the middle and right columns show results for the low and high management regimes, respectively. The top row shows results for vegetation starting in the low condition, the second and third rows show results for vegetation starting in the medium 1 and medium 2 condition, respectively. The bottom plot shows results for vegetation starting in the high condition under do-nothing. Note, results were not elicited for vegetation starting in the high condition under high or low management, as it was assumed that with management, it would retain its cover score.

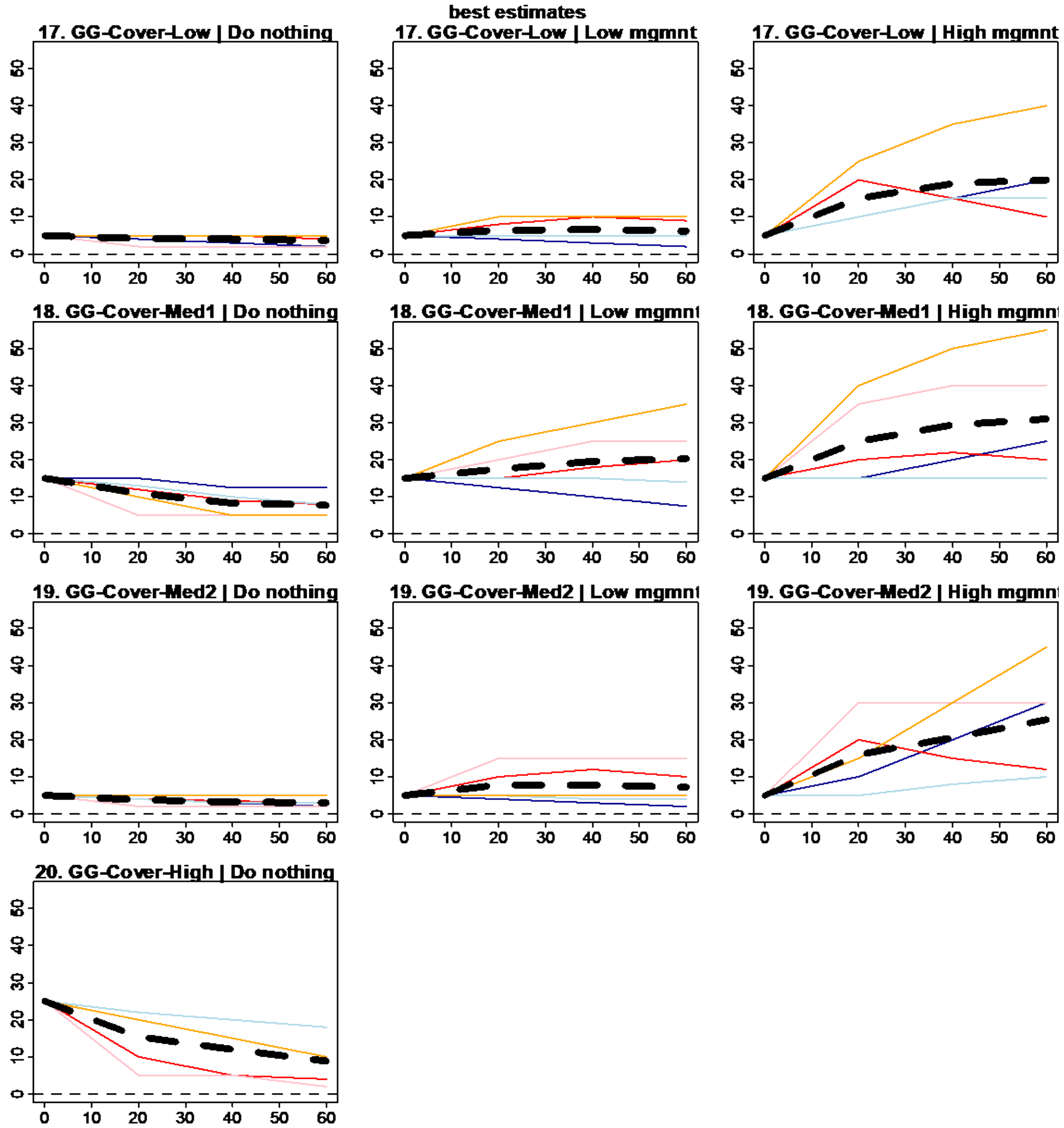

Figure A5. Results of the expert elicitation showing how grass crown cover (y-axis) for CPW is predicted to change over time (x-axis) for different initial conditions and management regimes in increments of t=20. The left column shows results for the do-nothing management scenario, while the middle and right columns show results for the low and high management regimes, respectively. The top row shows results for vegetation starting in the low condition, the second and third rows show results for vegetation starting in the medium 1 and medium 2 condition, respectively. The bottom plot shows results for vegetation starting in the high condition under do-nothing. Note, results were not elicited for vegetation starting in the high condition under high or low management, as it was assumed that with management, it would retain its cover score.

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2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document E – Biodiversity credit report

Supporting document E – Contents

Biodiversity credit report – GMAC

BAM Credit Summary Report

Proposal Details

Assessment Id

00013050/BAAS18134/18/00013052

Proposal Name

Western Sydney Strategic Biodiversity Certification - Greater Macarthur Growth Area

BAM data last updated *

10/06/2021

Assessor Name

Jane Raithby-Veall

Report Created

03/11/2021

BAM Data version *

45

Assessor Number

BAAS18134

BAM Case Status

Finalised

Date Finalised

03/11/2021

Assessment Revision

4

Assessment Type

Biocertification

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits
Cumberland moist shale woodland											
1	830_Thinned	Moist Shale Woodland in the Sydney Basin Bioregion	20.1	20.1	0.01	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		1

21	830_Intact	Moist Shale Woodland in the Sydney Basin Bioregion	48.3	48.3	0.04	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		1
										Subtotal	**2**
Cumberland riverflat forest											
2	835_Intact	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	76.6	76.6	1.3	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		49
3	835_Thinned	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	57.1	57.1	7.2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		207

4	835_Scattered_trees	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	68.7	68.7	0.18	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		6
17	835_NO_grassland	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	8	8.0	25.9	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		0
										Subtotal	**262**
Cumberland shale - sandstone Ironbark forest											
13	1395_Intact	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	72.9	72.9	34.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	1585
14	1395_Thinned	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	63.9	63.9	74.7	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	2986

15	1395_Scattered_trees	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	30	30.0	23.1	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	434
16	1395_DNG	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	28.4	28.4	56.3	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	997
20	1395_NO_grassland	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	5.4	5.4	471.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**6002**
Cumberland shale hills woodland											
9	850_Intact	Cumberland Plain Woodland in the Sydney Basin Bioregion	58.1	58.1	4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	147
10	850_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	41.9	41.9	21.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	570
11	850_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	38.1	38.1	6.9	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	163

12	850_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	25.7	25.7	12.4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	198
19	850_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	12.3	12.3	454.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**1078**
Cumberland shale plains woodland											
5	849_Intact	Cumberland Plain Woodland in the Sydney Basin Bioregion	53.9	53.9	10.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	362
6	849_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	42.3	42.3	37.4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	988
7	849_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	18.3	18.3	26.3	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	301
8	849_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	24.1	24.1	28.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	425

18	849_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	10.1	10.1	1341.1	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**2076**
										Total	**9420**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits
Acacia bynoeana / Bynoe's Wattle (Flora)								
1395_Intact	72.9	72.9	27.8	Endangered	Vulnerable	2	False	1015
1395_Thinned	63.9	63.9	60.4	Endangered	Vulnerable	2	False	1932
1395_Scattered_trees	30.0	30.0	20.6	Endangered	Vulnerable	2	False	310
1395_DNG	28.4	28.4	49.9	Endangered	Vulnerable	2	False	707
1395_NO_grassland	5.4	5.4	0.05	Endangered	Vulnerable	2	False	1
							Subtotal	**3965**
Acacia pubescens / Downy Wattle (Flora)								
835_Intact	76.6	76.6	1.2	Vulnerable	Vulnerable	2	False	47
835_Thinned	57.1	57.1	5.9	Vulnerable	Vulnerable	2	False	168
849_Intact	53.9	53.9	7.9	Vulnerable	Vulnerable	2	False	212
849_Thinned	42.3	42.3	34.4	Vulnerable	Vulnerable	2	False	728
849_Scattered_trees	18.3	18.3	22	Vulnerable	Vulnerable	2	False	201

849_DNG	24.1	24.1	23.6	Vulnerable	Vulnerable	2	False	283
1395_Intact	72.9	72.9	31	Vulnerable	Vulnerable	2	False	1130
1395_Thinned	63.9	63.9	65.7	Vulnerable	Vulnerable	2	False	2099
1395_Scattered_trees	30.0	30.0	21.4	Vulnerable	Vulnerable	2	False	321
1395_DNG	28.4	28.4	53	Vulnerable	Vulnerable	2	False	751
835_Scattered_trees	68.7	68.7	0.18	Vulnerable	Vulnerable	2	False	6
1395_NO_grassland	5.4	5.4	0.03	Vulnerable	Vulnerable	2	False	1
							Subtotal	**5947**
Callocephalon fimbriatum / Gang-gang Cockatoo (Fauna)								
835_Intact	76.6	76.6	0.09	Vulnerable	Not Listed	2	False	3
849_Intact	53.9	53.9	1.2	Vulnerable	Not Listed	2	False	32
1395_Intact	72.9	72.9	1.8	Vulnerable	Not Listed	2	False	65
							Subtotal	**100**
Calyptorhynchus lathami / Glossy Black-Cockatoo (Fauna)								
1395_Intact	72.9	72.9	7.5	Vulnerable	Not Listed	2	False	275
							Subtotal	**275**
Cercartetus nanus / Eastern Pygmy-possum (Fauna)								
835_Intact	76.6	76.6	1.3	Vulnerable	Not Listed	2	False	49
849_Intact	53.9	53.9	3.3	Vulnerable	Not Listed	2	False	88
850_Intact	58.1	58.1	2.3	Vulnerable	Not Listed	2	False	68
1395_Intact	72.9	72.9	28.3	Vulnerable	Not Listed	2	False	1031
830_Intact	48.3	48.3	0.04	Vulnerable	Not Listed	2	False	1

							Subtotal	**1237**
Chalinolobus dwyeri / Large-eared Pied Bat (Fauna)								
835_Intact	76.6	76.6	1.3	Vulnerable	Vulnerable	3	True	74
835_Thinned	57.1	57.1	6.7	Vulnerable	Vulnerable	3	True	285
849_Intact	53.9	53.9	10.7	Vulnerable	Vulnerable	3	True	433
849_Thinned	42.3	42.3	25	Vulnerable	Vulnerable	3	True	793
850_Intact	58.1	58.1	3.8	Vulnerable	Vulnerable	3	True	166
850_Thinned	41.9	41.9	16.9	Vulnerable	Vulnerable	3	True	532
1395_Intact	72.9	72.9	34.8	Vulnerable	Vulnerable	3	True	1902
1395_Thinned	63.9	63.9	74.6	Vulnerable	Vulnerable	3	True	3577
830_Intact	48.3	48.3	0.04	Vulnerable	Vulnerable	3	True	1
							Subtotal	**7763**
Epacris purpurascens var. purpurascens / Epacris purpurascens var. purpurascens (Flora)								
1395_Intact	N/A	N/A	156	Vulnerable	Not Listed	1.5	False	234
1395_Thinned	N/A	N/A	271	Vulnerable	Not Listed	1.5	False	407
							Subtotal	**641**
Eucalyptus benthamii / Camden White Gum (Flora)								
849_Intact	53.9	53.9	0	Vulnerable	Vulnerable	2	False	0
							Subtotal	**0**
Grevillea parviflora subsp. parviflora / Small-flower Grevillea (Flora)								
1395_Intact	72.9	72.9	0.13	Vulnerable	Vulnerable	2	False	5
1395_Thinned	63.9	63.9	2.2	Vulnerable	Vulnerable	2	False	69
							Subtotal	**74**

Haliaeetus leucogaster / White-bellied Sea-Eagle (Fauna)								
835_Intact	76.6	76.6	0.21	Vulnerable	Not Listed	2	False	8
849_Intact	53.9	53.9	0.36	Vulnerable	Not Listed	2	False	10
850_Intact	58.1	58.1	0.16	Vulnerable	Not Listed	2	False	5
1395_Intact	72.9	72.9	7.3	Vulnerable	Not Listed	2	False	266
830_Intact	48.3	48.3	0.04	Vulnerable	Not Listed	2	False	1
							Subtotal	**290**
Heleioporus australiacus / Giant Burrowing Frog (Fauna)								
1395_Intact	72.9	72.9	0.29	Vulnerable	Vulnerable	1.5	False	8
							Subtotal	**8**
Hibbertia fumana / Hibbertia fumana (Flora)								
849_Intact	53.9	53.9	0.05	Critically Endangered	Not Listed	3	True	2
849_Thinned	42.3	42.3	0.01	Critically Endangered	Not Listed	3	True	1
1395_Intact	72.9	72.9	0.57	Critically Endangered	Not Listed	3	True	31
1395_Thinned	63.9	63.9	6.2	Critically Endangered	Not Listed	3	True	298
849_NO_grassland	10.1	10.1	0.04	Critically Endangered	Not Listed	3	True	1
1395_NO_grassland	5.4	5.4	0.18	Critically Endangered	Not Listed	3	True	1
							Subtotal	**334**
Hibbertia puberula / Hibbertia puberula (Flora)								
849_Intact	53.9	53.9	0.05	Endangered	Not Listed	2	False	1

849_Thinned	42.3	42.3	0.01	Endangered	Not Listed	2	False	1
1395_Intact	72.9	72.9	0.57	Endangered	Not Listed	2	False	21
1395_Thinned	63.9	63.9	6.2	Endangered	Not Listed	2	False	199
849_NO_grassland	10.1	10.1	0.04	Endangered	Not Listed	2	False	1
1395_NO_grassland	5.4	5.4	0.18	Endangered	Not Listed	2	False	1
							Subtotal	**224**
Hieraaetus morphnoides / Little Eagle (Fauna)								
830_Thinned	20.1	20.1	0.01	Vulnerable	Not Listed	1.5	False	1
849_Intact	53.9	53.9	0.51	Vulnerable	Not Listed	1.5	False	10
849_Scattered_trees	18.3	18.3	0.25	Vulnerable	Not Listed	1.5	False	2
850_Intact	58.1	58.1	0.07	Vulnerable	Not Listed	1.5	False	2
850_Thinned	41.9	41.9	0.26	Vulnerable	Not Listed	1.5	False	4
1395_Intact	72.9	72.9	12.5	Vulnerable	Not Listed	1.5	False	342
1395_Thinned	63.9	63.9	2.5	Vulnerable	Not Listed	1.5	False	59
1395_Scattered_trees	30.0	30.0	2.7	Vulnerable	Not Listed	1.5	False	31
830_Intact	48.3	48.3	0.04	Vulnerable	Not Listed	1.5	False	1
							Subtotal	**452**
Lophoictinia isura / Square-tailed Kite (Fauna)								
849_Intact	53.9	53.9	0.51	Vulnerable	Not Listed	1.5	False	10
849_Thinned	42.3	42.3	0.62	Vulnerable	Not Listed	1.5	False	10
849_Scattered_trees	18.3	18.3	0.25	Vulnerable	Not Listed	1.5	False	2

850_Thinned	41.9	41.9	0.18	Vulnerable	Not Listed	1.5	False	3
1395_Intact	72.9	72.9	17.5	Vulnerable	Not Listed	1.5	False	478
1395_Thinned	63.9	63.9	3.4	Vulnerable	Not Listed	1.5	False	82
1395_Scattered_trees	30.0	30.0	2.7	Vulnerable	Not Listed	1.5	False	30
							Subtotal	**615**
Marsdenia viridiflora subsp. viridiflora - endangered population / Marsdenia viridiflora R. Br. subsp. viridiflora population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas (Flora)								
835_Intact	76.6	76.6	1.3	Endangered Population	Not Listed	2	False	49
835_Thinned	57.1	57.1	2.8	Endangered Population	Not Listed	2	False	81
849_Intact	53.9	53.9	0.93	Endangered Population	Not Listed	2	False	25
849_Thinned	42.3	42.3	12.2	Endangered Population	Not Listed	2	False	259
850_Intact	58.1	58.1	0.44	Endangered Population	Not Listed	2	False	13
850_Thinned	41.9	41.9	5.5	Endangered Population	Not Listed	2	False	116
1395_Intact	72.9	72.9	2.4	Endangered Population	Not Listed	2	False	88
1395_Thinned	63.9	63.9	7.3	Endangered Population	Not Listed	2	False	232
830_Intact	48.3	48.3	0.03	Endangered Population	Not Listed	2	False	1
							Subtotal	**864**

Melaleuca deanei / Deane's Paperbark (Flora)								
1395_Intact	72.9	72.9	18.6	Vulnerable	Vulnerable	3	True	1014
1395_Thinned	63.9	63.9	30	Vulnerable	Vulnerable	3	True	1436
1395_Scattered_trees	30.0	30.0	12.3	Vulnerable	Vulnerable	3	True	278
							Subtotal	**2728**
Meridolum corneovirens / Cumberland Plain Land Snail (Fauna)								
830_Thinned	20.1	20.1	0.01	Endangered	Not Listed	2	False	1
835_Intact	76.6	76.6	1.3	Endangered	Not Listed	2	False	49
835_Thinned	57.1	57.1	7.2	Endangered	Not Listed	2	False	207
849_Intact	53.9	53.9	3.3	Endangered	Not Listed	2	False	88
849_Thinned	42.3	42.3	32.2	Endangered	Not Listed	2	False	681
850_Intact	58.1	58.1	3.7	Endangered	Not Listed	2	False	108
850_Thinned	41.9	41.9	17.9	Endangered	Not Listed	2	False	376
1395_Intact	72.9	72.9	23.2	Endangered	Not Listed	2	False	848
1395_Thinned	63.9	63.9	66.1	Endangered	Not Listed	2	False	2113
830_Intact	48.3	48.3	0.04	Endangered	Not Listed	2	False	1
							Subtotal	**4472**
Myotis macropus / Southern Myotis (Fauna)								
835_Intact	76.6	76.6	1.1	Vulnerable	Not Listed	2	False	41
835_Thinned	57.1	57.1	4.4	Vulnerable	Not Listed	2	False	127
849_Intact	53.9	53.9	7.9	Vulnerable	Not Listed	2	False	214
849_Thinned	42.3	42.3	22.3	Vulnerable	Not Listed	2	False	471
849_Scattered_trees	18.3	18.3	16.4	Vulnerable	Not Listed	2	False	150

850_Intact	58.1	58.1	1.4	Vulnerable	Not Listed	2	False	42
850_Thinned	41.9	41.9	15.5	Vulnerable	Not Listed	2	False	324
850_Scattered_trees	38.1	38.1	4.5	Vulnerable	Not Listed	2	False	85
1395_Intact	72.9	72.9	12.4	Vulnerable	Not Listed	2	False	452
1395_Thinned	63.9	63.9	35.6	Vulnerable	Not Listed	2	False	1139
1395_Scattered_trees	30.0	30.0	12.7	Vulnerable	Not Listed	2	False	191
							Subtotal	**3236**
Ninox connivens / Barking Owl (Fauna)								
1395_Intact	72.9	72.9	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**
Ninox strenua / Powerful Owl (Fauna)								
850_Intact	58.1	58.1	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**
Persoonia bargoensis / Bargo Geebung (Flora)								
849_Intact	53.9	53.9	3.4	Endangered	Vulnerable	2	False	92
849_Thinned	42.3	42.3	5.2	Endangered	Vulnerable	2	False	109
1395_Intact	72.9	72.9	15.6	Endangered	Vulnerable	2	False	569
1395_Thinned	63.9	63.9	22.2	Endangered	Vulnerable	2	False	708
							Subtotal	**1478**
Petaurus norfolcensis / Squirrel Glider (Fauna)								
830_Thinned	20.1	20.1	0.01	Vulnerable	Not Listed	2	False	1
835_Intact	76.6	76.6	1.3	Vulnerable	Not Listed	2	False	49
835_Thinned	57.1	57.1	0.05	Vulnerable	Not Listed	2	False	1

849_Intact	53.9	53.9	1.1	Vulnerable	Not Listed	2	False	30
849_Thinned	42.3	42.3	11	Vulnerable	Not Listed	2	False	232
849_Scattered_trees	18.3	18.3	4	Vulnerable	Not Listed	2	False	37
850_Intact	58.1	58.1	2.3	Vulnerable	Not Listed	2	False	66
850_Thinned	41.9	41.9	7.5	Vulnerable	Not Listed	2	False	158
850_Scattered_trees	38.1	38.1	1.3	Vulnerable	Not Listed	2	False	25
1395_Intact	72.9	72.9	24.7	Vulnerable	Not Listed	2	False	900
1395_Thinned	63.9	63.9	41.9	Vulnerable	Not Listed	2	False	1340
1395_Scattered_trees	30.0	30.0	11.3	Vulnerable	Not Listed	2	False	170
830_Intact	48.3	48.3	0.04	Vulnerable	Not Listed	2	False	1
							Subtotal	**3010**
Phascolarctos cinereus / Koala (Fauna)								
835_Intact	76.6	76.6	1.1	Vulnerable	Vulnerable	2	False	41
849_Intact	53.9	53.9	9.9	Vulnerable	Vulnerable	2	False	267
849_Thinned	42.3	42.3	12.3	Vulnerable	Vulnerable	2	False	259
849_Scattered_trees	18.3	18.3	0.25	Vulnerable	Vulnerable	2	False	2
850_Intact	58.1	58.1	1.2	Vulnerable	Vulnerable	2	False	35
850_Thinned	41.9	41.9	8	Vulnerable	Vulnerable	2	False	168
1395_Intact	72.9	72.9	34.6	Vulnerable	Vulnerable	2	False	1260
1395_Thinned	63.9	63.9	63.2	Vulnerable	Vulnerable	2	False	2019

1395_Scattered_trees	30.0	30.0	4.7	Vulnerable	Vulnerable	2	False	70
830_Intact	48.3	48.3	0.04	Vulnerable	Vulnerable	2	False	1
							Subtotal	**4122**
Pimelea spicata / Spiked Rice-flower (Flora)								
835_Intact	76.6	76.6	0.85	Endangered	Endangered	2	False	33
849_Intact	53.9	53.9	2.9	Endangered	Endangered	2	False	78
849_Thinned	42.3	42.3	5.8	Endangered	Endangered	2	False	122
849_Scattered_trees	18.3	18.3	1.7	Endangered	Endangered	2	False	16
849_DNG	24.1	24.1	1.2	Endangered	Endangered	2	False	14
850_Intact	58.1	58.1	3.3	Endangered	Endangered	2	False	95
850_Thinned	41.9	41.9	4.3	Endangered	Endangered	2	False	89
850_Scattered_trees	38.1	38.1	2.8	Endangered	Endangered	2	False	53
850_DNG	25.7	25.7	0.58	Endangered	Endangered	2	False	7
1395_Intact	72.9	72.9	3.5	Endangered	Endangered	2	False	126
1395_Thinned	63.9	63.9	3.8	Endangered	Endangered	2	False	122
1395_Scattered_trees	30.0	30.0	0.72	Endangered	Endangered	2	False	11
849_NO_grassland	10.1	10.1	5.5	Endangered	Endangered	2	False	28
850_NO_grassland	12.3	12.3	21.1	Endangered	Endangered	2	False	130
1395_NO_grassland	5.4	5.4	3	Endangered	Endangered	2	False	8
							Subtotal	**932**

Pomaderris brunnea / Brown Pomaderris (Flora)								
835_Intact	76.6	76.6	1.3	Endangered	Vulnerable	2	False	49
835_Thinned	57.1	57.1	0.72	Endangered	Vulnerable	2	False	21
1395_Intact	72.9	72.9	5	Endangered	Vulnerable	2	False	182
1395_Thinned	63.9	63.9	15	Endangered	Vulnerable	2	False	480
							Subtotal	**732**
Pseudophryne australis / Red-crowned Toadlet (Fauna)								
1395_Intact	72.9	72.9	7	Vulnerable	Not Listed	1.5	False	192
							Subtotal	**192**
Pterostylis saxicola / Sydney Plains Greenhood (Flora)								
849_Intact	53.9	53.9	8	Endangered	Endangered	2	False	216
1395_Intact	72.9	72.9	27	Endangered	Endangered	2	False	986
							Subtotal	**1202**
Pultenaea pedunculata / Matted Bush-pea (Flora)								
849_Thinned	42.3	42.3	2	Endangered	Not Listed	2	False	43
849_Scattered_trees	18.3	18.3	2.7	Endangered	Not Listed	2	False	24
850_Thinned	41.9	41.9	0.62	Endangered	Not Listed	2	False	13
850_Scattered_trees	38.1	38.1	0.59	Endangered	Not Listed	2	False	11
1395_Intact	72.9	72.9	3.4	Endangered	Not Listed	2	False	124
1395_Thinned	63.9	63.9	14.5	Endangered	Not Listed	2	False	463
1395_Scattered_trees	30.0	30.0	2.5	Endangered	Not Listed	2	False	37
							Subtotal	**715**

Tyto novaehollandiae / Masked Owl (Fauna)								
850_Intact	58.1	58.1	0.06	Vulnerable	Not Listed	2	False	2
1395_Thinned	63.9	63.9	0.05	Vulnerable	Not Listed	2	False	2
							Subtotal	**4**

Biodiversity credit report – GPEC

BAM Credit Summary Report

Proposal Details

Assessment Id	Proposal Name	BAM data last updated *
00013050/BAAS18134/18/00013054	Western Sydney Strategic Biodiversity Certification - Greater Penrith to Eastern Creek Urban Release Investigation Area	10/06/2021
Assessor Name	**Report Created**	**BAM Data version ***
Jane Raithby-Veall	03/11/2021	45
Assessor Number	**BAM Case Status**	**Date Finalised**
BAAS18134	Finalised	03/11/2021
Assessment Revision	**Assessment Type**	
4	Biocertification	

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits

Castlereagh Ironbark forest										
4	725_Intact	Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	49.2	49.2	15.2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00	TRUE	373
5	725_Thinned	Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	43.3	43.3	10.1	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00	TRUE	218
										Subtotal	**591**
Castlereagh shale - gravel transition forest											
1	724_Intact	Shale Gravel Transition Forest in the Sydney Basin Bioregion	61.7	61.7	7.2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		223
2	724_Thinned	Shale Gravel Transition Forest in the Sydney Basin Bioregion	36.3	36.3	30.9	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		561
3	724_Scattered_trees	Shale Gravel Transition Forest in the Sydney Basin Bioregion	20.5	20.5	23.8	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		244
										Subtotal	**1028**

Coastal freshwater wetland											
6	781_Thinned	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	62.5	62.5	2.2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		70
										Subtotal	**70**
Cumberland riverflat forest											
7	835_Intact	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	76.6	76.6	12	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		461

8	835_Thinned	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	57.1	57.1	113	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		3228
9	835_Scattered_trees	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	68.7	68.7	2.7	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		92
18	835_NO_grassland	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	8	8.0	462.6	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		0
										Subtotal	**3781**

Cumberland shale hills woodland											
14	850_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	41.9	41.9	16.1	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	421
15	850_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	38.1	38.1	2.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	51
16	850_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	25.7	25.7	23	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	369
20	850_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	12.3	12.3	228.4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**841**
Cumberland shale plains woodland											
10	849_Intact	Cumberland Plain Woodland in the Sydney Basin Bioregion	53.9	53.9	4.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	143
11	849_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	42.3	42.3	83.4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	2204

12	849_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	18.3	18.3	4.1	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	46
13	849_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	24.1	24.1	8.9	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	133
19	849_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	10.1	10.1	757.9	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**2526**
Cumberland Swamp Oak riparian forest											
17	1800_Thinned	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	46.6	46.6	9	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		209
										Subtotal	**209**
										Total	**9046**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits

Acacia bynoeana / Bynoe's Wattle (Flora)								
725_Intact	49.2	49.2	15.2	Endangered	Vulnerable	2	False	373
725_Thinned	43.3	43.3	7.6	Endangered	Vulnerable	2	False	165
							Subtotal	**538**
Acacia pubescens / Downy Wattle (Flora)								
724_Intact	61.7	61.7	7.2	Vulnerable	Vulnerable	2	False	223
724_Thinned	36.3	36.3	29.6	Vulnerable	Vulnerable	2	False	536
724_Scattered_trees	20.5	20.5	23.7	Vulnerable	Vulnerable	2	False	243
725_Intact	49.2	49.2	15.2	Vulnerable	Vulnerable	2	False	373
725_Thinned	43.3	43.3	8.3	Vulnerable	Vulnerable	2	False	179
835_Intact	76.6	76.6	9.7	Vulnerable	Vulnerable	2	False	372
835_Thinned	57.1	57.1	77.8	Vulnerable	Vulnerable	2	False	2222
835_Scattered_trees	68.7	68.7	2.6	Vulnerable	Vulnerable	2	False	90
849_Intact	53.9	53.9	4.2	Vulnerable	Vulnerable	2	False	115
849_Thinned	42.3	42.3	80.3	Vulnerable	Vulnerable	2	False	1698
849_Scattered_trees	18.3	18.3	4	Vulnerable	Vulnerable	2	False	36
849_DNG	24.1	24.1	8	Vulnerable	Vulnerable	2	False	96
							Subtotal	**6183**
Allocasuarina glareicola / Allocasuarina glareicola (Flora)								
724_Intact	61.7	61.7	0.14	Endangered	Endangered	3	True	6
724_Thinned	36.3	36.3	14.7	Endangered	Endangered	3	True	400
725_Thinned	43.3	43.3	2.6	Endangered	Endangered	3	True	83

							Subtotal	**489**
Callocephalon fimbriatum / Gang-gang Cockatoo (Fauna)								
724_Intact	61.7	61.7	0.01	Vulnerable	Not Listed	2	False	1
725_Intact	49.2	49.2	0.02	Vulnerable	Not Listed	2	False	1
835_Intact	76.6	76.6	0.01	Vulnerable	Not Listed	2	False	1
							Subtotal	**3**
Cercartetus nanus / Eastern Pygmy-possum (Fauna)								
835_Intact	76.6	76.6	9.8	Vulnerable	Not Listed	2	False	374
849_Intact	53.9	53.9	4	Vulnerable	Not Listed	2	False	108
							Subtotal	**482**
Chalinolobus dwyeri / Large-eared Pied Bat (Fauna)								
849_Thinned	42.3	42.3	0.93	Vulnerable	Vulnerable	3	True	29
							Subtotal	**29**
Dillwynia tenuifolia / Dillwynia tenuifolia (Flora)								
724_Intact	61.7	61.7	5	Vulnerable	Not Listed	2	False	154
724_Scattered_trees	20.5	20.5	22.8	Vulnerable	Not Listed	2	False	234
724_Thinned	36.3	36.3	22.6	Vulnerable	Not Listed	2	False	410
725_Intact	49.2	49.2	15.1	Vulnerable	Not Listed	2	False	371
725_Thinned	43.3	43.3	6.2	Vulnerable	Not Listed	2	False	134
849_DNG	24.1	24.1	0.56	Vulnerable	Not Listed	2	False	7
849_Scattered_trees	18.3	18.3	0.59	Vulnerable	Not Listed	2	False	5
849_Thinned	42.3	42.3	24.7	Vulnerable	Not Listed	2	False	522
849_NO_grassland	10.1	10.1	1.4	Vulnerable	Not Listed	2	False	7

							Subtotal	**1844**
Grevillea juniperina subsp. juniperina / Juniper-leaved Grevillea (Flora)								
724_Intact	61.7	61.7	7.2	Vulnerable	Not Listed	1.5	False	166
724_Thinned	36.3	36.3	26.2	Vulnerable	Not Listed	1.5	False	357
724_Scattered_trees	20.5	20.5	23.5	Vulnerable	Not Listed	1.5	False	181
725_Intact	49.2	49.2	15.2	Vulnerable	Not Listed	1.5	False	280
725_Thinned	43.3	43.3	6.2	Vulnerable	Not Listed	1.5	False	100
835_Intact	76.6	76.6	5.9	Vulnerable	Not Listed	1.5	False	168
835_Thinned	57.1	57.1	13.1	Vulnerable	Not Listed	1.5	False	280
835_Scattered_trees	68.7	68.7	0.93	Vulnerable	Not Listed	1.5	False	24
849_Intact	53.9	53.9	4.2	Vulnerable	Not Listed	1.5	False	85
849_Thinned	42.3	42.3	66.8	Vulnerable	Not Listed	1.5	False	1060
849_Scattered_trees	18.3	18.3	3.1	Vulnerable	Not Listed	1.5	False	22
849_DNG	24.1	24.1	6.5	Vulnerable	Not Listed	1.5	False	59
835_NO_grassland	8.0	8.0	0.5	Vulnerable	Not Listed	1.5	False	1
849_NO_grassland	10.1	10.1	2.1	Vulnerable	Not Listed	1.5	False	8
							Subtotal	**2791**
Grevillea parviflora subsp. parviflora / Small-flower Grevillea (Flora)								
724_Intact	61.7	61.7	0.02	Vulnerable	Vulnerable	2	False	1
724_Thinned	36.3	36.3	3.9	Vulnerable	Vulnerable	2	False	71
725_Thinned	43.3	43.3	0.08	Vulnerable	Vulnerable	2	False	2
							Subtotal	**74**

Haliaeetus leucogaster / White-bellied Sea-Eagle (Fauna)								
724_Intact	61.7	61.7	0.08	Vulnerable	Not Listed	2	False	2
835_Intact	76.6	76.6	5.8	Vulnerable	Not Listed	2	False	221
849_Intact	53.9	53.9	0.01	Vulnerable	Not Listed	2	False	1
							Subtotal	**224**
Heleioporus australiacus / Giant Burrowing Frog (Fauna)								
725_Intact	49.2	49.2	0	Vulnerable	Vulnerable	1.5	False	0
							Subtotal	**0**
Hibbertia fumana / Hibbertia fumana (Flora)								
724_Intact	61.7	61.7	4	Critically Endangered	Not Listed	3	True	185
724_Thinned	36.3	36.3	6.2	Critically Endangered	Not Listed	3	True	167
725_Intact	49.2	49.2	14.1	Critically Endangered	Not Listed	3	True	520
725_Thinned	43.3	43.3	3.4	Critically Endangered	Not Listed	3	True	112
849_NO_grassland	10.1	10.1	3.8	Critically Endangered	Not Listed	3	True	28
							Subtotal	**1012**
Hibbertia puberula / Hibbertia puberula (Flora)								
724_Intact	61.7	61.7	4	Endangered	Not Listed	2	False	123
724_Thinned	36.3	36.3	8.7	Endangered	Not Listed	2	False	158
725_Intact	49.2	49.2	14.1	Endangered	Not Listed	2	False	347
725_Thinned	43.3	43.3	3.5	Endangered	Not Listed	2	False	76

849_Thinned	42.3	42.3	0.59	Endangered	Not Listed	2	False	12
849_NO_grassland	10.1	10.1	5.3	Endangered	Not Listed	2	False	27
							Subtotal	**743**
Hieraaetus morphnoides / Little Eagle (Fauna)								
724_Intact	61.7	61.7	0.01	Vulnerable	Not Listed	1.5	False	1
724_Thinned	36.3	36.3	0.03	Vulnerable	Not Listed	1.5	False	1
835_Intact	76.6	76.6	0.12	Vulnerable	Not Listed	1.5	False	3
835_Thinned	57.1	57.1	2.7	Vulnerable	Not Listed	1.5	False	58
849_Thinned	42.3	42.3	0.05	Vulnerable	Not Listed	1.5	False	1
850_Thinned	41.9	41.9	0.15	Vulnerable	Not Listed	1.5	False	2
1800_Thinned	46.6	46.6	0.1	Vulnerable	Not Listed	1.5	False	2
							Subtotal	**68**
Lathamus discolor / Swift Parrot (Fauna)								
781_Thinned	62.5	62.5	0.84	Endangered	Critically Endangered	3	True	39
835_Thinned	57.1	57.1	1.3	Endangered	Critically Endangered	3	True	55
835_Scattered_trees	68.7	68.7	0.01	Endangered	Critically Endangered	3	True	1
849_Thinned	42.3	42.3	4.5	Endangered	Critically Endangered	3	True	142
849_Scattered_trees	18.3	18.3	0.01	Endangered	Critically Endangered	3	True	1
850_Thinned	41.9	41.9	4.6	Endangered	Critically Endangered	3	True	144

850_Scattered_trees	38.1	38.1	0.08	Endangered	Critically Endangered	3	True	2
850_DNG	25.7	25.7	3.2	Endangered	Critically Endangered	3	True	61
1800_Thinned	46.6	46.6	0.06	Endangered	Critically Endangered	3	True	2
835_NO_grassland	8.0	8.0	4.1	Endangered	Critically Endangered	3	True	25
849_NO_grassland	10.1	10.1	3.4	Endangered	Critically Endangered	3	True	26
850_NO_grassland	12.3	12.3	3.9	Endangered	Critically Endangered	3	True	36
							Subtotal	**534**
Litoria aurea / Green and Golden Bell Frog (Fauna)								
724_Intact	61.7	61.7	0.08	Endangered	Vulnerable	2	False	2
724_Thinned	36.3	36.3	0.09	Endangered	Vulnerable	2	False	2
835_Intact	76.6	76.6	0.94	Endangered	Vulnerable	2	False	36
835_Thinned	57.1	57.1	0.14	Endangered	Vulnerable	2	False	4
849_Intact	53.9	53.9	0.8	Endangered	Vulnerable	2	False	22
849_Thinned	42.3	42.3	0.6	Endangered	Vulnerable	2	False	13
835_NO_grassland	8.0	8.0	5	Endangered	Vulnerable	2	False	20
849_NO_grassland	10.1	10.1	0.01	Endangered	Vulnerable	2	False	1
							Subtotal	**100**
Lophoictinia isura / Square-tailed Kite (Fauna)								
724_Intact	61.7	61.7	1.2	Vulnerable	Not Listed	1.5	False	28
725_Intact	49.2	49.2	3.1	Vulnerable	Not Listed	1.5	False	58

835_Intact	76.6	76.6	5.8	Vulnerable	Not Listed	1.5	False	166
835_Thinned	57.1	57.1	1.1	Vulnerable	Not Listed	1.5	False	24
849_Intact	53.9	53.9	1.9	Vulnerable	Not Listed	1.5	False	39
849_Thinned	42.3	42.3	0.01	Vulnerable	Not Listed	1.5	False	1
							Subtotal	**316**
Marsdenia viridiflora subsp. viridiflora - endangered population / Marsdenia viridiflora R. Br. subsp. viridiflora population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas (Flora)								
724_Intact	61.7	61.7	0.15	Endangered Population	Not Listed	2	False	5
724_Thinned	36.3	36.3	14.8	Endangered Population	Not Listed	2	False	268
725_Thinned	43.3	43.3	2.6	Endangered Population	Not Listed	2	False	56
835_Intact	76.6	76.6	6.9	Endangered Population	Not Listed	2	False	264
835_Thinned	57.1	57.1	56.3	Endangered Population	Not Listed	2	False	1608
849_Intact	53.9	53.9	0.01	Endangered Population	Not Listed	2	False	1
849_Thinned	42.3	42.3	63.9	Endangered Population	Not Listed	2	False	1352
850_Thinned	41.9	41.9	14	Endangered Population	Not Listed	2	False	293
1800_Thinned	46.6	46.6	8.6	Endangered Population	Not Listed	2	False	199
							Subtotal	**4046**

Maundia triglochinoides / Maundia triglochinoides (Flora)								
781_Thinned	62.5	62.5	1.2	Vulnerable	Not Listed	2	False	36
1800_Thinned	46.6	46.6	8.2	Vulnerable	Not Listed	2	False	191
							Subtotal	**227**
Meridolum corneovirens / Cumberland Plain Land Snail (Fauna)								
724_Intact	61.7	61.7	7	Endangered	Not Listed	2	False	216
724_Thinned	36.3	36.3	23.8	Endangered	Not Listed	2	False	433
725_Intact	49.2	49.2	14.7	Endangered	Not Listed	2	False	361
725_Thinned	43.3	43.3	6	Endangered	Not Listed	2	False	130
835_Intact	76.6	76.6	11.8	Endangered	Not Listed	2	False	451
835_Thinned	57.1	57.1	83.4	Endangered	Not Listed	2	False	2381
849_Intact	53.9	53.9	3.7	Endangered	Not Listed	2	False	100
849_Thinned	42.3	42.3	73.8	Endangered	Not Listed	2	False	1560
850_Thinned	41.9	41.9	14.6	Endangered	Not Listed	2	False	307
							Subtotal	**5939**
Micromyrtus minutiflora / Micromyrtus minutiflora (Flora)								
724_Intact	61.7	61.7	0.15	Endangered	Vulnerable	3	True	7
724_Thinned	36.3	36.3	12.4	Endangered	Vulnerable	3	True	337
725_Thinned	43.3	43.3	2.6	Endangered	Vulnerable	3	True	83
							Subtotal	**427**
Myotis macropus / Southern Myotis (Fauna)								
724_Intact	61.7	61.7	0.07	Vulnerable	Not Listed	2	False	2
724_Thinned	36.3	36.3	11.5	Vulnerable	Not Listed	2	False	208

724_Scattered_trees	20.5	20.5	14.9	Vulnerable	Not Listed	2	False	153
725_Intact	49.2	49.2	1.7	Vulnerable	Not Listed	2	False	41
725_Thinned	43.3	43.3	3.6	Vulnerable	Not Listed	2	False	77
781_Thinned	62.5	62.5	0.24	Vulnerable	Not Listed	2	False	8
835_Intact	76.6	76.6	6.1	Vulnerable	Not Listed	2	False	232
835_Thinned	57.1	57.1	97.6	Vulnerable	Not Listed	2	False	2788
835_Scattered_trees	68.7	68.7	2.1	Vulnerable	Not Listed	2	False	73
849_Intact	53.9	53.9	0.05	Vulnerable	Not Listed	2	False	1
849_Thinned	42.3	42.3	53.4	Vulnerable	Not Listed	2	False	1130
849_Scattered_trees	18.3	18.3	2.5	Vulnerable	Not Listed	2	False	23
850_Thinned	41.9	41.9	12.6	Vulnerable	Not Listed	2	False	265
850_Scattered_trees	38.1	38.1	2.1	Vulnerable	Not Listed	2	False	39
1800_Thinned	46.6	46.6	8.8	Vulnerable	Not Listed	2	False	206
							Subtotal	**5246**
Ninox connivens / Barking Owl (Fauna)								
835_Intact	76.6	76.6	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**
Ninox strenua / Powerful Owl (Fauna)								
835_Intact	76.6	76.6	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**

Persicaria elatior / Tall Knotweed (Flora)								
835_Thinned	57.1	57.1	40.2	Vulnerable	Vulnerable	2	False	1150
835_Scattered_trees	68.7	68.7	0.95	Vulnerable	Vulnerable	2	False	33
1800_Thinned	46.6	46.6	6.3	Vulnerable	Vulnerable	2	False	147
							Subtotal	**1330**
Persoonia nutans / Nodding Geebung (Flora)								
724_Intact	61.7	61.7	7.2	Endangered	Endangered	2	False	223
724_Thinned	36.3	36.3	29.5	Endangered	Endangered	2	False	535
724_Scattered_trees	20.5	20.5	23.8	Endangered	Endangered	2	False	244
725_Intact	49.2	49.2	15.2	Endangered	Endangered	2	False	373
725_Thinned	43.3	43.3	7.7	Endangered	Endangered	2	False	166
							Subtotal	**1541**
Petaurus norfolcensis / Squirrel Glider (Fauna)								
724_Intact	61.7	61.7	0.15	Vulnerable	Not Listed	2	False	5
724_Thinned	36.3	36.3	5.8	Vulnerable	Not Listed	2	False	105
724_Scattered_trees	20.5	20.5	22.6	Vulnerable	Not Listed	2	False	232
725_Thinned	43.3	43.3	1.4	Vulnerable	Not Listed	2	False	30
835_Intact	76.6	76.6	6.9	Vulnerable	Not Listed	2	False	265
835_Thinned	57.1	57.1	56.4	Vulnerable	Not Listed	2	False	1612
835_Scattered_trees	68.7	68.7	1.3	Vulnerable	Not Listed	2	False	45
849_Intact	53.9	53.9	0.01	Vulnerable	Not Listed	2	False	1

849_Thinned	42.3	42.3	36.5	Vulnerable	Not Listed	2	False	773
849_Scattered_trees	18.3	18.3	0.87	Vulnerable	Not Listed	2	False	8
850_Thinned	41.9	41.9	3.3	Vulnerable	Not Listed	2	False	70
1800_Thinned	46.6	46.6	1.5	Vulnerable	Not Listed	2	False	34
							Subtotal	**3180**
Pimelea curviflora var. curviflora / Pimelea curviflora var. curviflora (Flora)								
724_Intact	61.7	61.7	6.9	Vulnerable	Vulnerable	2	False	212
724_Thinned	36.3	36.3	17.7	Vulnerable	Vulnerable	2	False	322
849_Intact	53.9	53.9	3.3	Vulnerable	Vulnerable	2	False	89
849_Thinned	42.3	42.3	24.6	Vulnerable	Vulnerable	2	False	519
							Subtotal	**1142**
Pimelea spicata / Spiked Rice-flower (Flora)								
849_Intact	53.9	53.9	4.2	Endangered	Endangered	2	False	114
849_Thinned	42.3	42.3	27.8	Endangered	Endangered	2	False	588
849_Scattered_trees	18.3	18.3	0.15	Endangered	Endangered	2	False	1
849_DNG	24.1	24.1	3.3	Endangered	Endangered	2	False	39
850_Thinned	41.9	41.9	3.2	Endangered	Endangered	2	False	68
850_DNG	25.7	25.7	0.67	Endangered	Endangered	2	False	9
724_Intact	61.7	61.7	2.6	Endangered	Endangered	2	False	80
724_Thinned	36.3	36.3	9.7	Endangered	Endangered	2	False	176
724_Scattered_trees	20.5	20.5	19.7	Endangered	Endangered	2	False	202
725_Thinned	43.3	43.3	0.03	Endangered	Endangered	2	False	1

835_Intact	76.6	76.6	0.86	Endangered	Endangered	2	False	33
835_Thinned	57.1	57.1	5.2	Endangered	Endangered	2	False	148
1800_Thinned	46.6	46.6	0.02	Endangered	Endangered	2	False	1
835_NO_grassland	8.0	8.0	1.1	Endangered	Endangered	2	False	5
849_NO_grassland	10.1	10.1	29	Endangered	Endangered	2	False	146
850_NO_grassland	12.3	12.3	6.6	Endangered	Endangered	2	False	40
							Subtotal	**1651**
Pseudophryne australis / Red-crowned Toadlet (Fauna)								
724_Intact	61.7	61.7	0	Vulnerable	Not Listed	1.5	False	0
							Subtotal	**0**
Pterostylis saxicola / Sydney Plains Greenhood (Flora)								
849_Thinned	42.3	42.3	0.93	Endangered	Endangered	2	False	20
							Subtotal	**20**
Pultenaea parviflora / Pultenaea parviflora (Flora)								
724_Intact	61.7	61.7	7.2	Endangered	Vulnerable	2	False	222
724_Thinned	36.3	36.3	26.4	Endangered	Vulnerable	2	False	480
725_Intact	49.2	49.2	15	Endangered	Vulnerable	2	False	370
725_Thinned	43.3	43.3	5.9	Endangered	Vulnerable	2	False	127
849_Intact	53.9	53.9	0.5	Endangered	Vulnerable	2	False	13
849_Thinned	42.3	42.3	1.8	Endangered	Vulnerable	2	False	38
							Subtotal	**1250**
Pultenaea pedunculata / Matted Bush-pea (Flora)								
724_Intact	61.7	61.7	0.2	Endangered	Not Listed	2	False	6
724_Thinned	36.3	36.3	14.7	Endangered	Not Listed	2	False	267

724_Scattered_trees	20.5	20.5	20.1	Endangered	Not Listed	2	False	206
725_Thinned	43.3	43.3	3.9	Endangered	Not Listed	2	False	85
849_Intact	53.9	53.9	0.01	Endangered	Not Listed	2	False	1
849_Thinned	42.3	42.3	29.8	Endangered	Not Listed	2	False	630
849_Scattered_trees	18.3	18.3	2.4	Endangered	Not Listed	2	False	22
							Subtotal	**1217**
Tyto novaehollandiae / Masked Owl (Fauna)								
835_Thinned	57.1	57.1	0.52	Vulnerable	Not Listed	2	False	15
							Subtotal	**15**

Biodiversity credit report – Wilton

BAM Credit Summary Report

Proposal Details

Assessment Id

00013050/BAAS18134/18/00013051

Proposal Name

Western Sydney Strategic Biodiversity Certification - Wilton Growth Area

BAM data last updated *

10/06/2021

Assessor Name

Jane Raithby-Veall

Report Created

03/11/2021

BAM Data version *

45

Assessor Number

BAAS18134

BAM Case Status

Finalised

Date Finalised

03/11/2021

Assessment Revision

4

Assessment Type

Biocertification

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits
Cumberland shale - sandstone Ironbark forest											
7	1395_Intact	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	72.9	72.9	11	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	499

8	1395_Thinned	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	63.9	63.9	70.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	2830
9	1395_Scattered_trees	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	30	30.0	17.9	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	336
10	1395_DNG	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	28.4	28.4	171.2	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	3033
13	1395_NO_grassland	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	5.4	5.4	322.3	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**6698**
Cumberland shale hills woodland											
5	850_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	38.1	38.1	0.91	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	22
6	850_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	25.7	25.7	159.6	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	2559

12	850_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	12.3	12.3	12.3	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**2581**
Cumberland shale plains woodland											
1	849_Intact	Cumberland Plain Woodland in the Sydney Basin Bioregion	53.9	53.9	1.6	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	53
2	849_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	42.3	42.3	23.4	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	617
3	849_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	18.3	18.3	23.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	271
4	849_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	24.1	24.1	148.7	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	2237

11	849_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	10.1	10.1	676.5	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**3178**
										Total	**12457**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits
Acacia bynoeana / Bynoe's Wattle (Flora)								
1395_Intact	72.9	72.9	8.4	Endangered	Vulnerable	2	False	306
1395_Thinned	63.9	63.9	61.2	Endangered	Vulnerable	2	False	1955
1395_Scattered_trees	30.0	30.0	15.4	Endangered	Vulnerable	2	False	231
1395_DNG	28.4	28.4	155.4	Endangered	Vulnerable	2	False	2203
							Subtotal	**4695**
Acacia pubescens / Downy Wattle (Flora)								
849_Intact	53.9	53.9	1.2	Vulnerable	Vulnerable	2	False	32
849_Thinned	42.3	42.3	18.8	Vulnerable	Vulnerable	2	False	397
849_Scattered_trees	18.3	18.3	20.3	Vulnerable	Vulnerable	2	False	185
849_DNG	24.1	24.1	129	Vulnerable	Vulnerable	2	False	1553
1395_Intact	72.9	72.9	9.8	Vulnerable	Vulnerable	2	False	356
1395_Thinned	63.9	63.9	67.5	Vulnerable	Vulnerable	2	False	2158

1395_Scattered_trees	30.0	30.0	16.9	Vulnerable	Vulnerable	2	False	253
1395_DNG	28.4	28.4	164.6	Vulnerable	Vulnerable	2	False	2333
849_NO_grassland	10.1	10.1	0.18	Vulnerable	Vulnerable	2	False	1
							Subtotal	**7268**
Callocephalon fimbriatum / Gang-gang Cockatoo (Fauna)								
849_Intact	53.9	53.9	0.04	Vulnerable	Not Listed	2	False	1
1395_Intact	72.9	72.9	0.52	Vulnerable	Not Listed	2	False	19
							Subtotal	**20**
Calyptorhynchus lathami / Glossy Black-Cockatoo (Fauna)								
1395_Intact	72.9	72.9	1.4	Vulnerable	Not Listed	2	False	51
							Subtotal	**51**
Cercartetus nanus / Eastern Pygmy-possum (Fauna)								
849_Intact	53.9	53.9	1.3	Vulnerable	Not Listed	2	False	35
1395_Intact	72.9	72.9	5.7	Vulnerable	Not Listed	2	False	206
							Subtotal	**241**
Chalinolobus dwyeri / Large-eared Pied Bat (Fauna)								
849_Intact	53.9	53.9	1.6	Vulnerable	Vulnerable	3	True	63
849_Thinned	42.3	42.3	23.4	Vulnerable	Vulnerable	3	True	741
1395_Intact	72.9	72.9	11	Vulnerable	Vulnerable	3	True	599
1395_Thinned	63.9	63.9	70.8	Vulnerable	Vulnerable	3	True	3396
							Subtotal	**4799**
Epacris purpurascens var. purpurascens / Epacris purpurascens var. purpurascens (Flora)								
1395_Intact	N/A	N/A	33	Vulnerable	Not Listed	1.5	False	50

1395_Thinned	N/A	N/A	282	Vulnerable	Not Listed	1.5	False	423
							Subtotal	**473**
Grevillea parviflora subsp. parviflora / Small-flower Grevillea (Flora)								
1395_Intact	72.9	72.9	0.49	Vulnerable	Vulnerable	2	False	18
1395_Thinned	63.9	63.9	2.1	Vulnerable	Vulnerable	2	False	66
							Subtotal	**84**
Haliaeetus leucogaster / White-bellied Sea-Eagle (Fauna)								
1395_Intact	72.9	72.9	2.5	Vulnerable	Not Listed	2	False	90
							Subtotal	**90**
Heleioporus australiacus / Giant Burrowing Frog (Fauna)								
1395_Intact	72.9	72.9	0.33	Vulnerable	Vulnerable	1.5	False	9
							Subtotal	**9**
Hibbertia fumana / Hibbertia fumana (Flora)								
849_Intact	53.9	53.9	0.23	Critically Endangered	Not Listed	3	True	9
849_Thinned	42.3	42.3	1.1	Critically Endangered	Not Listed	3	True	35
849_Scattered_trees	18.3	18.3	0.02	Critically Endangered	Not Listed	3	True	1
849_DNG	24.1	24.1	0.12	Critically Endangered	Not Listed	3	True	2
1395_Intact	72.9	72.9	3.8	Critically Endangered	Not Listed	3	True	206
1395_Thinned	63.9	63.9	14.7	Critically Endangered	Not Listed	3	True	704

1395_Scattered_trees	30.0	30.0	0.43	Critically Endangered	Not Listed	3	True	10
1395_DNG	28.4	28.4	4.7	Critically Endangered	Not Listed	3	True	100
849_NO_grassland	10.1	10.1	0.86	Critically Endangered	Not Listed	3	True	7
1395_NO_grassland	5.4	5.4	2.4	Critically Endangered	Not Listed	3	True	10
							Subtotal	**1084**
Hibbertia puberula / Hibbertia puberula (Flora)								
849_Intact	53.9	53.9	0.18	Endangered	Not Listed	2	False	5
849_Thinned	42.3	42.3	1.1	Endangered	Not Listed	2	False	23
849_Scattered_trees	18.3	18.3	0.02	Endangered	Not Listed	2	False	1
849_DNG	24.1	24.1	0.12	Endangered	Not Listed	2	False	1
1395_Intact	72.9	72.9	3.3	Endangered	Not Listed	2	False	120
1395_Thinned	63.9	63.9	14.7	Endangered	Not Listed	2	False	469
1395_Scattered_trees	30.0	30.0	0.43	Endangered	Not Listed	2	False	6
1395_DNG	28.4	28.4	4.7	Endangered	Not Listed	2	False	66
849_NO_grassland	10.1	10.1	0.82	Endangered	Not Listed	2	False	4
1395_NO_grassland	5.4	5.4	2.3	Endangered	Not Listed	2	False	6
							Subtotal	**701**
Hieraaetus morphnoides / Little Eagle (Fauna)								
1395_Intact	72.9	72.9	0.48	Vulnerable	Not Listed	1.5	False	13

1395_Thinned	63.9	63.9	4.2	Vulnerable	Not Listed	1.5	False	99
1395_Scattered_trees	30.0	30.0	0.15	Vulnerable	Not Listed	1.5	False	2
							Subtotal	**114**
Lophoictinia isura / Square-tailed Kite (Fauna)								
1395_Intact	72.9	72.9	0.55	Vulnerable	Not Listed	1.5	False	15
1395_Thinned	63.9	63.9	4.2	Vulnerable	Not Listed	1.5	False	101
1395_Scattered_trees	30.0	30.0	0.21	Vulnerable	Not Listed	1.5	False	2
							Subtotal	**118**
Melaleuca deanei / Deane's Paperbark (Flora)								
1395_Intact	72.9	72.9	3.5	Vulnerable	Vulnerable	3	True	194
1395_Thinned	63.9	63.9	31.5	Vulnerable	Vulnerable	3	True	1508
1395_Scattered_trees	30.0	30.0	10.4	Vulnerable	Vulnerable	3	True	234
							Subtotal	**1936**
Meridolum corneovirens / Cumberland Plain Land Snail (Fauna)								
849_Intact	53.9	53.9	1.2	Endangered	Not Listed	2	False	33
849_Thinned	42.3	42.3	14.7	Endangered	Not Listed	2	False	311
1395_Intact	72.9	72.9	8.8	Endangered	Not Listed	2	False	319
1395_Thinned	63.9	63.9	63.8	Endangered	Not Listed	2	False	2041
							Subtotal	**2704**
Myotis macropus / Southern Myotis (Fauna)								
849_Intact	53.9	53.9	1.1	Vulnerable	Not Listed	2	False	30
849_Thinned	42.3	42.3	10.7	Vulnerable	Not Listed	2	False	227

849_Scattered_trees	18.3	18.3	9.6	Vulnerable	Not Listed	2	False	88
850_Scattered_trees	38.1	38.1	0.39	Vulnerable	Not Listed	2	False	7
1395_Intact	72.9	72.9	3.4	Vulnerable	Not Listed	2	False	124
1395_Thinned	63.9	63.9	44.8	Vulnerable	Not Listed	2	False	1433
1395_Scattered_trees	30.0	30.0	13	Vulnerable	Not Listed	2	False	195
							Subtotal	**2104**
Ninox connivens / Barking Owl (Fauna)								
1395_Intact	72.9	72.9	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**
Ninox strenua / Powerful Owl (Fauna)								
1395_Intact	72.9	72.9	0	Vulnerable	Not Listed	2	False	0
							Subtotal	**0**
Persoonia bargoensis / Bargo Geebung (Flora)								
849_Thinned	42.3	42.3	3	Endangered	Vulnerable	2	False	63
1395_Intact	72.9	72.9	3.6	Endangered	Vulnerable	2	False	133
1395_Thinned	63.9	63.9	30.5	Endangered	Vulnerable	2	False	974
							Subtotal	**1170**
Petaurus norfolcensis / Squirrel Glider (Fauna)								
849_Intact	53.9	53.9	0.06	Vulnerable	Not Listed	2	False	2
849_Thinned	42.3	42.3	1.6	Vulnerable	Not Listed	2	False	35
849_Scattered_trees	18.3	18.3	0.73	Vulnerable	Not Listed	2	False	7

1395_Intact	72.9	72.9	4.9	Vulnerable	Not Listed	2	False	179
1395_Thinned	63.9	63.9	42	Vulnerable	Not Listed	2	False	1341
1395_Scattered_trees	30.0	30.0	8.8	Vulnerable	Not Listed	2	False	132
							Subtotal	**1696**
Phascolarctos cinereus / Koala (Fauna)								
849_Intact	53.9	53.9	1.6	Vulnerable	Vulnerable	2	False	42
849_Thinned	42.3	42.3	21.1	Vulnerable	Vulnerable	2	False	446
849_Scattered_trees	18.3	18.3	0.23	Vulnerable	Vulnerable	2	False	2
1395_Intact	72.9	72.9	11	Vulnerable	Vulnerable	2	False	399
1395_Thinned	63.9	63.9	70.7	Vulnerable	Vulnerable	2	False	2261
1395_Scattered_trees	30.0	30.0	2.3	Vulnerable	Vulnerable	2	False	35
							Subtotal	**3185**
Pimelea spicata / Spiked Rice-flower (Flora)								
849_Intact	53.9	53.9	1.4	Endangered	Endangered	2	False	39
849_Thinned	42.3	42.3	21.9	Endangered	Endangered	2	False	464
849_Scattered_trees	18.3	18.3	19.4	Endangered	Endangered	2	False	177
849_DNG	24.1	24.1	112.5	Endangered	Endangered	2	False	1353
1395_Intact	72.9	72.9	1.1	Endangered	Endangered	2	False	40
1395_Thinned	63.9	63.9	21.3	Endangered	Endangered	2	False	680
1395_Scattered_trees	30.0	30.0	3.8	Endangered	Endangered	2	False	57

1395_DNG	28.4	28.4	29.2	Endangered	Endangered	2	False	414
849_NO_grassland	10.1	10.1	133	Endangered	Endangered	2	False	672
1395_NO_grassland	5.4	5.4	43.5	Endangered	Endangered	2	False	118
							Subtotal	**4014**
Pomaderris brunnea / Brown Pomaderris (Flora)								
1395_Intact	72.9	72.9	2.2	Endangered	Vulnerable	2	False	80
1395_Thinned	63.9	63.9	14.8	Endangered	Vulnerable	2	False	472
							Subtotal	**552**
Pseudophryne australis / Red-crowned Toadlet (Fauna)								
1395_Intact	72.9	72.9	2.3	Vulnerable	Not Listed	1.5	False	63
							Subtotal	**63**
Pterostylis saxicola / Sydney Plains Greenhood (Flora)								
849_Intact	53.9	53.9	1.4	Endangered	Endangered	2	False	36
1395_Intact	72.9	72.9	9.8	Endangered	Endangered	2	False	358
							Subtotal	**394**
Pultenaea pedunculata / Matted Bush-pea (Flora)								
849_Intact	53.9	53.9	1.1	Endangered	Not Listed	2	False	29
849_Thinned	42.3	42.3	2.1	Endangered	Not Listed	2	False	44
849_Scattered_trees	18.3	18.3	0.74	Endangered	Not Listed	2	False	7
850_Scattered_trees	38.1	38.1	0.1	Endangered	Not Listed	2	False	2
1395_Intact	72.9	72.9	3.2	Endangered	Not Listed	2	False	116
1395_Thinned	63.9	63.9	12.6	Endangered	Not Listed	2	False	404

1395_Scattered_trees	30.0	30.0	4.3	Endangered	Not Listed	2	False	65
							Subtotal	**667**
Tyto novaehollandiae / Masked Owl (Fauna)								
1395_Intact	72.9	72.9	0	Vulnerable	Not Listed	2	False	0
1395_Thinned	63.9	63.9	0.01	Vulnerable	Not Listed	2	False	1
							Subtotal	**1**

Biodiversity credit report – WSA

BAM Credit Summary Report

Proposal Details

Assessment Id	Proposal Name	BAM data last updated *
00013050/BAAS18134/18/00013053	Western Sydney Strategic Biodiversity Certification - Western Sydney Aerotropolis Growth Area	10/06/2021
Assessor Name	**Report Created**	**BAM Data version ***
Jane Raithby-Veall	03/11/2021	45
Assessor Number	**BAM Case Status**	**Date Finalised**
BAAS18134	Finalised	03/11/2021
Assessment Revision	**Assessment Type**	
4	Biocertification	

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits

Castlereagh Ironbark forest											
3	725_Intact	Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	49.2	49.2	0.81	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00	TRUE	20
4	725_Thinned	Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	43.3	43.3	8.6	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00	TRUE	187
5	725_Scattered_trees	Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion	19.6	19.6	2.9	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00	TRUE	29
										Subtotal	**236**
Castlereagh shale - gravel transition forest											
1	724_Thinned	Shale Gravel Transition Forest in the Sydney Basin Bioregion	36.2	36.2	44.4	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		804
2	724_Scattered_trees	Shale Gravel Transition Forest in the Sydney Basin Bioregion	20.5	20.5	2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		20
										Subtotal	**824**

Coastal freshwater wetland										
6	781_Thinned	Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	62.5	62.5	1.9	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		61
										Subtotal	**61**
Cumberland riverflat forest											
7	835_Intact	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	76.6	76.6	0.56	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		21

8	835_Thinned	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	57.1	57.1	29.8	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		850
9	835_Scattered_trees	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	68.7	68.7	19.2	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		662
20	835_NO_grassland	River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	8	8.0	712.8	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		0
										Subtotal	**1533**

Cumberland shale hills woodland											
14	850_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	41.9	41.9	5.8	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	151
15	850_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	38.1	38.1	1.6	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	38
16	850_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	25.7	25.7	0.19	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	3
22	850_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	12.3	12.3	10	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**192**
Cumberland shale plains woodland											
10	849_Intact	Cumberland Plain Woodland in the Sydney Basin Bioregion	53.9	53.9	10.9	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	367
11	849_Thinned	Cumberland Plain Woodland in the Sydney Basin Bioregion	42.3	42.3	157.6	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	4166

12	849_Scattered_trees	Cumberland Plain Woodland in the Sydney Basin Bioregion	18.3	18.3	66.5	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	759
13	849_DNG	Cumberland Plain Woodland in the Sydney Basin Bioregion	24.1	24.1	41.5	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	625
21	849_NO_grassland	Cumberland Plain Woodland in the Sydney Basin Bioregion	10.1	10.1	2567.6	Critically Endangered Ecological Community		High Sensitivity to Potential Gain	2.50	TRUE	0
										Subtotal	**5917**
Cumberland Swamp Oak riparian forest											
17	1800_Intact	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	43.2	43.2	0.65	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		14

18	1800_Thinned	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	46.6	46.6	15	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		350
19	1800_Scattered_trees	Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	41.2	41.2	1.6	Endangered Ecological Community		High Sensitivity to Potential Gain	2.00		32
										Subtotal	**396**
										Total	**9159**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits
Acacia bynoeana / Bynoe's Wattle (Flora)								
725_Intact	49.2	49.2	0.81	Endangered	Vulnerable	2	False	20
725_Thinned	43.3	43.3	8.6	Endangered	Vulnerable	2	False	186
725_Scattered_trees	19.6	19.6	2.9	Endangered	Vulnerable	2	False	29
							Subtotal	**235**

Acacia pubescens / Downy Wattle (Flora)								
724_Thinned	36.2	36.2	44.4	Vulnerable	Vulnerable	2	False	804
724_Scattered_trees	20.5	20.5	2	Vulnerable	Vulnerable	2	False	20
725_Intact	49.2	49.2	0.81	Vulnerable	Vulnerable	2	False	20
725_Thinned	43.3	43.3	8.6	Vulnerable	Vulnerable	2	False	187
725_Scattered_trees	19.6	19.6	2.9	Vulnerable	Vulnerable	2	False	29
835_Intact	76.6	76.6	0.28	Vulnerable	Vulnerable	2	False	11
835_Thinned	57.1	57.1	23	Vulnerable	Vulnerable	2	False	656
835_Scattered_trees	68.7	68.7	17.5	Vulnerable	Vulnerable	2	False	601
849_Intact	53.9	53.9	10.4	Vulnerable	Vulnerable	2	False	279
849_Thinned	42.3	42.3	144.8	Vulnerable	Vulnerable	2	False	3061
849_Scattered_trees	18.3	18.3	64.4	Vulnerable	Vulnerable	2	False	588
849_DNG	24.1	24.1	37.5	Vulnerable	Vulnerable	2	False	451
835_NO_grassland	8.0	8.0	0.01	Vulnerable	Vulnerable	2	False	1
							Subtotal	**6708**
Cercartetus nanus / Eastern Pygmy-possum (Fauna)								
835_Intact	76.6	76.6	0.42	Vulnerable	Not Listed	2	False	16
849_Intact	53.9	53.9	10.7	Vulnerable	Not Listed	2	False	288
							Subtotal	**304**

Dillwynia tenuifolia / Dillwynia tenuifolia (Flora)								
724_Scattered_trees	20.5	20.5	1.7	Vulnerable	Not Listed	2	False	18
724_Thinned	36.2	36.2	12.2	Vulnerable	Not Listed	2	False	221
725_Intact	49.2	49.2	0.79	Vulnerable	Not Listed	2	False	19
725_Scattered_trees	19.6	19.6	2	Vulnerable	Not Listed	2	False	19
725_Thinned	43.3	43.3	5.1	Vulnerable	Not Listed	2	False	111
849_DNG	24.1	24.1	15.6	Vulnerable	Not Listed	2	False	188
849_Intact	53.9	53.9	2.1	Vulnerable	Not Listed	2	False	58
849_Scattered_trees	18.3	18.3	22.9	Vulnerable	Not Listed	2	False	209
849_Thinned	42.3	42.3	12.4	Vulnerable	Not Listed	2	False	263
							Subtotal	**1106**
Grevillea juniperina subsp. juniperina / Juniper-leaved Grevillea (Flora)								
724_Thinned	36.2	36.2	41.7	Vulnerable	Not Listed	1.5	False	567
724_Scattered_trees	20.5	20.5	1.9	Vulnerable	Not Listed	1.5	False	14
725_Intact	49.2	49.2	0.73	Vulnerable	Not Listed	1.5	False	13
725_Thinned	43.3	43.3	5.7	Vulnerable	Not Listed	1.5	False	93
725_Scattered_trees	19.6	19.6	2.5	Vulnerable	Not Listed	1.5	False	18
835_Thinned	57.1	57.1	15.6	Vulnerable	Not Listed	1.5	False	335
835_Scattered_trees	68.7	68.7	8.6	Vulnerable	Not Listed	1.5	False	221
849_Intact	53.9	53.9	3.4	Vulnerable	Not Listed	1.5	False	68

849_Thinned	42.3	42.3	130.5	Vulnerable	Not Listed	1.5	False	2070
849_Scattered_trees	18.3	18.3	46.9	Vulnerable	Not Listed	1.5	False	321
849_DNG	24.1	24.1	28.6	Vulnerable	Not Listed	1.5	False	258
850_Thinned	41.9	41.9	0	Vulnerable	Not Listed	1.5	False	0
1800_Thinned	46.6	46.6	0	Vulnerable	Not Listed	1.5	False	0
							Subtotal	**3978**
Grevillea parviflora subsp. parviflora / Small-flower Grevillea (Flora)								
724_Thinned	36.2	36.2	4.4	Vulnerable	Vulnerable	2	False	79
725_Intact	49.2	49.2	0.04	Vulnerable	Vulnerable	2	False	1
725_Thinned	43.3	43.3	2.7	Vulnerable	Vulnerable	2	False	58
							Subtotal	**138**
Haliaeetus leucogaster / White-bellied Sea-Eagle (Fauna)								
835_Intact	76.6	76.6	0.42	Vulnerable	Not Listed	2	False	16
849_Intact	53.9	53.9	0.21	Vulnerable	Not Listed	2	False	6
1800_Intact	43.2	43.2	0.65	Vulnerable	Not Listed	2	False	14
							Subtotal	**36**
Hibbertia fumana / Hibbertia fumana (Flora)								
724_Thinned	36.2	36.2	1.5	Critically Endangered	Not Listed	3	True	40
725_Intact	49.2	49.2	0.03	Critically Endangered	Not Listed	3	True	1
725_Thinned	43.3	43.3	2.6	Critically Endangered	Not Listed	3	True	83

725_Scattered_tree s	19.6	19.6	0.04	Critically Endangered	Not Listed	3	True	1
835_NO_grassland	8.0	8.0	1.6	Critically Endangered	Not Listed	3	True	9
849_NO_grassland	10.1	10.1	0.19	Critically Endangered	Not Listed	3	True	1
							Subtotal	**135**
Hibbertia puberula / Hibbertia puberula (Flora)								
724_Thinned	36.2	36.2	1.5	Endangered	Not Listed	2	False	27
725_Intact	49.2	49.2	0.03	Endangered	Not Listed	2	False	1
725_Thinned	43.3	43.3	2.6	Endangered	Not Listed	2	False	56
725_Scattered_tree s	19.6	19.6	0.04	Endangered	Not Listed	2	False	1
835_NO_grassland	8.0	8.0	1.6	Endangered	Not Listed	2	False	6
849_NO_grassland	10.1	10.1	0.19	Endangered	Not Listed	2	False	1
							Subtotal	**92**
Hieraaetus morphnoides / Little Eagle (Fauna)								
724_Thinned	36.2	36.2	0.06	Vulnerable	Not Listed	1.5	False	1
725_Thinned	43.3	43.3	0.01	Vulnerable	Not Listed	1.5	False	1
835_Intact	76.6	76.6	0.07	Vulnerable	Not Listed	1.5	False	2
835_Thinned	57.1	57.1	0.76	Vulnerable	Not Listed	1.5	False	16
849_Intact	53.9	53.9	0.31	Vulnerable	Not Listed	1.5	False	6
849_Thinned	42.3	42.3	0.06	Vulnerable	Not Listed	1.5	False	1
1800_Thinned	46.6	46.6	0.12	Vulnerable	Not Listed	1.5	False	2
							Subtotal	**29**

Lophoictinia isura / Square-tailed Kite (Fauna)								
835_Intact	76.6	76.6	0.42	Vulnerable	Not Listed	1.5	False	12
849_Intact	53.9	53.9	0.21	Vulnerable	Not Listed	1.5	False	4
1800_Intact	43.2	43.2	0.65	Vulnerable	Not Listed	1.5	False	11
							Subtotal	**27**
Marsdenia viridiflora subsp. viridiflora - endangered population / Marsdenia viridiflora R. Br. subsp. viridiflora population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas (Flora)								
724_Thinned	36.2	36.2	42	Endangered Population	Not Listed	2	False	759
725_Intact	49.2	49.2	0.73	Endangered Population	Not Listed	2	False	18
725_Thinned	43.3	43.3	5.8	Endangered Population	Not Listed	2	False	126
835_Intact	76.6	76.6	0.42	Endangered Population	Not Listed	2	False	16
835_Thinned	57.1	57.1	27.3	Endangered Population	Not Listed	2	False	780
849_Intact	53.9	53.9	3.6	Endangered Population	Not Listed	2	False	97
849_Thinned	42.3	42.3	127.8	Endangered Population	Not Listed	2	False	2702
850_Thinned	41.9	41.9	5.6	Endangered Population	Not Listed	2	False	116
1800_Thinned	46.6	46.6	11.6	Endangered Population	Not Listed	2	False	270
1800_Intact	43.2	43.2	0.5	Endangered Population	Not Listed	2	False	11

							Subtotal	**4895**
Maundia triglochinoides / Maundia triglochinoides (Flora)								
781_Thinned	62.5	62.5	1.9	Vulnerable	Not Listed	2	False	61
1800_Thinned	46.6	46.6	10.7	Vulnerable	Not Listed	2	False	250
1800_Intact	43.2	43.2	0.64	Vulnerable	Not Listed	2	False	14
							Subtotal	**325**
Meridolum corneovirens / Cumberland Plain Land Snail (Fauna)								
724_Thinned	36.2	36.2	44.4	Endangered	Not Listed	2	False	804
725_Intact	49.2	49.2	0.63	Endangered	Not Listed	2	False	16
725_Thinned	43.3	43.3	8.4	Endangered	Not Listed	2	False	181
835_Intact	76.6	76.6	0.42	Endangered	Not Listed	2	False	16
835_Thinned	57.1	57.1	29.2	Endangered	Not Listed	2	False	834
849_Intact	53.9	53.9	10.7	Endangered	Not Listed	2	False	288
849_Thinned	42.3	42.3	138.9	Endangered	Not Listed	2	False	2938
850_Thinned	41.9	41.9	5.1	Endangered	Not Listed	2	False	107
							Subtotal	**5184**
Micromyrtus minutiflora / Micromyrtus minutiflora (Flora)								
724_Thinned	36.2	36.2	14.8	Endangered	Vulnerable	3	True	402
725_Thinned	43.3	43.3	1.8	Endangered	Vulnerable	3	True	60
							Subtotal	**462**
Myotis macropus / Southern Myotis (Fauna)								
724_Thinned	36.2	36.2	36.5	Vulnerable	Not Listed	2	False	660
724_Scattered_trees	20.5	20.5	1.8	Vulnerable	Not Listed	2	False	19

725_Intact	49.2	49.2	0.67	Vulnerable	Not Listed	2	False	16
725_Thinned	43.3	43.3	5.4	Vulnerable	Not Listed	2	False	117
725_Scattered_trees	19.6	19.6	1.5	Vulnerable	Not Listed	2	False	14
781_Thinned	62.5	62.5	1.9	Vulnerable	Not Listed	2	False	60
835_Intact	76.6	76.6	0.55	Vulnerable	Not Listed	2	False	21
835_Thinned	57.1	57.1	26.9	Vulnerable	Not Listed	2	False	768
835_Scattered_trees	68.7	68.7	16.3	Vulnerable	Not Listed	2	False	561
849_Intact	53.9	53.9	7.5	Vulnerable	Not Listed	2	False	201
849_Thinned	42.3	42.3	148.8	Vulnerable	Not Listed	2	False	3147
849_Scattered_trees	18.3	18.3	53.7	Vulnerable	Not Listed	2	False	490
850_Thinned	41.9	41.9	5.8	Vulnerable	Not Listed	2	False	121
850_Scattered_trees	38.1	38.1	1.6	Vulnerable	Not Listed	2	False	30
1800_Intact	43.2	43.2	0.65	Vulnerable	Not Listed	2	False	14
1800_Thinned	46.6	46.6	13.8	Vulnerable	Not Listed	2	False	322
1800_Scattered_trees	41.2	41.2	1.4	Vulnerable	Not Listed	2	False	28
							Subtotal	**6589**
Ninox strenua / Powerful Owl (Fauna)								
835_Intact	76.6	76.6	0.06	Vulnerable	Not Listed	2	False	2
							Subtotal	**2**

Persicaria elatior / Tall Knotweed (Flora)								
781_Thinned	62.5	62.5	0.07	Vulnerable	Vulnerable	2	False	2
835_Intact	76.6	76.6	0.14	Vulnerable	Vulnerable	2	False	5
835_Thinned	57.1	57.1	1.4	Vulnerable	Vulnerable	2	False	41
1800_Thinned	46.6	46.6	0.61	Vulnerable	Vulnerable	2	False	14
1800_Scattered_trees	41.2	41.2	0.14	Vulnerable	Vulnerable	2	False	3
							Subtotal	**65**
Persoonia nutans / Nodding Geebung (Flora)								
724_Thinned	36.2	36.2	44.4	Endangered	Endangered	2	False	804
724_Scattered_trees	20.5	20.5	2	Endangered	Endangered	2	False	20
725_Intact	49.2	49.2	0.81	Endangered	Endangered	2	False	20
725_Thinned	43.3	43.3	8.6	Endangered	Endangered	2	False	187
725_Scattered_trees	19.6	19.6	2.9	Endangered	Endangered	2	False	29
							Subtotal	**1060**
Pimelea spicata / Spiked Rice-flower (Flora)								
849_Intact	53.9	53.9	8.9	Endangered	Endangered	2	False	240
849_Thinned	42.3	42.3	77.7	Endangered	Endangered	2	False	1643
849_Scattered_trees	18.3	18.3	20.1	Endangered	Endangered	2	False	183
849_DNG	24.1	24.1	8.7	Endangered	Endangered	2	False	105
850_Thinned	41.9	41.9	1.9	Endangered	Endangered	2	False	39

850_Scattered_trees	38.1	38.1	0.23	Endangered	Endangered	2	False	4
724_Thinned	36.2	36.2	26.8	Endangered	Endangered	2	False	486
724_Scattered_trees	20.5	20.5	0.21	Endangered	Endangered	2	False	2
781_Thinned	62.5	62.5	0.87	Endangered	Endangered	2	False	27
835_Thinned	57.1	57.1	13	Endangered	Endangered	2	False	371
835_Scattered_trees	68.7	68.7	2.6	Endangered	Endangered	2	False	90
1800_Thinned	46.6	46.6	2.2	Endangered	Endangered	2	False	52
835_NO_grassland	8.0	8.0	55.6	Endangered	Endangered	2	False	222
849_NO_grassland	10.1	10.1	80.6	Endangered	Endangered	2	False	406
850_NO_grassland	12.3	12.3	0.67	Endangered	Endangered	2	False	4
							Subtotal	**3874**
Pultenaea parviflora / Pultenaea parviflora (Flora)								
724_Thinned	36.2	36.2	42	Endangered	Vulnerable	2	False	761
725_Intact	49.2	49.2	0.75	Endangered	Vulnerable	2	False	18
725_Thinned	43.3	43.3	5.9	Endangered	Vulnerable	2	False	128
							Subtotal	**907**
Pultenaea pedunculata / Matted Bush-pea (Flora)								
724_Thinned	36.2	36.2	35.8	Endangered	Not Listed	2	False	648
724_Scattered_trees	20.5	20.5	2	Endangered	Not Listed	2	False	20
725_Intact	49.2	49.2	0.81	Endangered	Not Listed	2	False	20
725_Thinned	43.3	43.3	6.8	Endangered	Not Listed	2	False	147

725_Scattered_trees	19.6	19.6	2.9	Endangered	Not Listed	2	False	28
849_Intact	53.9	53.9	0.31	Endangered	Not Listed	2	False	8
849_Thinned	42.3	42.3	18.7	Endangered	Not Listed	2	False	395
849_Scattered_trees	18.3	18.3	19.8	Endangered	Not Listed	2	False	180
							Subtotal	**1446**

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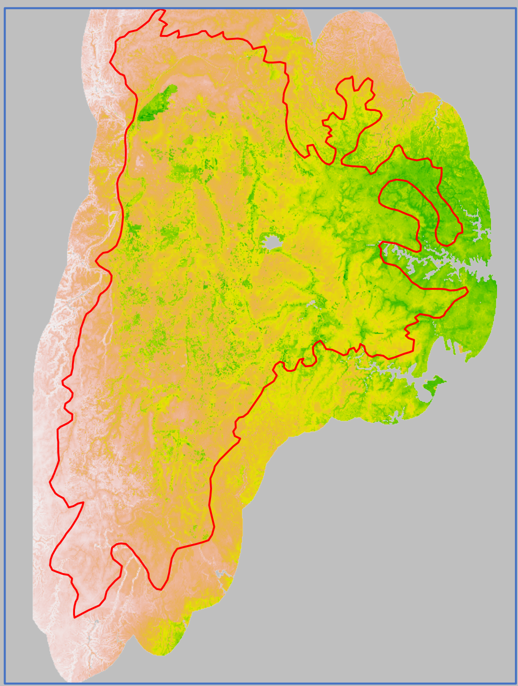
2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document F – SDM Report

23 NOVEMBER 2018

WESTERN SYDNEY STRATEGIC PLAN - SPECIES DISTRIBUTION MODELLING



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PREPARED FOR THE NSW DEPARTMENT OF
PLANNING AND ENVIRONMENT, BIOSIS, AND OPEN LINES

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Suggest citation:

Gordon, A., Koshkina V. (2018) Western Sydney Strategic Plan – species distribution modelling (2018). RMIT University, Melbourne, Victoria. 38 pages.

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Ascelin Gordon is an RMIT University Vice Chancellor's Senior Research Fellow within the ICON Science research group that sits within the Centre for Urban Research, in the School of Global Urban and Social Studies. He undertakes research on a range of conservation problems with a particular focus on ecological modelling, decision making for conservation, and biodiversity offsetting.

Vira Koshkina is undertaking a PhD at RMIT University in mathematical sciences within the School of Science. Her PhD focuses on developing new approaches for species distribution modelling that integrates different data sources and can better account for spatial correlations.

Acknowledgments

A range of people have been invaluable in pulling together the data required for this study and providing expert advice on species focussed on here. In particular we would like to thank: Tom Holden, Steve Douglas, Peter Hemphill, Rebecca Dwyer, Paul Burcher, Greg Steenbeeke, Enhua Lee, and Darren James.

Table of Contents

Summary

The NSW Government is planning for the future growth of Sydney, and as part of the planning process the Department of Planning and Environment are preparing the Western Sydney Strategic Sustainability Plan (WSSSP). The WSSSP includes a conservation plan for the Cumberland Subregion (IBRA 7), and within this, habitat mapping is being undertaken for all Category 1 EPBC Act listed species. This report details the process to develop species distribution models (SDMs) for 19 EPBC listed species (6 fauna species and 13 flora species), which were deemed suitable for this approach.

Occurrence data for the species were obtained from BioNet, and 21 spatial predictors layers were selected to as likely covariates that could be used to develop models to predict the likelihood of occurrence of the species. SDMs were developed using the software 'Maxent'.

An approach was developed to account for the different levels of bias likely present in the species occurrence records from BioNet. This resulted in three maps with different assumptions regarding bias in the occurrence data, depicting the likelihood of occurrence for each species. These maps were then combined to produce a single risk-based SDM with three classes of occurrence for each species: "unlikely to occur" - none of the SDMs showed the species occurring; "potential to occur"- at least one on the SDMs showed the species occurring; and "likely to occur" - all 3 of the SMDs showed the species as occurring.

Results for all species are presented, and the limitations of the approach are discussed in detail. Options for improving the resulting SDMs also presented. Software to undertake the analysis was developed in R, and is available via GitHub. All SDMs produced are available for download as raster files for use in subsequent analysis, and the predictor layers used in generating the SDMs are also available.

Introduction

The NSW Government is planning for the future growth of Sydney to provide new jobs, homes, services and transport links in the West and South West Districts of Western Sydney. As part of the planning process, priority growth areas (PGAs) have been defined, and the NSW Department of Planning and Environment (DPE) is preparing the Western Sydney Strategic Sustainability Plan (WSSSP).

The WSSSP will provide an overarching strategy for managing environmental and development outcomes in the West and South West Districts of Western Sydney and will consist of three components: (i) a strategic conservation plan (ii); a green infrastructure plan; and (iii) an urban sustainability plan. The strategic conservation plan will be utilized to support strategic avoidance and mitigation of development impacts, and also to increase persistence of biodiversity values in Western Sydney through identifying the most suitable patches of native vegetation for protection. The plan will be assessed strategically at both the NSW and Commonwealth level through:

- Biodiversity certification under the NSW Biodiversity Conservation Act 2016 (BC Act);

- A strategic assessment under the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

As part of the conservation plan, DPE is undertaking habitat mapping across the Cumberland Subregion (IBRA 7) for all Category 1 EPBC Act species. This is being done through one of two methods: (i) species distribution models (SDMs; the focus of this report); and (ii) an expert knowledge-based approach (where SDMs are not possible), undertaken by Biosis (not dealt with any further here). In addition to the subregion mapping, detailed mapping is being undertaken within the PGAs as part of the NSW Biodiversity Assessment Methodology (BAM) process.

SDMs are statistical models used to estimate the relationship between species records at sites and the environmental and/or spatial characteristics of those sites (Franklin 2010). Once this relationship has been estimated, the statistical model can be used to predict other locations in the landscape where the species is likely to occur. Thus, SDMs are useful as they can provide estimates over large areas of where a species (or its habitat) is likely to occur. SDMs are used in broad range of applications including the management of threatened species, conservation planning, predicting the impacts of threatening processes such as development or climate change and to manage landscapes (Guillera-Arroita et al. 2015).

In this context of the WSSSP, it is envisaged that SDMs will be used in three ways:

1. They will provide context for the detailed impact analysis being undertaken within the PGAs. For example, they will provide information about the relative importance of habitat within the PGAs compared to the rest of the Cumberland Subregion;

2. They will enable an indicative impact assessment for transport corridors. Transport corridors will be intersected with the SDM predictions to provide an indication of possible impacts on Matters of National Environmental Significance. It is critical to note the transport corridors will be surveyed in detail as part of future NSW biodiversity approvals process, and that the SDM outputs are for indicative impact assessment only;

3. They will help evaluate proposed conservation measures by providing indicative information about the amount of habitat available for biodiversity offsetting. It is critical to note that any sites proposed for offsets or other measures will be surveyed prior to being secured. Thus, the SDM outputs are for indicative evaluation of offsets or other conservation measures.

Undertaking species distribution modelling to produce accurate predictions regarding where a species, or its habitat, is likely to occur can be challenging for a number of reasons. Firstly, the species occurrence data used for modelling is often highly biased (Elith et al. 2006). In regions where there are no species occurrences, it's often not clear whether the species really doesn't occur there, or whether no one has looked. Secondly, spatial data capturing appropriate predictors that are driving the species occurrences needs to be available. Thirdly detectability may be an issue, where if a species is present, it may be less likely to be seen in some parts or its range than in others, further biasing the presence records (Guillera-Arroita 2016). Finally, a species may not occur in every location where its environmental niche is present, due to interactions with other species, or historical accidents.

On top this, SDMs are more challenging in human dominated regions such as the Cumberland Plain. This landscape has a long history of human use that has resulted in it becoming increasing modified, and placing great importance on the remaining biodiversity values. These landscape modifications mean that there are a range of additional anthropogenic other factors driving where species currently occur, such as land clearing and invasive species. The species occurrence records in the Cumberland Plain may be driven by all the above factors. This means the predictions derived from SDMs will be predicting some combination of where species originally occurred, and where it is now due to current anthropogenic threats.

Given the limitation of this approach, SDMs should be supplemented with expert derived methods. However, the advantage of this approach is that it is data-driven, systematic, repeatable, and easily able to be updated once further data on species locations is gathered or improved predictor layers becomes available.

Species distribution models using 'Maxent'

Developing a species distribution model starts with collecting observations of species occurrences and data on environmental factors that are thought to affect the occurrence of the species. The locations are then linked to the values of the environmental predictors, and the values of the predictors at the locations of the specific observations are extracted to a table along with the results of the survey. A statistical, machine learning, or another type of model describing the relationship between species occurrence and environmental data is then fitted to the data. The model coefficients that are estimated during the model fitting process are then applied to the environmental data to produce a prediction map of the species habitat (Franklin 2010). There are two common types of species occurrence data which can be used to build SDMs: presence-background data and site-occupancy data (Phillips et al. 2006).

The two types differ by the collection method and have various levels of reliability. *Site - occupancy data i*s collected during a planned survey, when the researchers split the geographical domain of interests into fixed sized areas called survey sites. The sites are then inspected looking for the species of interest and either the presence or absence of the species is recorded. In many cases, researchers conduct repeated surveys to ensure that the individuals present at the site have been detected. Critically the absence of a species at a location is also available from this type of data.

Presence-background (PB) data consists of "presence-only" data which comprises a set of locations where individuals of the species under investigation have been observed, combined with some background points selected from the areas where the species has not been detected. The presence only data is often collected opportunistically from surveys and is usually added to online publicly accessible databases which aggregate presence only data from multiple sources. To use this data in modelling, "background points" are needed and these are randomly selected from the area where predictions are to be made (Merow et al. 2013). There are multiple ways that points can be sampled to generate the background data. Due to being the most widely available, presence-background data is the most common data used in SDMs.

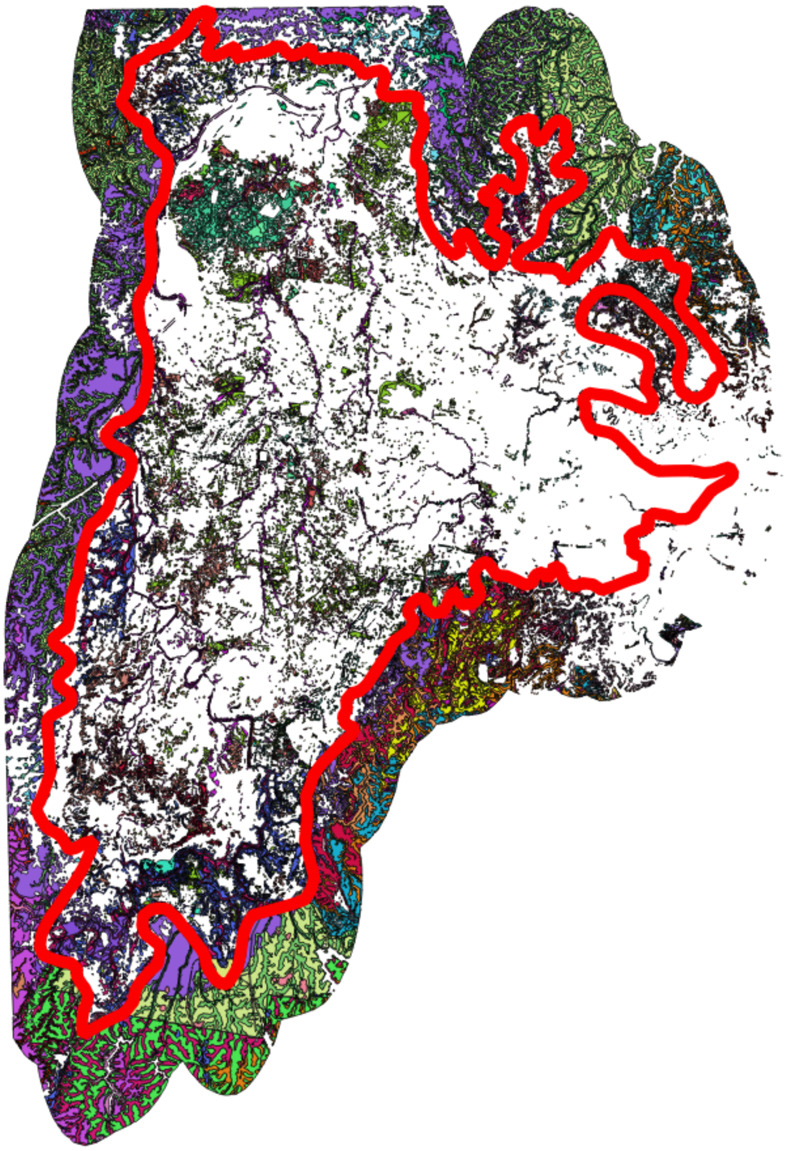


Figure 1 The map of the study area: a 10 km buffer around was placed around the Cumberland Subregion (the Cumberland Subregion outline is shown as a red line). A map of native vegetation is overlaid. The vegetation is classified by Plant Community Type. Areas the north and south-west are visible where the buffer was reduced due to limited data.

While PB data is pervasive, it can have high levels of bias since the observations are done in non-structured fashion and locations of species detections are likely to correlate with the areas that are more accessible by humans (Phillips and Dudík 2008a). Using this data without accounting for these biases can lead to a model that predicts the probability of a species being detected by humans rather than the likelihood of a species being present in the area. This effect is called overfitting, meaning that while the model is doing an excellent job at fitting the coefficients that explain the observed presence data, it does a poor job of predicting the probability of a species being present at other locations. To avoid overfitting, ecologists choose background points in the PB data according to the bias that is present in the presence records (Elith et al. 2011). This is described further below.

All the models presented here were built using Maxent, which is a free software that has been widely used and evaluated in the peer reviewed literature, and is accepted as a powerful method for generating SDMs with PB data (Phillips and Dudík 2008b; Elith et al. 2011; Merow, Smith, and Silander 2013; Phillips et al. 2017). It estimates the probability of the species presence in each point of the landscape based in the environmental parameters of that point relative to the values of the same parameters in locations where the species is known to occur.

Maxent estimates species distribution by trying to achieve the most uniform distribution (i.e maximum entropy) of the parameters in the predicter areas of likely occurrence, while obeying the constraints that the expected number of species in each location closely matches the observed presences (Phillips et al 2006). To do that, the method heavily relies on the background points selected from the study area in the locations where the species has not been observed.

In this report we present the results of using Maxent with PB data for 19 EPBC-listed species in the Cumberland Subregion consisting of 6 fauna species and 13 flora species.

Methods

Study area

For the study area we chose an area that includes a 10 km buffer around the Cumberland (IBRA 7) Subregion (Figure 1). The study area does not include the full 10km buffer around the all areas of the Cumberland Subregion due to some areas in the buffer lacking appropriate vegetation and soil data. Thus, the buffer is reduced in areas to the north and south west of the Cumberland Subregion (Figure 1).

Species occurrence data

Occurrence data used in the analysis was obtained from BioNet, a repository for biodiversity data products managed by the NSW Office of Environment and Heritage (http://www.bionet.nsw.gov.au). The BioNet Atlas application contains data collections comprising (i) species sightings; (ii) systematic surveys; (iii) threatened biodiversity; and (iv) species names. The initial list of species considered for the modelling is shown in Table 1, and BioNet sighting records were extracted for a 100km buffer around the Cumberland Subregion for initial analysis.

Scientific name	Common name	Order	Kingdom
Acacia pubescens	Downy Wattle	Flora	Plantae
Persoonia nutans	Nodding Geebung	Flora	Plantae
Pimelea spicata	Spiked Rice-flower	Flora	Plantae
Phascolarctos cinereus	Koala	Diprotodonta	Animalia
Pultenaea parviflora	NA	Flora	Plantae
Pteropus poliocephalus	Grey-headed Flying-fox	Chiroptera	Animalia
Eucalyptus benthamii	Camden White Gum	Flora	Plantae
Casuarina glauca	Swamp Oak	Flora	Plantae
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	Flora	Plantae
Persoonia bargoensis	Bargo Geebung	Flora	Plantae
Micromyrtus minutiflora	NA	Flora	Plantae
Litoria aurea	Green and Golden Bell Frog	Anura	Animalia
Acacia bynoeana	Bynoe's Wattle	Flora	Plantae
Lathamus discolor	Swift Parrot	Psittaciformes	Animalia
Melaleuca deanei	Deane's Paperbark	Flora	Plantae
Chalinolobus dwyeri	Large-eared Pied Bat	Chiroptera	Animalia
Pomaderris brunnea	Brown Pomaderris	Flora	Plantae
Petauroides volans	Greater Glider	Diprotodonta	Animalia
Commersonia prostrata	Dwarf Kerrawang	Flora	Plantae
Pommerhelix duralensis	Dural Woodland Snail	Eupulmonata	Animalia
Persoonia hirsuta	Hairy Geebung	Flora	Plantae
Allocasuarina glareicola	NA	Flora	Plantae
Dasyurus maculatus	Spotted-tailed Quoll	Dasyuromorphia	Animalia
Syzygium paniculatum	Magenta Lilly Pilly	Flora	Plantae
Botaurus poiciloptilus	Australasian Bittern	Ciconiiformes	Animalia
Anthochaera phrygia	Regent Honeyeater	Passeriformes	Animalia
Persoonia mollis subsp. maxima	NA	Flora	Plantae
Cynanchum elegans	White-flowered Wax Plant	Flora	Plantae
Persoonia glaucescens	Mittagong Geebung	Flora	Plantae
Pimelea curviflora var. curviflora	NA	Flora	Plantae
Pterostylis saxicola	Sydney Plains Greenhood	Flora	Plantae
Darwinia biflora	NA	Flora	Plantae
Leucopogon exolasius	Woronora Beard-heath	Flora	Plantae
Heleioporus australiacus	Giant Burrowing Frog	Anura	Animalia
Lasiopetalum joyceae	NA	Flora	Plantae
Acacia gordonii	NA	Flora	Plantae
Rostratula australis	Australian Painted Snipe	Charadriiformes	Animalia
Eucalyptus camfieldii	Camfield's Stringybark	Flora	Plantae
Genoplesium baueri	Bauer's Midge Orchid	Flora	Plantae
Haloragodendron lucasii	NA	Flora	Plantae
Macquaria australasica	Macquarie Perch	Perciformes	Animalia

Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern)	Peramelemorphia	Animalia
Thesium australe	Austral Toadflax	Flora	Plantae
Hoplocephalus bungaroides	Broad-headed Snake	Squamata	Animalia
Pterostylis gibbosa	Illawarra Greenhood	Flora	Plantae
Eucalyptus sp. Cattai	NA	Flora	Plantae
Haloragis exalata subsp. exalata	Square Raspwort	Flora	Plantae
Trachystoma petardi	Pinkeye Mullet; Fresh Water Mullet	Mugiliformes	Animalia
Hibbertia spanantha	Julian's Hibbertia	Flora	Plantae
Acacia terminalis subsp. terminalis	Sunshine Wattle	Flora	Plantae
Prostanthera marifolia	Seaforth Mintbush	Flora	Plantae
Caladenia tessellata	Thick Lip Spider Orchid	Flora	Plantae
Leptospermum deanei	NA	Flora	Plantae
Thelymitra kangaloonica	Kangaloon Sun Orchid	Flora	Plantae
Hibbertia sp. Bankstown	NA	Flora	Plantae
Deyeuxia appressa	NA	Flora	Plantae
Rhizanthella slateri	Eastern Australian Underground Orchid	Flora	Plantae
Prototroctes maraena	Australian Grayling	Osmeriformes	Animalia

Table 1. The initial list of species considered for modelling.

Species were then excluded due to a range of factors. This included having a small number of records (in general more than 50 occurrences was required for modelling, though an indicative SDM has been produced for the White-flowered Wax Plant (Cynanchum elegans) with only 23 records—see below) and the fact they were generalist species for which appropriate predictor layers were not available to predict occurrence. It was also found that some candidate species were considered based on erroneous records, so that after a manual review of the records (see below) very few legitimate records remained. Table 2 shows the final species for which SDMs were undertaken using Maxent.

The data extracted from Bionet included records up until the 14 August, 2018. Records were filtered so that only records with a spatial accuracy of 100m or less were retained. No filter was applied to exclude records older than a specified date, as it was deemed that the 100m accuracy filter would remove all old records with low accuracy.

It was found that there were various errors in the species occurrence data derived from BioNet. To address this, external consultants were contracted to undertake a manual review of the occurrence records for all records up until 14 Aug 2018. Steve Douglass (Ecological Surveys & Planning) reviewed the flora records, and Paul Burcher (Aquila Ecological Surveys) reviewed the fauna records.

Scientific name	Common name	Order	Kingdom
Acacia bynoeana	Bynoe's Wattle	Fabaceae (Mimosoideae)	Flora
Acacia pubescens	Downy Wattle	Fabaceae (Mimosoideae)	Flora
Botaurus poiciloptilus	Australasian Bittern	Ardeidae	Fauna

Cynanchum elegans	White-flowered Wax Plant	Apocynaceae	Flora
Darwinia biflora	NA	Myrtaceae	Flora
Eucalyptus benthamii	Camden White Gum	Myrtaceae	Flora
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	Proteaceae	Flora
Heleioporus australiacus	Giant Burrowing Frog	Myobatrachidae	Fauna
Litoria aurea	Green and Golden Bell Frog	Hylidae	Fauna
Micromyrtus minutiflora	NA	Myrtaceae	Flora
Persoonia bargoensis	Bargo Geebung	Proteaceae	Flora
Persoonia hirsuta	Hairy Geebung	Proteaceae	Flora
Persoonia nutans	Nodding Geebung	Proteaceae	Flora
Phascolarctos cinereus	Koala	Phascolarctidae	Fauna
Pimelea spicata	Spiked Rice-flower	Thymelaeaceae	Flora
Pomaderris brunnea	Brown Pomaderris	Rhamnaceae	Flora
Pommerhelix duralensis	Dural Woodland Snail	Camaenidae	Fauna
Pteropus poliocephalus	Grey-headed Flying-fox	Pteropodidae	Fauna
Pultenaea parviflora	NA	Fabaceae (Faboideae)	Flora

Table 2. The final list of species for which SDMs were undertaken.

The data review process involved a manual review of occurrence records, and updating information associated with species occurrence records, or removing the record as appropriate. The process consisted of:

- addressing erroneous records which could occur through
    - misidentification;
    - data entry error (wrong species input);
    - incorrect spatial data (co-ordinates and/or location description);
    - inappropriate spatial accuracy assignment (too coarse, too fine, depending on data quality);
    - plantings or naturalisations
- for some of the very old records, there was sufficient information to allow them to be located with high accuracy in remnant habitats (such as urban bushland) in highly developed suburbs, in these cases the records were kept and the locations and accuracy records were updated.

The fauna data cleaning also involved marking records as to whether or not they should be counted as 'informative' or not for the modelling. This was based on whether the record was in breeding habitat for the species, or whether it was likely to in foraging habitat, or in locations of where the species was dispersing outside its habitat (or possibly road kill). Specifically:

- for the Grey-headed Flying-fox (*Pteropus poliocephalus*), only records associated with roosts where retained;
- for the Koala (*Phascolarctos cinereus*), only records associated with native vegetation were retained, due to the male koalas being known to disperse through non-native habitat after the breeding season;

- for Australasian Bittern, records were only retained if they were in or close to appropriate mapped native vegetation, and records associated with open water were excluded.

The number of records for each of the species being modelled is displayed below in Table 3, including a breakdown the proportion of records overlapping native vegetation and the number within the Cumberland Subregion.

Scientific name	Common name	Total number of presences in study area	Number of presences in Cumberland	Percentage of presences in areas with native vegetation (%)
Litoria aurea	Green and Golden Bell Frog	13496	12587	0.6
Acacia pubescens	Downy Wattle	5344	5138	85
Phascolarctos cinereus	Koala	3983	1191	76.9
Pteropus poliocephalus	Grey-headed Flying-fox	2590	1639	54.6
Persoonia nutans	Nodding Geebung	1559	1511	88.6
Pimelea spicata	Spiked Rice-flower	1312	1312	93.5
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	1292	1089	97.3
Pultenaea parviflora	NA	1221	1211	79.4
Darwinia biflora	NA	1181	27	11.1
Eucalyptus benthamii	Camden White Gum	582	577	72.3
Persoonia hirsuta	Hairy Geebung	503	38	68.4
Persoonia bargoensis	Bargo Geebung	390	271	80.4
Acacia bynoeana	Bynoe's Wattle	268	113	77
Micromyrtus minutiflora	NA	190	188	66.5
Heleioporus australiacus	Giant Burrowing Frog	134	13	30.8
Pommerhelix duralensis	Dural Woodland Snail	79	16	87.5
Pomaderris brunnea	Brown Pomaderris	75	71	88.7
Botaurus poiciloptilus	Australasian Bittern	56	34	44.1
Cynanchum elegans	White-flowered Wax Plant	23	23	82.6

Table 3. Number of occurrence records in BioNet for each species after the data cleaning was completed. For each species, the total number of records in the study area is shown, the number within the Cumberland Subregion, and the percentage of the records that overlap with native vegetation.

Environmental predictors

Through discussions with a range of experts on the flora and fauna of the Cumberland Plain, and drawing on similar studies utilizing SDMs in NSW (Kujala at al. 2016) a range of potential predictors layers were selected. The experts providing feedback into the selection of predictors included staff members of NSW Government Departments (OEH and DPE) as well as a range of consultants involved in WSSSP. The list of the initial 37 predictors considered in the analysis is shown in Table 4.

Predictor code	Predictor description
vegetation	Native vegetation
ct_temp_maxsum	Average daily max temperature - Summer
ct_tempannrnge	Temperature Annual Range: difference between bio5 and bio6 (bio7)
cw_precipann	Annual Precipitation (bio12)
gp_k_fillspl	filtered potassium (K), gaps filled in using geograhically weighted regession model and spline function
lf_aspect_tr	Beer's Apsect- transformation of aspect to a continuous scaled variable. Changed for the southern hemisphere by setting maximum value (2) to SE slopes (coolest) and minimum (0) to NW slopes (warmest).
lf_cti	Compound topographic index or CTI also known as wetness index, topographic wetness index. Based on DEM-H (for flow direction and accumulation)
lf_rough0100	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 100 m neighbourhood. Derived from DEM-S
lf_tpi0120	Topographic position index using neighbourhood of 120m radius
dl_lat_grid	Latitude (surrogate for location, disperal, isolation)
dl_long_grid	Longitude (surrogate for location, dispersal, isolation)
ce_radhp	Highest Period Radiation (bio21)
ce_radlp	Lowest Period Radiation (bio22)
ct_frostdays_lt2	Number of days/annum with minimum temperature less than 2 degrees
ct_temp_maxwin	Average daily max temperature - Winter
ct_temp_minsum	Average daily min temperature - Summer
ct_temp_minwin	Average daily min temperature - Winter
ct_tempdiurn	Mean Diurnal Range (Mean(period max-min)) (bio2)
ct_tempmtcp	Min Temperature of Coldest Period (bio6)
ct_tempmtwp	Max Temperature of Warmest Period (bio5)
cw_etaaann	Average areal actual evapotranspiration - Annual
cw_etapann	Average areal potential evapotranspiration - Annual
dl_strmdstge2	Euclidean distance to 2nd order streams and above
dl_strmdstge4	Euclidean distance to 4th order streams and above
dl_strmdstge6	Euclidean distance to 6th order streams and above
gp_u_fillspl	filtered uranium (U), gaps filled in using geograhically weighted regession model and spline function
lf_rough0500	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 500 m neighbourhood. Derived from DEM-S
ct_tempann	Mean annual temperature (ANUCLIM)
ct_tempmtcp	Mean temperature of the coldest period (ANUCLIM)
ct_tempmtwp	Mean temperature of the hottest period (ANUCLIM)
cw_precipann	Mean annual rainfall (ANUCLIM)
cw_precipseas	Precipitation of Seasonality: Coefficient of Variation (ANUCLIM)

ce_radann	Mean annual solar radiation (ANUCLIM)
DEM	The altitude of a cell above sea level
lf_slope_deg	The slope of a cell (derived from Altitude)
lf_rough1000	Topographic ruggedness (standard deviation in altitude) in a 1000 metres m radius (derived from Altitude)
lf_cti	Compound topographic index (derived from Altitude)

Table 4. List of the predictors recommended by experts considered for modelling.

The vegetation layer used as a predictors consisted of data from the Sydney Metropolitan Area vegetation mapping "SydneyMetroArea_v2_0_2013_E_3817" (see https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/BioNet/bionet-vegetation-map-data-release-notes-170144.pdf) and the 2013 update to the western parts of the Remnant Vegetation of the Cumberland Plain "CumberlandPlainWest_2013_E_4207" (see https://datasets.seed.nsw.gov.au/dataset/e0bed919-8e8b-45a0-803d-bcfb2a2d47e3). In addition, vegetation mapping from the PGAs undertaken by Biosis was also included in the analysis. The original vegetation maps are shape files, and the analysis used the Plant Community Type (PCT) attribute in the shape file to convert merge the above layers and convert them to a single raster layer.

The soil data used was from the NSW Soil Conservation Services 1:100,000 map series, sourced from eSpade (https://www.environment.nsw.gov.au/eSpade2Webapp). See Appendix 4 for a description of the numerical codes used for the modelling for each soil type. The soil type map was originally a shape file, and was converted to a raster file based on the soil type. Detailed consideration was given to the appropriateness of using the soil data in the modelling due to it known to be relatively coarse, and to contain some errors. On balance, it was decided the importance soil as predictor means the models are likely to be better with soil data included, compared to leaving it out.

All other predictors were provided by the NSW Department of Planning and Environment and were already in raster format.

The predictor layers were rasterized to 27m meter resolution (matching the resolution of many of the existing predictor layers) for subsequent use in the analysis, and cropped to the study area.

Checking for collinearity

Multicollinearity of predictors is a term that refers to a situation when two or more covariates are strongly correlated (Farrar and Glauber 1967). These strong correlations can have a negative effect on coefficient estimates during modelling. It can lead to situations where small changes in the data may cause large changes in estimated coefficients, resulting unreliable predictions of species occurrence (Renner and Warton 2013; Dormann et al. 2013).

The correlation coefficients for all combinations of potential predictors were calculated (see Appendix 3 for details of the correlations between predictor pairs). The correlations between predictors were estimated using the Pearson correlation, except for categorical variables, where Goodman and Kruskal's tau measure was used (Appendix 3).

If two predictors had a correlation coefficient larger than 0.8, one of them was removed. To select which predictor to remove, the following procedure was used: (i) the predictors were ranked based on the number of other predictors they are correlated with; (ii) the predictors with the highest ranks were then removed until all the remaining predictors had a correlation of less than 0.8.

After this process was completed, there were 21 predictor layers remaining, which are listed in Table 5.

Predictor code	Predictor description
ce_radann	Annual Mean Radiation
ce_radhp	Highest Period Radiation
ce_radlp	Lowest Period Radiation
ct_frostdays_lt2deg_1	Number of days/annum with minimum temperature less than 2 degrees
ct_tempann_1	Mean annual temperature
ct_tempseas_1	Temperature of Seasonality: Coefficient of Variation
cw_precipseas	Precipitation of Seasonality: Coefficient of Variation
DEM_c	The altitude of a cell above sea level
dl_lat_grid	Latitude (surrogate for location, disperal, isolation)
dl_strmdstge2	Euclidean distance to 2nd order streams and above
dl_strmdstge4	Euclidean distance to 4th order streams and above
dl_strmdstge6	Euclidean distance to 6th order streams and above
gp_k_fillspl	filtered potassium (K), gaps filled in using geograhically weighted regession model and spline function
lf_aspect_tr	Beer's Apsect
lf_slope_deg_c	The slope of a cell (derived from Altitude)
lf_cti	Compound topographic index
lf_rough0100	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 100 m neighbourhood.
lf_tpi0120	Topographic position index using neighbourhood of 120m radius
sfc_aut_b_95	Seasonal Fractional Cover representing proportions of green (g), bare (b), and non
soil	Soil type (see Appendix 4 for correspondence between numerical codes and soil code
vegitation_pct_b	Native vegetation (PCT)

Table 5. The final list of predictor layers used in the analysis.

SDM approach

Maxent requires as inputs a list of the species presences and a set of spatial predictor layers. The after running, the software produces its spatial layers depicting likelihood of species occurrence, and also returns the value for the contributions for each of the environmental predictors used for model fitting. The higher the value of the contribution the more important the predictor is fitting the model to the data, and therefor for predicting the species occurrence.

For the categorical variables (vegetation and soil type) the software returns the contribution of the individual categories. For example, for the vegetation the output is the contribution of each individual PCT, depicting which PCTs are most strongly associated with the locations of the species.

Modelling

The full inputs required for Maxent are (i) the locations of the presence and background points used for model training, (ii) the location of the presence and background points that are to be used for model validation and (iii) the spatial layers of the environmental covariates that are thought to explain species occurrences (Phillips et al., 2006).

The main output of Maxent is a spatial layer of the predicted likelihood of occurrence. Each point in this layer is assigned a value between 0 and 1 that represent the likelihood of the species being present there. Note that this is the *relative likelihood* and not a probability of occurrence, meaning it is just an estimate of how likely the species is to occur there, relative the other locations in the study area and not an absolute probability of the species being present (Phillips and Dudík 2008b; Elith et al. 2011). These values can then thresholded to obtain a binary map of likely and unlikely occurrence areas. There are multiple ways to select a threshold values (Liu, White, and Newell 2013). The threshold value was selected so the sum of the sensitivity (i.e. the true positive rate) and specificity (i.e. the true negative rate) is highest, as this has been shown to perform well compared to other approaches (Liu, White, and Newell 2013).

When running Maxent, all presence records for each species were split in 2 parts: 80% of the points were used in the modelling process to fit the modes (‘training data’), and 20% was used as ‘testing data’. The test data was used to evaluate the performance of the model by understanding how well it predicts data points it hasn’t been trained on.

The models were evaluated using ROC curves, a commonly used approach for evaluating the performance of models for binary data (Franklin 2010) . The ROC curve plots the true positive rate (correctly identified presences) against the false positive rate for different threshold (cut off) settings (Liu et al. 2016). The accuracy of the model prediction can then be measured by the *Area under the ROC curve (AUC)* metric, where a value of 1 implies a model perfectly predicts presences and absences, and the lower the value the worse the model performance.

The AUC metric was originally utilized for the site-occupancy data, to determine how well the model could predict presences and absences in data it hadn’t been trained on. In cases of PB data, AUC uses background points instead of absences and compares presences to background data. Therefore, it provides a measure for how well the model is predicting the presences locations not used to train the model.

Predictor selection

To select the predictor layers to use for the SDMs for each species a model selection process was used. Model selection starts with the list of the final environmental predictors shown in Table 5. An automated variable selection process was then undertaken for each of the species individually which consisted of the following steps:

1. The model is fitted to the training data using all the covariates in Table 5
2. The AUC for the model and the covariates contributions are calculated
3. Covariates with the lowest contribution (less than 0.02) are removed from the predictor list

4. The model is refitted with the updated predictor list and new AUC and variable contribution are calculated
5. If the AUC of the new model has either increased, or has not become lower by more than 0.05, then a new iteration starting at step 3 is undertaken to remove another predictor
6. If the AUC has decreased by more than 0.05, then the final model is selected using the predictors from the previous iteration before the AUC decreased
7. However, if there are no covariates with contribution less than 0.02 the final model is selected from this iteration

This process results in a set of predictors that unique to each species, that allows Maxent predictions that are most accurate in predicting the 20% of data that was not used in training the maxent model.

Dealing with biases in the occurrence data

Background and summary of the problem

When using PB data in the modelling, we need to compare the set of recorded presences with a set of points selected from the area where the species has not been detected.

The approach Maxent uses is randomly selecting "background points" from throughout the study area where species occurrence is to be predicted. If the presence points are unbiased (meaning people just looked in random locations and reported the species when they saw it), then this approach works well and with enough presences, can give a good prediction of the species locations.

However, the occurrence data is not unbiased as the locations where species are recorded are not randomly selected. This is due to a combination of many factors: they may be close to roads or in more easily accessible locations, they can result from targeted surveys undertaken where the species is thought likely to occur, there may be far more records on public land than on private land, etc.

Maxent provides a method to help account for these potential biases in the occurrence data. It allows users to provide a spatial layer (called a "bias layer") describing the bias in where the species locations are recorded. It tells Maxent that in certain locations, no one ever looked for the species. Maxent then uses this bias layer to select its background points. If the bias layer is known correctly, then including the bias layer can greatly improve the SDM predictions. The problem is that while it's likely that the occurrence records for each species in Cumberland Subregion are biased, we don't exactly how they are biased, and the bias may be different for each species.

Using multiple bias layers

Our proposed solution to this problem was to undertake three models for each species, each with different assumptions regarding the potential bias in the records:

1. *Bias layer 1*: assumes the records are unbiased and that the species was searched for at random locations in the landscape with only presences recorded. Thus, the bias layer is the whole study area.
2. *Bias layer 2*: assumes that there are biases in where the species were searched for, but that it is the same for all species. It aggregates the records of all species together,

buffers them, and assumes this provides a good description of the bias in where species were searched for.

3. *Bias layer 3*: assumes there are biases in where the species where searched for, but that this may vary between species. It generates a separate bias layer for each species, by buffering just presence locations of the species being modelled, and assumes this is a good description of where the species was searched for.

While none of these bias layers are going be an accurate description of where the species was searched for, our assumption is that for each species, one of these bias layers is going to be a reasonable approximation in describing the biases in the presence records. Thus, our approach is to run 3 maxent models, with each of the 3 bias layers above. Though it should be noted, that the model selection process as described above was used to select the predictors for each species using *bias layer 1*. These same selected predictors were then used in generating the models with *bias layer 2* and *bias layer 3*. Thus, the three different SDMs all had the same set of predictors, making comparing and summarizing the predictor contributions more appropriate across the three SDMs.

For each of these SDMs, generated with a different bias layer, were then converted into a binary presence-absence layer (using maxent's build-in method that selects a threshold based on getting the same rate of false presences and false absences; see above). This produced 3 binary layers which can be aggregated into to a single layer with 3 possible values:

0 ("***unlikely to occur***") - locations where none of the binary maps showed the species occurring

1 ("***potential to occur***") - locations where at least one on the maps showed the species occurring

3 ("***likely to occur***") - locations where all 3 of the maps showed the species to occur

Interpretation

"Unlikely to occur" areas are where none of the binary maps predicted that the species is likely to be present. "Potential to occur" is a conservative estimate showing everywhere the species could potentially occur, accounting for the different plausible assumptions about how we could approximate the biases in the data. "Likely to occur" shows only areas that were predicted to be habitat under all 3 assumptions regarding how the data would be biased. This is likely to miss some locations where the species occurs, but as these areas always come up no matter what we assume regarding the biases, they can more robustly be assumed to capture the presence of the species.

This can also be seen as a risk-based approach where (subject to model assumptions), "potential to occur" minimizes the risk of missing an area where the species occurs, and "likely to occur" minimizes the risk of selecting an area where the species doesn't occur. Thus "potential to occur" is more appropriate for assessing the impacts on species, while "likely to occur" is more appropriate targeting conservation actions such as offsets.

Source code and data availability

The analysis was undertaken using open source statistical programming language R (version 3.5.1), and utilized the following packages:

- rJava version 0.9-10
- caTools version 1.17.1.1
- ENMeval version 0.3.0

- dismo version 1.1-4
- maptools version 0.9-4
- raster version 2.6-7
- rgdal version 1.3-4
- sp version 1.3-1
- knitr version 1.20

The knitr_1.20 package was used to generate the automated reports presented in Appendices 1 and 2.

All the source code to undertake the analysis is available via Github at: https://github.com/thekoshkina/WSSSP-Modelling/tree/master/SDM

The spatial layers for the covariates used in the analysis are available at: http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/covariates.zip

Results

The full results for all species are presented in Appendix 1 and 2. Appendix 1 contains the SDMs produced by Maxent for each species with each of the three different bias layers. For each of 19 species, the Appendix 1 presents:

- Summary information for the species
- A table with the predictor layers used for the species (the three SDMs with the different bias layer all use the same predictors)
- Maps of the Maxent output for the each of the three bias layers showing:
    - The relative likelihood of occurrence map produced for the species, and then this map thresholded into a binary presence/absence map such that false presence absence and false presence rates are the same
    - The AUC value for the SDMs
    - These two maps are shown with and without the species presences overlaid as blue dots
- The contribution of each predictor layer for each the three SDMs with different bias layers
- For layers where the categorical variables of soil and vegetation are used, the contributions of each of the soil and vegetation categories are given.

Appendix 2 then presents the single SDMs for each species aggregated from the SDMs generated with the three bias layers, as described above. For each of the 19 species, the Appendix 2 shows:

- Summary information for the species, and
- A table with the predictor layers used for the species
- A table with average contribution of each predictors across the 3 SDMs with the different bias layers, and the 3 highest contributing soil types and PCTs for across the 3 SDMs (where vegetation and soil type were included as predictors)
- The three-category risk-based occurrence map for the species, both with and without the species occurrences overlaid

Figure 2 – Figure 4 show example output SDMs for *Pultenaea parviflora* for the three different bias layers, with the occurrences of the species shown as blue points. The SDM results for bias layers 1 and 2 are similar (Figure 2 and Figure 3), however using bias layer 3 (where the background points are chosen from the areas around the recorded presences the species), results in a significantly different SDM with areas of higher likelihood of occurrence spread over a much larger area (Figure 4). This trend of the bias layers 1 and 2 producing more similar results and bias layer 3 producing a significantly different result was a common result across most of the species modelled (Appendix 1). However, for the Grey-headed Flying-fox (*Pteropus poliocephalus*) all three bias layers resulted in more similar results (Appendix 1) and for the Australasian Bittern (*Botaurus poiciloptilus*), bias layer 2 resulted in a significantly different result, while bias layers 1 and 3 were more similar (Appendix 1).

The results from the three bias layers are then combined to produce the three-category risk-based map shown in for the example of *Pultenaea parviflora* (Figure 5). In this case, the areas depicted where the species are “most likely to occur” overlaps the vast majority of the species occurrences.

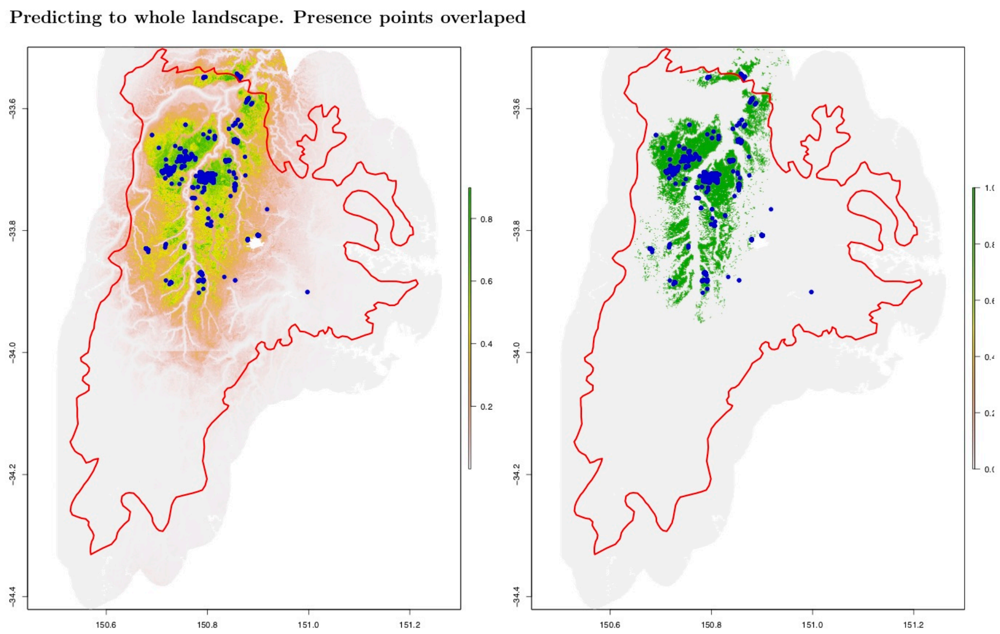


Figure 2 Predicted likelihood of occurrence map generated by Maxent for *Pultenaea parviflora* using bias layer 1. The left figure shows the raw likelihood of occurrence map generated by Maxent, the right figure shows the version of the map where it has been thresholded to produce a binary map of predicted presence/absence of the species based on selecting a threshold level such that false presence and false absence rate are the same. Occurrences of the species are shown as blue points.

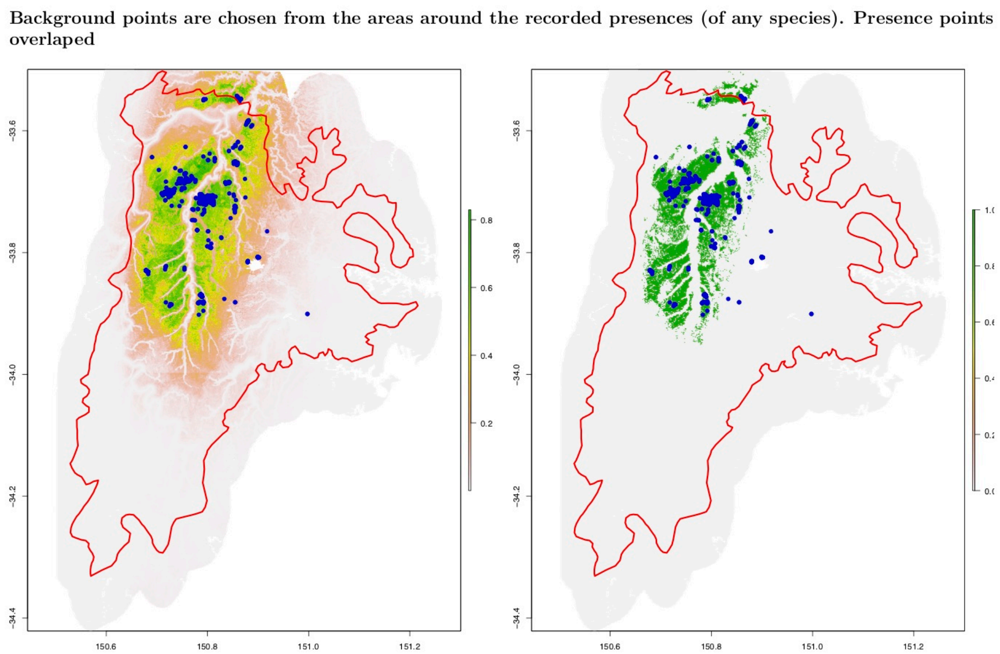


Figure 3 Predicted likelihood of occurrence map generated by Maxent for *Pultenaea parviflora* using bias layer 2. The left figure shows the raw likelihood of occurrence map generated by Maxent, the right figure shows the version of the map where it has been thresholded to produce a binary map of predicted presence/absence as described in Figure 2. Occurrences of the species are shown as blue points.

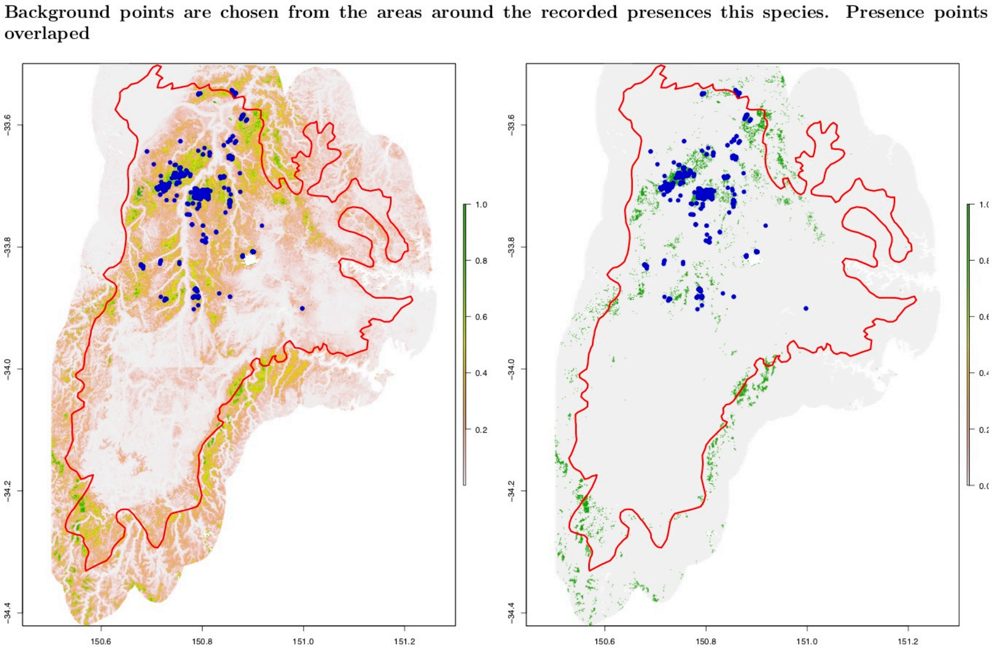


Figure 4 Predicted likelihood of occurrence map generated by Maxent for *Pultenaea parviflora* using bias layer 3. The left figure shows the raw likelihood of occurrence map generated by Maxent, the right figure shows the version of the map where it has been thresholded to produce a binary map of predicted presence/absence as described in Figure 2. Occurrences of the species are shown as blue points.

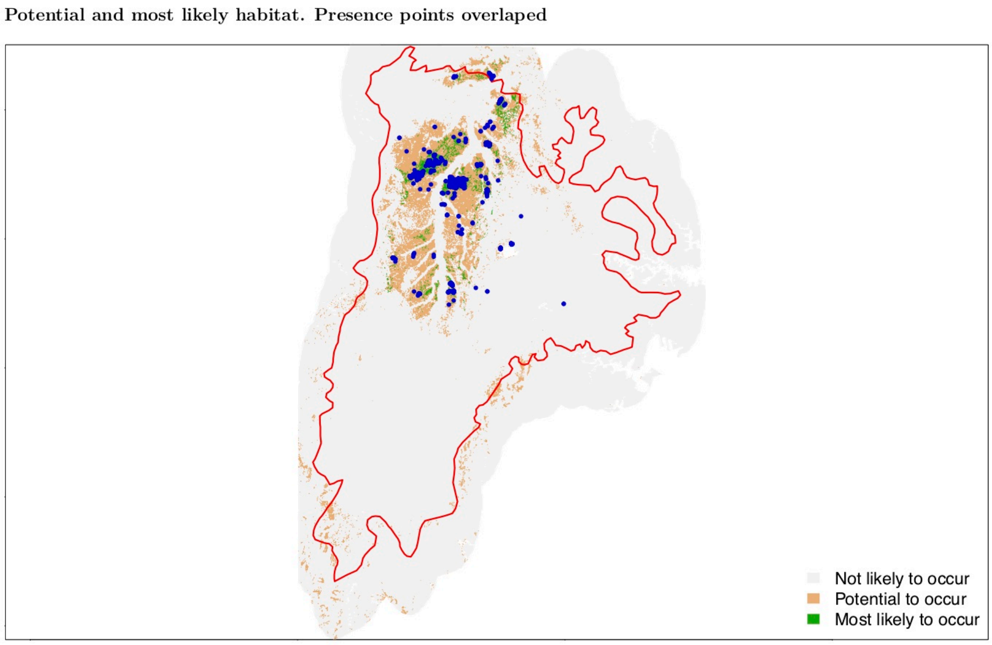


Figure 5 The final risk-based likelihood of occurrence map for *Pultenaea parviflora*. This is generated from maps in the three previous figures as described in the methods, and indicates areas where the species is "not likely to occur" (none of the previous three maps thresholded maps predicted occurrence), has "potential to occur" (at least one of the previous three maps thresholded maps predicted occurrence) and is "most likely to occur" (all three of the previous thresholded maps predicted occurrence). Occurrences of the species are shown as blue points.

Potential and most likely habitat. Presence points overlaped

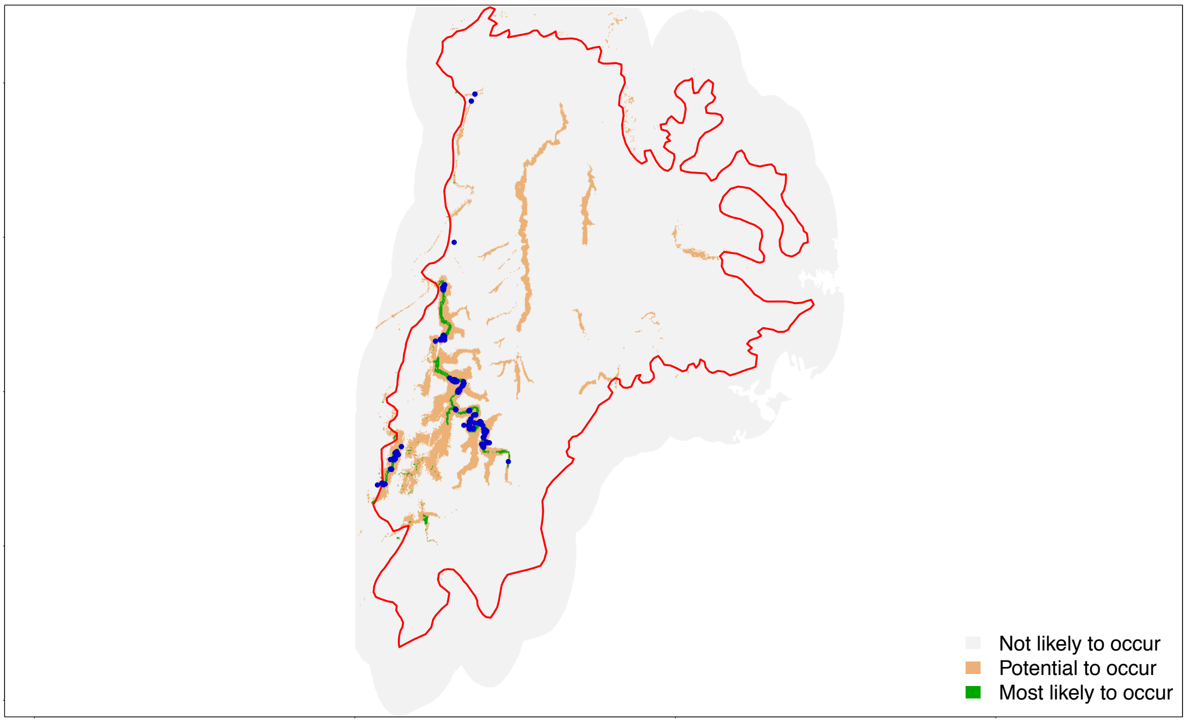


Figure 6 The risk-based SMD output for the Camden White Gum (*Eucalyptus benthamii*). Occurrences of the species are shown as blue points.

Potential and most likely habitat. Presence points overlaped

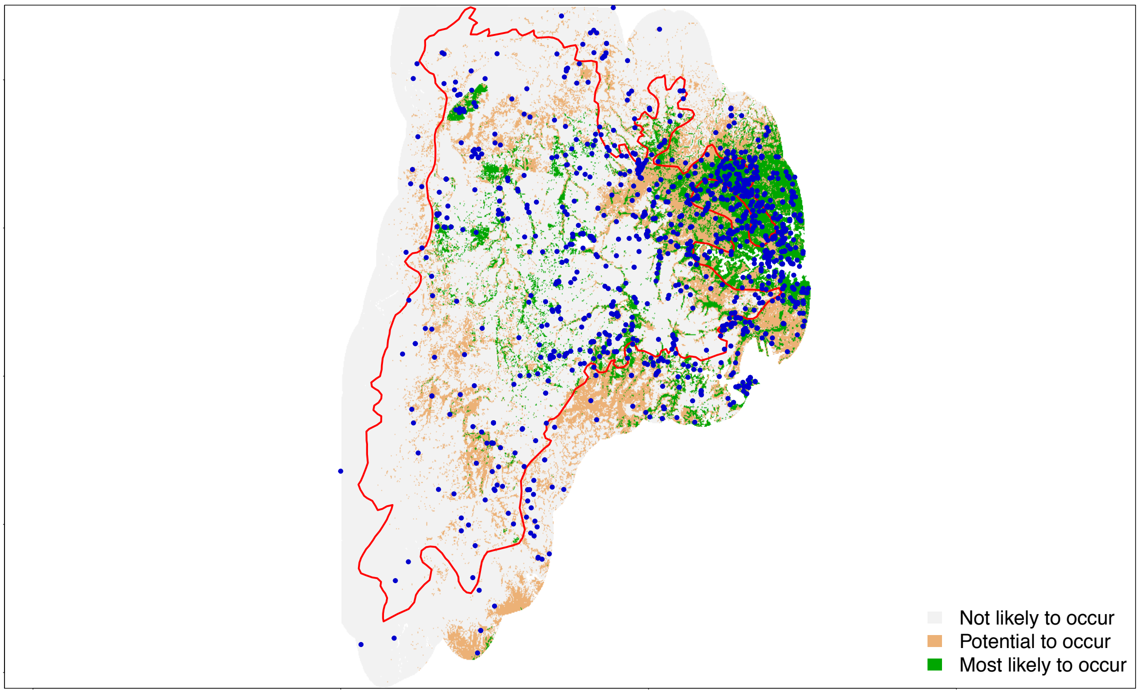
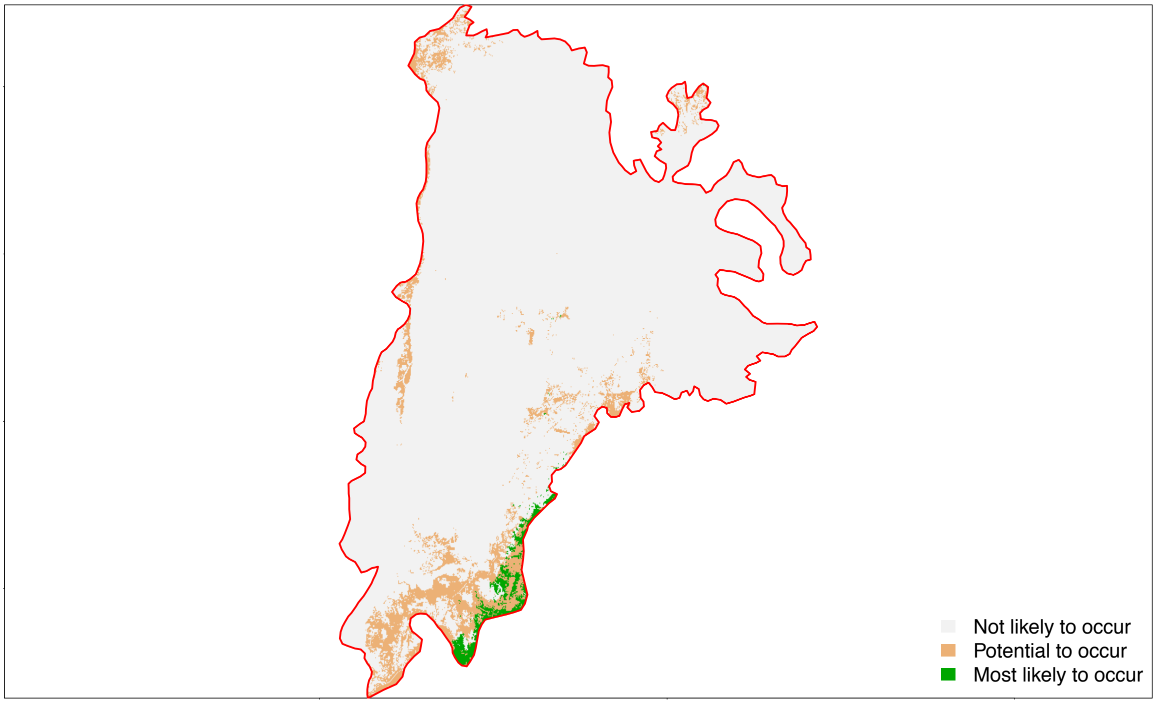


Figure 7 The risk-based SMD output for the Grey-headed Flying-fox (*Pteropus poliocephalus*). Occurrences of the species are shown as blue points.

Potential and most likely habitat



Potential and most likely habitat. Presence points overlaped

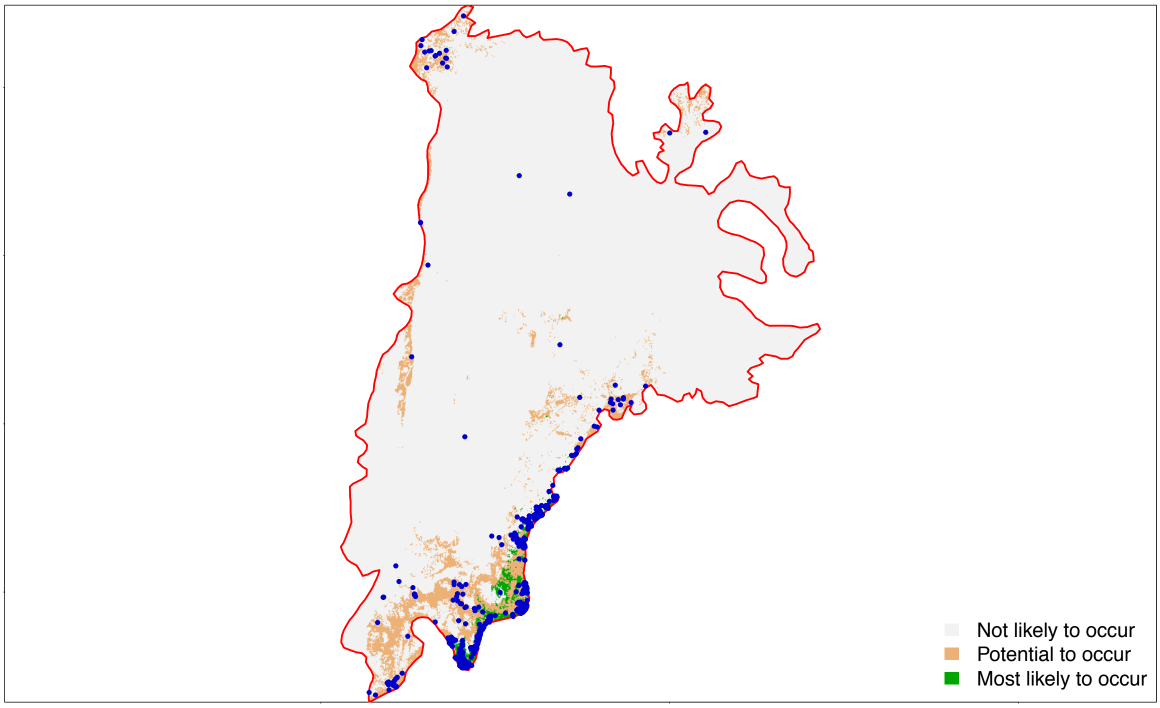


Figure 8 The risk-based SMD output for the Koala (Phascolarctos cinereus). For clarity the SDM outputs are presented with (bottom plot) and without (top plot) the occurrences of the species (shown as blue points).

Figures 6–Figure 8, show three additional examples of the risk-based SDMs for the Camden White Gum, the Grey-headed Flying-fox and Koala, respectively. These show a SDM outputs for a more localised species (Camden White Gum; Figure 6), compared to the wide spread presence sighting of the Grey-headed Flying-fox (Figure 7). For the Grey-headed Flying-fox, only records associated with colonies were used and for this species it's clear that a greater proportion of the records do overlap the potential or likely to occur areas in the risk-based SDM. Figure 8 shows the results for the Kola. Due to the large number of presence records (915 used in the modelling), the SDM is shown for clarity both with and without the Koala presences overlaid. It should be noted that unlike the other species the Koala SDM was only undertaken for the Cumberland Subregion, excluding the buffer (see Discussion). For the Koala, only records associated with native vegetation were used, to exclude records associated with dispersing males outside their habitat. In this case almost all of the records overlapped areas of potential and most likely habitat.

The predictors with the highest contributions varied for each species, and while the same predictors were used in the SDMs for each of the three bias layers, their relative contributions are often differed between the SDMs with the three different bias layers. The number of predictors used for each species could also vary, due to the model selection process (described above). Species had as low as 5 predictors (e.g. the Bargo Geebung *Persoonia bargoensis*) or as many as 15 (e.g. the Giant Burrowing Frog *Heleioporus australiacus*) (see Appendix 2). While soil type and vegetation were important predictors for many of the species they were not always the ones with the largest contributions.

Figure 9 shows the AUC values for SDMs produced for each species, with the AUC values for each of the bias layers shown in a different colour. In general, SDMs with bias layer 3 tended to have lower AUC scores. There is only one poor performing model, which is for the Australasian Bittern (*Botaurus poiciloptilus*), when using bias layer 3 (results in an AUC score of 0.57; Figure 9). All other SDMs across species and bias layers have AUC scores greater than 0.7, with the majority of them having AUC score greater than 0.9 (Figure 9).

Results availability online

The full results presented here are available by contacting the authors or online as follows.

Pdf documents containing all risk-based maps are available here:
http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/risk-based-occurence-maps.pdf

A pdf document containing the all the SDMs with different bias layers is available here:
http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/full-SDMs-for-all-spp.pdf

Raster files of the Maxent risk-based SMDs are available here:
http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/risk-based-occurence-maps_tiffs.zip

Raster files of the Maxent SMDs with the three bias layers are available here:
http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/full-SDMs-for-all-spp.zip

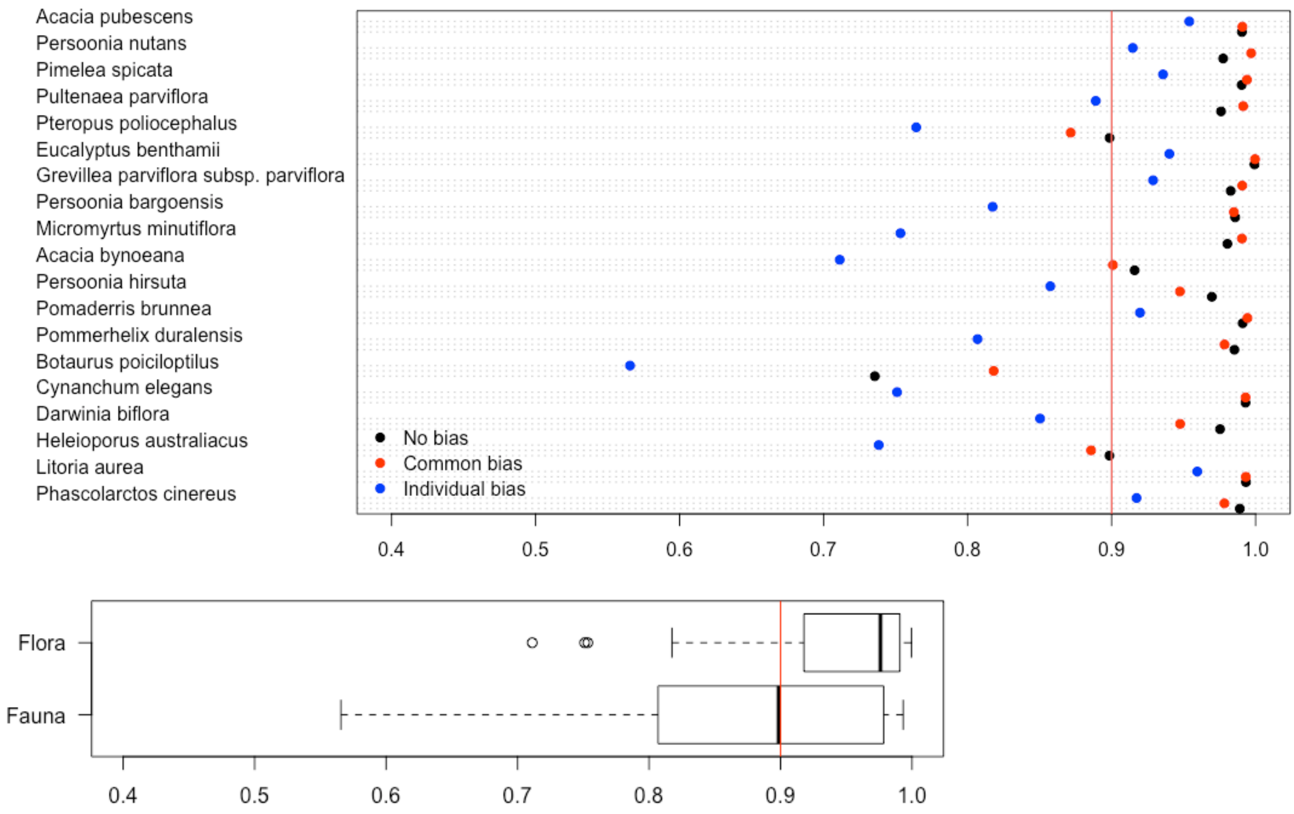


Figure 9 The AUC values for the SDMs for all species. The results for the 3 bias layers are shown in black (bias layer 1–no bias), red (bias layer 2–common bias) and blue (bias layer 3–individual bias). The lower plot shows the distribution of AUC scores for all flora and all fauna, as box plots.

Discussion

We have presented SDMs for 13 flora species and 6 fauna species for the Cumberland Subregion (IBRA 7). Using the risk-based approach we have produced maps using the Maxent species distribution modelling package that depict where a species is likely to occur using three classes of: “unlikely to occur”, "potential to occur" and "likely to occur".

Species maps

All the resulting SDMs tended to have high AUC scores (the majority of them were over 0.9 with only one model less than 0.7; Figure 9). This means that in most cases the resulting models accurately predicted the locations of records that were not used to train the model. However, a high AUC score does not necessarily mean it should be concluded that the resulting SDM is an accurate representation of the true species likelihood of occurrence. It just means that it is an accurate representation of the presence records used to train the model. If these species records are highly biased, an SDM output may have a high AUC score and still provide a highly biased result. We have tried to control for bias in the occurrence data by using different bias layers in Maxent as described above.

In general, the approach to generating SDMs may over-predict the habitat for species. This may be partly due to anthropogenic factors limiting the current distribution of species, and the fact that predictors capturing these factors were not incorporated due to lack of available data. In other cases, errors in the occurrence data and/or covariate layers (particularly vegetation and soil) mean that Maxent may pick up associations between species and PCTs or soil types that are artefacts. However, the "likely to occur" regions of the SDMs are significantly reduced compared to the “potential to occur” regions and thus are less likely to involve over-predictions.

It should be noted that risk-based SMD results do not always predict regions for "likely to occur" and “potential to occur” that overlap every single species presence record used in the modelling. There can be numerous reasons for this. However, the general point is that Maxent is designed to produce a probability layer that does not “overfit” the data (see methods). A model that is overfitted produce an SDM that predicts to all occurrences used to train the model accurately, while predicting to locations not used to train the model poorly. The result of not overfitting (achieved through using the “maximum entropy distributions”) is that while most species occurrences will be located in predicted and likely/potential to occur areas, not all presences will be in these areas.

Below we discuss some of the SDMs for specific species.

Fauna

The koala is a difficult species to model, and more detailed modelling of its potential feed trees is being undertaken by OEH. The SDM presented here results from the records used from BioNet (which may be highly biased away from the heavily cleared and fragmented parts of Cumberland Plain) and their associations with the available predictors. As discussed above, records not associated with native vegetation were excluded from the model, as it was hypothesized that in many cases these would correspond to dispersing male koalas (a known behaviour after breeding) and would not be associated with breeding habitat. In addition, it’s important to note the SDM here differs from the other SDMs in that we exclude the 10km buffer around the Cumberland Plain when modelling this species, and only use the records within the Cumberland Subregion. The reason for this was that there were a large number of additional Koala records located in the buffer region (>2700 records). This large number of records outside the Cumberland Subregion, skewed the model to predict only a small amount of habitat within the Cumberland Subregion, compared to modelling the species just with the Cumberland Subregion. While the model trained just on the presences for the Cumberland Subregion, predicts a greater amount of koala habitat, it still predicts an absence of koala occurrence on most of the Cumberland Plain. While there may not be koalas in many of these areas now due to fragmentation and anthropogenic threats, there may much more theoretically sound potential habitat on the plain in terms of PCTs on the Cumberland Plain then is currently depicted by the SDM produced here.

After some consideration it was decided to undertake an SDM for the Green and Golden Bell Frog (*Litoria aurea*). However, the resulting predictions should be used with some caution as there are important factors driving its distribution for which appropriate predictors were not available. For example, Chytridiomycosis is known to impact where the species occurs. In addition, the Green and Golden Bell Frog is known not to be restricted to areas surrounded by native vegetation and has been found in quarries, constructed ponds, and small bodies of the water on the ground (Enhua Lee, OEH, personal communication).

As the Grey-headed Flying-fox (Pteropus poliocephalus), forages widely, it was decided to exclude foraging records and only use those associated with colonies, as otherwise without this constraint, the whole region may be potential foraging habitat for the species. In the resulting SDMs, there is more habitat than expected, so the model may be over predicting slightly (Paul Burcher, personal communication).

Further the SDM for Dural Woodland Snail may have overestimated most ‘potential to occur’ habitat as the species is thought to be restricted to the northern margins of the sub-region at the shale/sandstone interface (Paul Burcher, personal communication).

Plants

The White-flowered Wax Plant (*Cynanchum elegans*) has 23 records that were used for the modelling. Due to the small number of records, the SDM resulting from this species should be treated with some caution.

Hairy Geebung (*Persoonia hirsute*), and *Darwinia biflora* have a small proportion of their records within the Cumberland Subregion (most records being in the 10km buffer region) and the resulting SDMs estimate that a small proportion of their habitat occurs inside the Cumberland subregion.

Several of the SDM layers are expected to over-predict the likely areas where the species occur. While this may be acceptable from a precautionary approach, in some cases the models are predicting likely occurrences beyond the range where the species is known to occur. For example, the *Persoonia nutans*, the habitat map predicts the potential for the species to occur in too far south and to the northeast. It has never been known to occur in the Hornsby Plateau, and is confined to the Cumberland Plain except for an outlier in the North West, and an outlier in the South, both in close proximity to the Plain (Steve Douglas, personal communication). Likewise, the model for *Acacia pubescens* likely over-predicts potential habitat and the model for *Acacia bynoeana* may also predict more potential habitat than would be expected based on soils and PCTs (Steve Douglas, personal communication).

Limitations

As discussed earlier in this report, there are multiple factors that limit the SDM approach for the fauna and flora species in the Cumberland Subregion.

Firstly, for some of the species, this study area only involves a small part of the species range, in which case we may be missing parts of species’ niche and making poor predictions. Initially this project planned to model species within a 100km buffer of the Cumberland Subregion, however at the time undertaking this analysis, vegetation maps containing PCT information was not available for all of this region. There was also not full coverage of this region for soil data (see https://www.environment.nsw.gov.au/eSpade2Webapp). Thus, we limited the study area to a 10 km buffer around the Cumberland Subregion (constrained to where PCT information was available). For these wider ranging species, modelling over a great proportion of their range may result in improved SDMs. However, the ranges of some of the other species modelled here are very range restricted and are limited to within or near the Cumberland Subregion. This species also pose other challenges to model as historical accidents and competition with other species could be driving their current locations, both factors that are unaccounted for in most SDMs (however see Pollock et al. 2014).

The highly-modified landscapes with the Cumberland Subregion mean that in many areas there are high level of fragmentation and anthropogenic threats. This may result in the standard assumptions regarding a species occupying its niche not to apply, meaning that large areas of previous potential habitat may no longer be occupied.

As discussed there is an unknown but potentially large amounts bias in the occurrence records. Here we have first to cleaned the data, and then used multiple bias layers in an attempt to deal with different amount of bias.

Another point to note is that the analysis presented her should be considered purely as attempting to model where the species are *likely to occur*. It does not attempt to model the most effectively locations to conserve the species in the Cumberland Subregion. To do this would require multiple additional factors to be incorporated, including connectivity between locations where the species is likely to occur, and other factors known to affect the viability of the species such as the size of habitat patches, the surrounding landuses and the presence of threats to the species. To undertake this type of analysis there are a range of spatial prioritization tool that can be used such as Zonation (Gordon et al. 2009), however such an analysis is beyond the scope is this project.

Other issues that may also limit or confound the outputs of the SDMs are:

- The fact that detectability may be an issue for some species, meaning they are more likely to be observed in some locations than others (Guillera-Arroita 2016)
- Although we used the best available soil mapping, it is known to be relatively coarse and to contain some errors
- For some of the species, there may be false associations between records and PCTs. This due to spatial errors in the point locations and and/or the PCT maps (Steve Douglas, personal communication)

Extensions of this work

This work could be extended in several ways to improve the predictions produced by the Maxent SDMs. When PCT information is available for all of NSE, it will be possible to model many of the species over a greater area. This may result in improved predictions within the Cumberland Subregion.

For some flora species, there are survey results that incorporate both presence and absence of the species. Having presence and absence data can result in more accurate SDM predictions and there are now approaches where models can be fit with presence-absence data and presence only data simultaneously, making better use of all available data (Koshkina et al. 2017).

It is likely that some of the SDMs presented here over-predict the locations of species beyond their known range. One solution to this issue would be to use expert-derived estimates of the predicted range of the species and then only use SDMs to make predictions to areas within the this predicted range. These range maps would likely capture all the presence records of the species, and constrain the SDM predictions reducing the amount they over-predict.

References

Brown, Christopher D., and Herbert T. Davis. 2006. 'Receiver Operating Characteristics Curves and Related Decision Measures: A Tutorial'. *Chemometrics and Intelligent Laboratory Systems* 80 (1): 24–38. https://doi.org/10.1016/j.chemolab.2005.05.004.

Dormann, Carsten F., Jane Elith, Sven Bacher, Carsten Buchmann, Gudrun Carl, Gabriel Carré, Jaime R. García Marquéz, et al. 2013. 'Collinearity: A Review of Methods to Deal with It and a Simulation Study Evaluating Their Performance'. *Ecography* 36 (1): 027–046. https://doi.org/10.1111/j.1600-0587.2012.07348.x.

Elith, Jane, Catherine H. Graham, Robert P. Anderson, Miroslav Dudík, Simon Ferrier, Antoine Guisan, Robert J. Hijmans, et al. 2006. 'Novel Methods Improve Prediction of Species' Distributions from Occurrence Data'. *Ecography* 29 (2): 129–151. https://doi.org/10.1111/j.2006.0906-7590.04596.x.

Elith, Jane, Steven J. Phillips, Trevor Hastie, Miroslav Dudík, Yung En Chee, and Colin J. Yates. 2011. 'A Statistical Explanation of MaxEnt for Ecologists'. *Diversity and Distributions* 17 (1): 43–57. https://doi.org/10.1111/j.1472-4642.2010.00725.x.

Farrar, Donald E., and Robert R. Glauber. 1967. 'Multicollinearity in Regression Analysis: The Problem Revisited'. *The Review of Economics and Statistics* 49 (1): 92. https://doi.org/10.2307/1937887.

Franklin, Janet. 2010. *Mapping Species Distributions: Spatial Inference and Prediction*. Cambridge University Press.

Gordon, Ascelin, David Simondson, Matt White, Atte Moilanen, and Sarah Adine Bekessy. 2009. 'Integrating Conservation Planning and Landuse Planning in Urban Landscapes'. *Landscape and Urban Planning* 91 (4): 183–94. https://doi.org/10.1016/j.landurbplan.2008.12.011.

Guillera-Arroita, Gurutzeta. 2016. 'Modelling of Species Distributions, Range Dynamics and Communities under Imperfect Detection: Advances, Challenges and Opportunities'. *Ecography*, June. https://doi.org/10.1111/ecog.02445.

Guillera-Arroita, Gurutzeta, José J. Lahoz-Monfort, Jane Elith, Ascelin Gordon, Heini Kujala, Pia E. Lentini, Michael A. McCarthy, Reid Tingley, and Brendan A. Wintle. 2015. 'Is My Species Distribution Model Fit for Purpose? Matching Data and Models to Applications: Matching Distribution Models to Applications'. *Global Ecology and Biogeography* 24 (3): 276–92. https://doi.org/10.1111/geb.12268.

Koshkina, Vira, Yan Wang, Ascelin Gordon, Robert M. Dorazio, Matt White, and Lewi Stone. 2017. 'Integrated Species Distribution Models: Combining Presence-Background Data and Site-Occupancy Data with Imperfect Detection'. Edited by David Warton. *Methods in Ecology and Evolution* 8 (4): 420–30. https://doi.org/10.1111/2041-210X.12738.

Kujala, Heini, Amy L Whitehead, and Brendan A Wintle. n.d. 'Identifying Conservation Priorities and Assessing Impacts and Trade-offs of Potential Future Development in the Lower Hunter Valley in New South Wales', 106.

Liu, Canran, Matt White, and Graeme Newell. 2013. ‘Selecting Thresholds for the Prediction of Species Occurrence with Presence-Only Data’. *Journal of Biogeography* 40 (4): 778–89. https://doi.org/10.1111/jbi.12058.

Merow, Cory, Matthew J. Smith, and John a. Silander. 2013. ‘A Practical Guide to MaxEnt for Modeling Species’ Distributions: What It Does, and Why Inputs and Settings Matter’. *Ecography* 36 (10): 1058–1069. https://doi.org/10.1111/j.1600-0587.2013.07872.x.

Phillips, Steven J., Robert P. Anderson, Miroslav Dudík, Robert E. Schapire, and Mary E. Blair. 2017. ‘Opening the Black Box: An Open-Source Release of Maxent’. *Ecography* 40 (7): 887–93. https://doi.org/10.1111/ecog.03049.

Phillips, Steven J., Robert P. Anderson, and Robert E. Schapire. 2006. ‘Maximum Entropy Modeling of Species Geographic Distributions’. *Ecological Modelling* 190 (3–4): 231–59. https://doi.org/10.1016/j.ecolmodel.2005.03.026.

Phillips, Steven J., and Miroslav Dudík. 2008a. ‘Modeling of Species Distributions with Maxent: New Extensions and a Comprehensive Evaluation’. *Ecography* 31 (2): 161–175. https://doi.org/10.1111/j.0906-7590.2008.5203.x.

———. 2008b. ‘Modeling of Species Distributions with Maxent: New Extensions and a Comprehensive Evaluation’. *Ecography* 31 (2): 161–175.

Pollock, Laura J., Reid Tingley, William K. Morris, Nick Golding, Robert B. O’Hara, Kirsten M. Parris, Peter A. Vesk, and Michael A. McCarthy. 2014. ‘Understanding Co-Occurrence by Modelling Species Simultaneously with a Joint Species Distribution Model (JSDM)’. *Methods in Ecology and Evolution* 5 (5): 397–406. https://doi.org/10.1111/2041-210X.12180.

Renner, Ian W., and David I. Warton. 2013. ‘Equivalence of MAXENT and Poisson Point Process Models for Species Distribution Modeling in Ecology: Equivalence of MAXENT and Poisson Point Process Models’. *Biometrics* 69 (1): 274–81. https://doi.org/10.1111/j.1541-0420.2012.01824.x.

Appendix 1 - Maxent model results for all species and all bias layers

All maps and tables are contained in the supporting document “full-SDMs-for-all-spp.pdf” supplied with this report. This file is also available by contacting the authors or from http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/full-SDMs-for-all-spp.pdf. Summary information supplied in this document:

- A table with the predictor layers used for the species (the three SDMs with the different bias layer all use the same predictors)
- Maps of the Maxent output for the each of the three bias layers showing:
    - The relative likelihood of occurrence map produced for the species, and then this map thresholded into a binary presence/absence map such that false presence absence and false presence rates are the same
    - The AUC value for the SDMs
    - These two maps are shown with and without the species presences overlaid as blue dots
- The contribution of each predictor layer for each the three SDMs with different bias layers
- For layers where the categorical variables of soil and vegetation are used, the contributions to the of each of the soil and vegetation categories are given.

Appendix 2 - Risk-based 3-category SDMs for each species

All maps and tables are contained in the supporting document "risk-based-occurence-maps.pdf" supplied with this report. This file is also available by contacting the authors or from http://glass.eres.rmit.edu.au/tzar_input/sydney-cumberland-plain-SDM/risk-based-occurence-maps.pdf. Summary information supplied in this document:

- Summary information for the species, and a table with the predictor layers used for the species
- A table with average contribution of each predictors across the 3 SDMs with the different bias layers, and the 3 highest contributing soil types and PCTs for across the 3 SDMs (where vegetation and soil type were included as predictors)
- The three-category risk-based occurrence map for the species, both with and without the species occurrences overlaid.

Appendix 3 - Correlations between predictor variable

The correlations between predictors were estimated using the Pearson correlation, except for categorical variables, where Goodman and Kruskal's tau measure was used. Figure A3.1 shows the correlations between the categorical predicators. Table A3.1 shows the Person correlation between all other predictors.

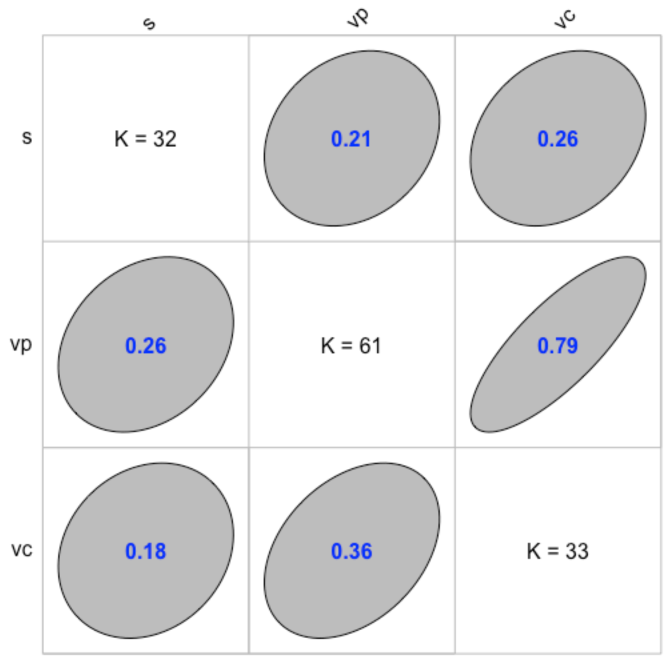


Figure A3.1 TS – The correlations between the categorical predictor layers used in the analysis. In this plot, S is soil, Vp is vegetation PCT, Vc, vegetation community. K is the number of categories in of the categorical predictors.

	ce_radann_c	ce_radhp_c	ce_radlp_c	ct_frostdays_lt2deg_1_c	ct_temp_maxsum_1_c	ct_temp_maxwin_1_c	ct_temp_minsum_1_c	ct_temp_minwin_1_c	ct_tempann_1_c	ct_tempannrnge_1_c	ct_tempdiurn_1_c	ct_tempmtcp_1_c	ct_tempmtwp_1_c	ct_tempseas_1_c	cw_etaaann_1_c	cw_precipann_1_c	cw_precipseas_c	DEM_c	dl_lat_grid_c	dl_long_grid_c
ce_radann_c	1.0	0.7	0.7	0.2	0.5	0.3	-0.1	-0.5	0.2	0.7	0.7	-0.4	0.7	0.6	-0.1	-1.0	0.3	-0.4	0.0	-0.5
ce_radhp_c	0.7	1.0	0.0	0.2	-0.1	0.0	-0.2	-0.3	0.0	0.3	0.3	-0.3	0.1	0.2	0.2	-0.8	-0.4	-0.1	-0.5	-0.3
ce_radlp_c	0.7	0.0	1.0	-0.1	0.9	0.6	0.3	-0.2	0.6	0.6	0.6	-0.1	0.9	0.5	-0.6	-0.5	0.8	-0.6	0.7	-0.2
ct_frostdays_lt2deg_1_c	0.2	0.2	-0.1	1.0	-0.3	-0.8	-0.9	-0.9	-0.8	0.7	0.6	-0.9	0.1	0.7	0.8	-0.4	0.2	0.7	-0.5	-0.9
ct_temp_maxsum_1_c	0.5	-0.1	0.9	-0.3	1.0	0.8	0.4	-0.1	0.7	0.4	0.5	0.1	0.9	0.4	-0.7	-0.4	0.8	-0.7	0.8	0.0
ct_temp_maxwin_1_c	0.3	0.0	0.6	-0.8	0.8	1.0	0.9	0.5	0.9	-0.2	-0.1	0.6	0.5	-0.3	-0.9	0.0	0.3	-0.9	0.7	0.5
ct_temp_minsum_1_c	-0.1	-0.2	0.3	-0.9	0.4	0.9	1.0	0.9	0.9	-0.6	-0.6	0.9	0.0	-0.7	-0.8	0.4	0.0	-0.8	0.6	0.9
ct_temp_minwin_1_c	-0.5	-0.3	-0.2	-0.9	-0.1	0.5	0.9	1.0	0.6	-0.9	-0.9	1.0	-0.4	-0.9	-0.6	0.7	-0.4	-0.5	0.3	1.0
ct_tempann_1_c	0.2	0.0	0.6	-0.8	0.7	0.9	0.9	0.6	1.0	-0.2	-0.2	0.7	0.4	-0.3	-0.9	0.0	0.2	-1.0	0.7	0.6
ct_tempannrnge_1_c	0.7	0.3	0.6	0.7	0.4	-0.2	-0.6	-0.9	-0.2	1.0	1.0	-0.9	0.8	1.0	0.2	-0.8	0.7	0.1	0.0	-0.9
ct_tempdiurn_1_c	0.7	0.3	0.6	0.6	0.5	-0.1	-0.6	-0.9	-0.2	1.0	1.0	-0.8	0.8	1.0	0.2	-0.8	0.7	0.1	0.0	-0.9
ct_tempmtcp_1_c	-0.4	-0.3	-0.1	-0.9	0.1	0.6	0.9	1.0	0.7	-0.9	-0.8	1.0	-0.3	-0.9	-0.6	0.6	-0.3	-0.6	0.4	1.0
ct_tempmtwp_1_c	0.7	0.1	0.9	0.1	0.9	0.5	0.0	-0.4	0.4	0.8	0.8	-0.3	1.0	0.7	-0.4	-0.6	0.8	-0.5	0.6	-0.4
ct_tempseas_1_c	0.6	0.2	0.5	0.7	0.4	-0.3	-0.7	-0.9	-0.3	1.0	1.0	-0.9	0.7	1.0	0.3	-0.7	0.7	0.2	0.0	-0.9
cw_etaaann_1_c	-0.1	0.2	-0.6	0.8	-0.7	-0.9	-0.8	-0.6	-0.9	0.2	0.2	-0.6	-0.4	0.3	1.0	-0.1	-0.3	0.8	-0.8	-0.6
cw_precipann_1_c	-1.0	-0.8	-0.5	-0.4	-0.4	0.0	0.4	0.7	0.0	-0.8	-0.8	0.6	-0.6	-0.7	-0.1	1.0	-0.2	0.1	0.2	0.7
cw_precipseas_c	0.3	-0.4	0.8	0.2	0.8	0.3	0.0	-0.4	0.2	0.7	0.7	-0.3	0.8	0.7	-0.3	-0.2	1.0	-0.2	0.7	-0.4
DEM_c	-0.4	-0.1	-0.6	0.7	-0.7	-0.9	-0.8	-0.5	-1.0	0.1	0.1	-0.6	-0.5	0.2	0.8	0.1	-0.2	1.0	-0.6	-0.5
dl_lat_grid_c	0.0	-0.5	0.7	-0.5	0.8	0.7	0.6	0.3	0.7	0.0	0.0	0.4	0.6	0.0	-0.8	0.2	0.7	-0.6	1.0	0.4
dl_long_grid_c	-0.5	-0.3	-0.2	-0.9	0.0	0.5	0.9	1.0	0.6	-0.9	-0.9	1.0	-0.4	-0.9	-0.6	0.7	-0.4	-0.5	0.4	1.0
dl_strmdstge2_c	-0.2	-0.2	-0.1	-0.4	0.0	0.3	0.4	0.5	0.3	-0.4	-0.4	0.5	-0.2	-0.4	-0.3	0.3	-0.1	-0.2	0.2	0.4
dl_strmdstge4_c	-0.3	-0.2	-0.1	-0.4	0.0	0.2	0.4	0.5	0.2	-0.5	-0.5	0.5	-0.2	-0.5	-0.3	0.4	-0.1	-0.2	0.2	0.5
dl_strmdstge6_c	-0.7	-0.5	-0.3	-0.4	-0.3	0.0	0.3	0.6	0.0	-0.6	-0.6	0.5	-0.4	-0.5	-0.2	0.8	-0.2	0.1	0.2	0.6
gp_k_fillspl_c	-0.1	0.1	-0.5	0.6	-0.6	-0.7	-0.7	-0.4	-0.8	0.2	0.1	-0.5	-0.4	0.2	0.8	-0.1	-0.3	0.7	-0.6	-0.5
gp_u_fillspl_c	-0.2	0.0	-0.5	0.5	-0.6	-0.7	-0.6	-0.4	-0.7	0.1	0.0	-0.4	-0.4	0.1	0.7	0.0	-0.3	0.7	-0.6	-0.4
lf_aspect_tr_c	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
lf_cti_c	0.1	0.1	0.2	-0.1	0.2	0.2	0.1	0.0	0.2	0.0	0.0	0.1	0.1	0.0	-0.1	-0.1	0.0	-0.2	0.1	0.0
lf_rough0100_c	-0.2	0.0	-0.3	0.3	-0.3	-0.4	-0.3	-0.2	-0.4	0.1	0.1	-0.3	-0.2	0.1	0.4	0.1	0.0	0.4	-0.2	-0.2
lf_slope_deg_c	-0.2	0.0	-0.2	0.3	-0.3	-0.4	-0.3	-0.2	-0.4	0.1	0.1	-0.3	-0.2	0.1	0.3	0.1	0.0	0.4	-0.2	-0.2
lf_tpi0120_c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
sfc_aut_b_95_c	-0.2	-0.1	-0.1	-0.5	0.0	0.3	0.5	0.5	0.4	-0.5	-0.5	0.5	-0.2	-0.5	-0.4	0.3	-0.2	-0.4	0.2	0.5
soil_c	-0.2	0.0	-0.3	0.0	-0.3	-0.2	-0.1	0.1	-0.2	-0.2	-0.2	0.0	-0.3	-0.2	0.1	0.1	-0.3	0.3	-0.3	0.1
vegitation_pct_b_c	-0.5	-0.3	-0.5	0.1	-0.4	-0.4	-0.2	0.1	-0.4	-0.2	-0.3	0.0	-0.4	-0.2	0.3	0.4	-0.2	0.4	-0.2	0.0
lf_rough0500_c	-0.2	0.0	-0.3	0.4	-0.4	-0.5	-0.4	-0.3	-0.5	0.1	0.1	-0.3	-0.2	0.1	0.5	0.1	-0.1	0.5	-0.3	-0.2
lf_rough1000_c	-0.2	0.0	-0.3	0.5	-0.4	-0.5	-0.5	-0.3	-0.5	0.1	0.1	-0.4	-0.2	0.2	0.5	0.1	0.0	0.5	-0.3	-0.3
lf_tpi0250_c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
lf_tpi0500_c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
vegetation_merged_c	0.3	0.3	0.3	-0.2	0.3	0.4	0.3	0.1	0.4	0.0	0.0	0.2	0.2	0.0	-0.4	-0.2	0.1	-0.4	0.2	0.1
vegitation_vegcom_b_c	-0.4	-0.4	-0.2	0.1	-0.2	-0.2	-0.1	0.0	-0.2	-0.1	-0.1	0.0	-0.2	-0.1	0.2	0.3	-0.1	0.2	0.0	0.0

	dl_strmdstge2_c	dl_strmdstge4_c	dl_strmdstge6_c	gp_k_fillspl_c	gp_u_fillspl_c	lf_aspect_tr_c	lf_cti_c	lf_rough0100_c	lf_slope_deg_c	lf_tpi0120_c	sfc_aut_b_95_c	soil_c	vegitation_pct_b_c	lf_rough0500_c	lf_rough1000_c	lf_tpi0250_c	lf_tpi0500_c	vegetation_merged_c	vegitation_vegcom_b_c
ce_radann_c	-0.2	-0.3	-0.7	-0.1	-0.2	0.0	0.1	-0.2	-0.2	0.0	-0.2	-0.2	-0.5	-0.2	-0.2	0.0	0.0	0.3	-0.4
ce_radhp_c	-0.2	-0.2	-0.5	0.1	0.0	-0.1	0.1	0.0	0.0	0.0	-0.1	0.0	-0.3	0.0	0.0	0.0	0.0	0.3	-0.4
ce_radlp_c	-0.1	-0.1	-0.3	-0.5	-0.5	0.0	0.2	-0.3	-0.2	0.0	-0.1	-0.3	-0.5	-0.3	-0.3	0.0	0.0	0.3	-0.2
ct_frostdays_lt2deg_1_c	-0.4	-0.4	-0.4	0.6	0.5	0.0	-0.1	0.3	0.3	0.0	-0.5	0.0	0.1	0.4	0.5	0.0	0.0	-0.2	0.1
ct_temp_maxsum_1_c	0.0	0.0	-0.3	-0.6	-0.6	0.0	0.2	-0.3	-0.3	0.0	0.0	-0.3	-0.4	-0.4	-0.4	0.0	0.0	0.3	-0.2
ct_temp_maxwin_1_c	0.3	0.2	0.0	-0.7	-0.7	0.0	0.2	-0.4	-0.4	0.0	0.3	-0.2	-0.4	-0.5	-0.5	0.0	0.0	0.4	-0.2
ct_temp_minsum_1_c	0.4	0.4	0.3	-0.7	-0.6	0.0	0.1	-0.3	-0.3	0.0	0.5	-0.1	-0.2	-0.4	-0.5	0.0	0.0	0.3	-0.1
ct_temp_minwin_1_c	0.5	0.5	0.6	-0.4	-0.4	0.0	0.0	-0.2	-0.2	0.0	0.5	0.1	0.1	-0.3	-0.3	0.0	0.0	0.1	0.0
ct_tempann_1_c	0.3	0.2	0.0	-0.8	-0.7	0.0	0.2	-0.4	-0.4	0.0	0.4	-0.2	-0.4	-0.5	-0.5	0.0	0.0	0.4	-0.2
ct_tempannrnge_1_c	-0.4	-0.5	-0.6	0.2	0.1	0.0	0.0	0.1	0.1	0.0	-0.5	-0.2	-0.2	0.1	0.1	0.0	0.0	0.0	-0.1
ct_tempdiurn_1_c	-0.4	-0.5	-0.6	0.1	0.0	0.0	0.0	0.1	0.1	0.0	-0.5	-0.2	-0.3	0.1	0.1	0.0	0.0	0.0	-0.1
ct_tempmtcp_1_c	0.5	0.5	0.5	-0.5	-0.4	0.0	0.1	-0.3	-0.3	0.0	0.5	0.0	0.0	-0.3	-0.4	0.0	0.0	0.2	0.0
ct_tempmtwp_1_c	-0.2	-0.2	-0.4	-0.4	-0.4	0.0	0.1	-0.2	-0.2	0.0	-0.2	-0.3	-0.4	-0.2	-0.2	0.0	0.0	0.2	-0.2
ct_tempseas_1_c	-0.4	-0.5	-0.5	0.2	0.1	0.0	0.0	0.1	0.1	0.0	-0.5	-0.2	-0.2	0.1	0.2	0.0	0.0	0.0	-0.1
cw_etaaann_1_c	-0.3	-0.3	-0.2	0.8	0.7	0.0	-0.1	0.4	0.3	0.0	-0.4	0.1	0.3	0.5	0.5	0.0	0.0	-0.4	0.2
cw_precipann_1_c	0.3	0.4	0.8	-0.1	0.0	0.0	-0.1	0.1	0.1	0.0	0.3	0.1	0.4	0.1	0.1	0.0	0.0	-0.2	0.3
cw_precipseas_c	-0.1	-0.1	-0.2	-0.3	-0.3	0.1	0.0	0.0	0.0	0.0	-0.2	-0.3	-0.2	-0.1	0.0	0.0	0.0	0.1	-0.1
DEM_c	-0.2	-0.2	0.1	0.7	0.7	0.0	-0.2	0.4	0.4	0.1	-0.4	0.3	0.4	0.5	0.5	0.1	0.1	-0.4	0.2
dl_lat_grid_c	0.2	0.2	0.2	-0.6	-0.6	0.0	0.1	-0.2	-0.2	0.0	0.2	-0.3	-0.2	-0.3	-0.3	0.0	0.0	0.2	0.0
dl_long_grid_c	0.4	0.5	0.6	-0.5	-0.4	0.0	0.0	-0.2	-0.2	0.0	0.5	0.1	0.0	-0.2	-0.3	0.0	0.0	0.1	0.0
dl_strmdstge2_c	1.0	0.5	0.3	-0.2	-0.2	0.0	0.0	-0.1	-0.1	0.0	0.4	0.1	-0.1	-0.2	-0.2	0.1	0.1	0.2	0.1
dl_strmdstge4_c	0.5	1.0	0.4	-0.2	-0.1	0.0	0.0	-0.1	-0.1	0.0	0.4	0.1	-0.1	-0.1	-0.2	0.0	0.0	0.1	0.1
dl_strmdstge6_c	0.3	0.4	1.0	-0.1	-0.1	0.0	-0.1	0.1	0.1	0.0	0.3	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.2
gp_k_fillspl_c	-0.2	-0.2	-0.1	1.0	0.8	0.0	-0.1	0.4	0.3	0.0	-0.3	0.1	0.2	0.4	0.5	0.0	0.0	-0.3	0.0
gp_u_fillspl_c	-0.2	-0.1	-0.1	0.8	1.0	0.0	-0.1	0.2	0.2	0.0	-0.3	0.2	0.4	0.3	0.3	0.0	0.0	-0.4	0.2
lf_aspect_tr_c	0.0	0.0	0.0	0.0	0.0	1.0	-0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
lf_cti_c	0.0	0.0	-0.1	-0.1	-0.1	-0.1	1.0	-0.4	-0.4	-0.3	0.0	-0.1	-0.1	-0.3	-0.3	-0.3	-0.3	0.1	0.0
lf_rough0100_c	-0.1	-0.1	0.1	0.4	0.2	0.1	-0.4	1.0	1.0	0.0	-0.2	0.0	0.2	0.8	0.7	0.0	0.0	-0.1	0.1
lf_slope_deg_c	-0.1	-0.1	0.1	0.3	0.2	0.1	-0.4	1.0	1.0	0.0	-0.2	0.0	0.2	0.8	0.6	0.0	0.0	-0.1	0.1
lf_tpi0120_c	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.9	0.7	0.0	-0.1
sfc_aut_b_95_c	0.4	0.4	0.3	-0.3	-0.3	0.0	0.0	-0.2	-0.2	0.0	1.0	0.1	-0.1	-0.2	-0.3	0.0	0.0	0.1	0.0
soil_c	0.1	0.1	0.2	0.1	0.2	0.0	-0.1	0.0	0.0	0.0	0.1	1.0	0.3	0.1	0.1	0.1	0.1	-0.2	-0.1
vegitation_pct_b_c	-0.1	-0.1	0.2	0.2	0.4	0.0	-0.1	0.2	0.2	0.0	-0.1	0.3	1.0	0.2	0.2	-0.1	-0.1	-0.8	0.2
lf_rough0500_c	-0.2	-0.2	-0.1	0.4	0.3	0.1	-0.3	0.8	0.8	0.0	-0.2	0.1	0.2	1.0	0.9	0.0	0.0	-0.2	0.0
lf_rough1000_c	-0.2	-0.2	0.0	0.5	0.3	0.1	-0.3	0.7	0.6	0.0	-0.3	0.1	0.2	0.9	1.0	0.0	0.0	-0.2	0.0
lf_tpi0250_c	0.1	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.9	0.0	0.1	-0.1	0.0	0.0	1.0	0.9	0.0	-0.1
lf_tpi0500_c	0.1	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.7	0.0	0.1	-0.1	0.0	0.0	0.9	1.0	0.1	-0.1
vegetation_merged_c	0.2	0.1	0.0	-0.3	-0.4	0.0	0.1	-0.1	-0.1	0.0	0.1	-0.2	-0.8	-0.2	-0.2	0.0	0.1	1.0	0.0
vegitation_vegcom_b_c	0.1	0.1	0.2	0.0	0.2	0.0	0.0	0.1	0.1	-0.1	0.0	-0.1	0.2	0.0	0.0	-0.1	-0.1	0.0	1.0

Table A3.1 The Pearson correlations between all initial non-categorical predictor layers. Coloured cells represent high negative (light- or dark-blue) correlations or high positive (light- or dark-orange) correlations. See Table 4 for descriptions of each predictor.

Appendix 4 - Soil landscape codes and corresponding numerical values

The spoil landscape codes and corresponding numerical value used when quoting soil type results for the SDMs. See https://www.environment.nsw.gov.au/topics/land-and-soil/information/soil-maps for further information.

LANDSCAPE code	Numerical representation
AEab	1
AEnh	2
AEnp	3
AEtg	4
AEww	5
ALbg	6
ALbp	7
ALdc	8
ALfr	9
ALlc	10
ALmk	11
ALri	12
ALsc	13
ALtp	14
ALup	15
BEna	16
COha	17
COhw	18
COpn	19
COwb	20
COwn	21
COwp	22
DTxx	23
ERgn	24
ERgy	25
ERgy/ERla	26
ERla	27
ERlu	28
ERwl	29
ERya	30
ESmc	31
REbt	32
REbu	33

REfb	34
REho	35
REkg	36
RElh	37
REmd	38
REso	39
REvo	40
SWba	41
SWbs	42
SWet	43
SWwa	44
TRof	45
WATER	46

Appendix 5 - AUC values for each SDM under each of the three different bias layers

Scientific name	**Common name**	**AUC for bias layer 1 (whole landscape)**	**AUC for bias layer 2 (common bias)**	**AUC for bias layer 3 (individual bias)**
Acacia pubescens	Downy Wattle	0.9905	0.9908	0.9539
Persoonia nutans	Nodding Geebung	0.9775	0.9969	0.9147
Pimelea spicata	Spiked Rice-flower	0.9903	0.994	0.9357
Pultenaea parviflora	NA	0.976	0.9914	0.889
Pteropus poliocephalus	Grey-headed Flying-fox	0.8986	0.8716	0.7643
Eucalyptus benthamii	Camden White Gum	0.9992	0.9996	0.9401
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	0.9827	0.9907	0.9288
Persoonia bargoensis	Bargo Geebung	0.9858	0.9849	0.8174
Micromyrtus minutiflora	NA	0.9804	0.9905	0.7534
Acacia bynoeana	Bynoe's Wattle	0.916	0.9009	0.7112
Persoonia hirsuta	Hairy Geebung	0.9696	0.9475	0.8574
Pomaderris brunnea	Brown Pomaderris	0.991	0.9943	0.9197
Pommerhelix duralensis	Dural Woodland Snail	0.9853	0.9784	0.8069
Botaurus poiciloptilus	Australasian Bittern	0.7356	0.8181	0.5656
Cynanchum elegans	White-flowered Wax Plant	0.993	0.993	0.751
Darwinia biflora	NA	0.9753	0.9476	0.8503
Heleioporus australiacus	Giant Burrowing Frog	0.8985	0.8857	0.7383
Litoria aurea	Green and Golden Bell Frog	0.9933	0.9932	0.9595
Phascolarctos cinereus	Koala	0.989	0.9783	0.9173

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document G – Implications of the 2019/20 bushfires

DOCUMENT TRACKING

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VERSION CONTROL:	
VERSION:	Final This version of the report is the version submitted to regulators in 2021 with the application for biodiversity certification under the BC Act and for endorsement under the EPBC Act. Since then, several changes have been made to the Plan and to species listings under the EPBC Act. These changes are addressed in two addendums to this report.
DATE:	2021

Contents

1 Introduction

NSW experienced extensive bushfires throughout the spring and summer of 2019-20. As of 3rd February 2020, the fires had burnt 5.4 million hectares of land in the state (approximately 7 per cent of NSW). This includes (DPIE, 2020):

- 37 per cent of the national park estate, including 81 per cent of the Greater Blue Mountains World Heritage Area
- 42 per cent of state forests
- 52 per cent of heathland, 50 per cent of wet sclerophyll, and 37 per cent of rainforest vegetation formations in NSW
- 25 per cent of the most suitable koala habitat in eastern NSW (moderate, high and very high suitable habitat), particularly areas on the north coast, central and southern tablelands, central coast and the south coast

Of the fire affected national parks, 23 per cent were subject to full canopy damage, 36 per cent had partial canopy damage, and for 27 per cent the canopy was unburnt. Note that areas where the canopy was unburnt may have been affected by fire through the understorey (DPIE, 2020).

The fires also affected large areas of species habitat where species have been recorded and are known to occur. A total of 680 threatened flora species have records within fire affected areas. Of these:

- 61 species (approximately 9 per cent) have more than 80 per cent of their records within fire affected areas, including 19 with more than 30 per cent of records in areas where the canopy was fully damaged
- 37 species have 50 to 80 per cent of records within fire affected areas

A total of 293 threatened fauna species have records within fire affected areas. Of these:

- 5 species have more than 80 per cent of records within fire affected areas, including:
  - *Petaurus australis* (Yellow-bellied Glider) endangered population on Bago Plateau
  - *Petauroides volans* (Greater Glider) endangered population in Eurobodalla
- 99 species have more than 10 per cent of records within fire affected areas

Further, a total of 26 Commonwealth-listed threatened ecological communities (TECs) which occur within NSW were impacted by fire, of which (DAWE, 2020b):

- 2 had over 50 per cent of their distribution within fire affected areas
- 3 had between 30 and 50 per cent of their distribution within fire affected areas
- 11 had between 10 and 30 per cent of their distribution within fire affected areas

The long-term survival of flora and fauna after fire is complex and the full impact of the fires on biodiversity will not be understood for some time (EES, 2020). Fauna recovery depends on factors such as access to food, water and habitat recovery, which depend on fire severity and future weather conditions. Flora recovery depends on drought, fire frequency and severity, and impacts from pest animals, weeds and pathogens on regrowth (EES, 2020). The recovery of TECs depends upon the flora and fauna which live within the communities.

Because the extent and intensity of the 2019-20 fires in NSW were so substantial, ultimate recovery of some species and TECs impacted by the fires is uncertain and could be affected. This means that:

- The fires may increase the significance of the impacts of the development under the Plan for some species and TECs
- Additional commitments under the Plan may be needed for some species and TECs to help address the impacts of the fires

An assessment of the implications of the fires for the Plan has been undertaken based on available information.

2 Purpose of assessment

The purpose of the assessment was to identify species or TECs where:

- The species/TEC have been substantially affected by fires of the 2019-2020 period, and
- The Cumberland subregion is already important for species/TEC persistence in NSW and/or has the potential to become more important for persistence because of the impacts of the fires to other areas of habitat, and
- The Plan has known or likely impacts to the species/TEC

Where these three criteria are met, the implication of the fires in relation to the Plan, including the need for commitments to address impacts, should be considered. The rationale for this approach is that:

- Where a species is not reliant on the Cumberland subregion, the Plan has limited opportunity to help address the impacts of the fires on the species or influence conservation outcomes for the species
- Where a species is not being impacted by development under the Plan, the impacts of the fires and consideration of the need for commitments specific to the species, is not directly relevant to the Plan

3 Approach to assessment

3.1 ASSESSMENT OF THREATENED SPECIES

The approach to the assessment of threatened species involved:

- Identifying each listed threatened species potentially impacted by the Plan (these are Category 1 Commonwealth-listed species and NSW-listed candidate species-credit species and ecosystem-credit species – see Chapter 11)
- Undertaking an assessment to identify the species which:
  - <u>Were substantially impacted by fires</u>. This was done by:
    - Obtaining spatial data on fire extent over the 2019-20 period from the GEEBAM dataset available on SEED (DAWE, 2020d)
    - Obtaining species records from NSW BioNet (under a licenced extract to source as-held data)
    - Overlaying fire extent with species records and analysing the data using GIS. All records within 100 m of the fire footprint boundary were included as impacted by the fire to account for level of record accuracy and fire-ground extent accuracy
  - <u>Are vulnerable to impacts from fires</u>. This was done by identifying whether each species has life-history traits that make the species more susceptible to fire or relies on habitat features that are likely to be affected by fires. This was done based on existing knowledge and/or information in literature or government databases, such as BioNet species profiles
  - <u>Are likely to have an increased reliance on the Cumberland subregion as an important area of habitat to ensure species' regional persistence during post-fire recovery</u>. This was done by determining the percentage of total records in NSW that occur within the Cumberland subregion. This provides an indication of the importance of the subregion for persistence of the species in NSW, although the data density is skewed towards the greater Sydney area due to opportunity for observation and high survey effort
- Considering the findings of the Wildlife and Threatened Species Bushfire Recovery Expert Panel (WTSBR Expert Panel). This included identifying species which have been identified as priority matters by the WTSBR Expert Panel, which have also been identified as threatened species potentially impacted by the Plan (DAWE, 2020c, 2020a)

Data was also obtained from the Commonwealth Department of Agriculture, Water and the Environment (DAWE) on the estimated extent of fire impacts on the known or predicted distribution of Commonwealth listed species at a national scale.

The importance of the Cumberland subregion for species persistence was estimated on the basis of record counts. Where the subregion has greater than 10 per cent of existing total NSW records, it was considered that the subregion:

- Is already important for species persistence, and/or

- Has the potential to become more important as a result of the impacts of the fires on the species habitat elsewhere (as it is likely that a reasonable amount of suitable habitat exists in the subregion for the species)

The Cumberland subregion has a high human population density and is well-surveyed compared to other areas in NSW. Therefore, there is a higher probability that records within this subregion reflect the actual distribution and density of a species, and that absence of records suggests that a species is not present. By comparison, absence of records in other, more remote parts of the state may indicate inadequate survey rather than species absence.

The Cumberland subregion was considered to be important to a species if it contained over 10 per cent of the species' NSW records. While 10 per cent is a high threshold, this threshold considers:

- The density of records present in the Cumberland subregion is likely to broadly reflect actual species' distributions due to high survey effort (i.e. it is unlikely that there are very large populations within the subregion of species which have very few records in the area)
- Species records are more likely to occur in the Cumberland subregion than other subregions within NSW. This is because there tends to be a disproportionately high survey effort in the Cumberland subregion compared to other areas of the state (which may lack records due to absence of surveys, rather than a true absence of the species)
- The land area of the Cumberland subregion in the context of NSW. It is noted that the subregion covers 0.3 per cent of NSW's total land area

3.2 ASSESSMENT OF TECS

The approach to the assessment of TECs involved:

- Identifying each Commonwealth-listed TEC potentially impacted by the Plan
- Considering the findings of the WTSBR Expert Panel, specifically the:
  - Initial list of TECs potentially affected by the 2019-20 bushfires
  - TECs identified as priority matters for funding in Tranche 1 of the Wildlife and Habitat Bushfire Recovery Program
  - TECs identified as priorities for management intervention in at least one fire-affected NRM region

TECs within the Strategic Assessment Area are identified slightly differently under their Commonwealth listing when compared to their NSW listing, and as such, equivalent TECs under each Act may have slightly different distributions. The assessment considered fire impact statistics for Commonwealth-listed TECs. NSW-listed TECs were not addressed given that:

- The identified Commonwealth-listed TECs are broadly equivalent to NSW-listed TECs
- There is limited information available regarding impacts to NSW-listed TECs

However, it is considered that assessment and protection of Commonwealth-listed TECs will provide sufficient protection to listed equivalent TECs listed under NSW legislation.

4 Limitations

The assessment of species undertook two approaches: analysis of fire impacts to species records, and consideration of priority species identified by the WTSBR Expert Panel.

Consideration of impacts to species records is beneficial as it enables assessment of all species which are impacted by the Plan and provides contextual information regarding the potential relative severity of impacts. The key limitations of the assessment based on impacts to species records are:

- Reliance on records and record accuracy to provide an indication of species distribution and reliance on the subregion. Records are often only an indicator of survey effort relating to development assessments and ease of accessibility, and are likely to be biased towards iconic and more observable species, in particular birds and mammals
- No age cut-off was applied to the records despite increasing spatial inaccuracy for older records

- Each record may relate to one individual or a much larger population, so the overall significance of a record being impacted by the fires is difficult to quantify
- Impacts within the fire extent are likely to be variable and uneven, and to include areas of low intensity and less damaging burns, small refugia and patches of unburnt habitat
- Treating all of the populations in NSW as a single entity and not recognising bioregional or genetic separations in determining the impact upon a species by the fires

The list of priority species identified by the WTSBR Expert Panel is more refined, as it considers a broader range of parameters in determining priority status beyond impact area, such as characteristics of each species' ecology and vulnerability to stochastic events. However, the limitations of the available information from the WTSBR Expert Panel is that detailed information is not available for all species which are potentially impacted by the Plan. As the WTSBR Expert Panel's work was conducted at a national scale to only identify the species at the highest risk, there is a possibility that other species which are of a more moderate risk level may not be identified in their findings, yet which are still relevant to the Plan.

Combining the two approaches to identify the species which have been most severely impacted by the 2019/20 bushfire season enables identification of the highest priority impacted species (those identified by the WTSBR Expert Panel), in addition to other potentially at risk species.

5 Results of assessment

5.1 THREATENED SPECIES

The results of the assessment for threatened species are summarised in Table 5-1. The table shows:

- Species assessed under the Plan with greater than 10 per cent of NSW records affected by fires. It is ordered to show the species with the greatest proportion of NSW records affected to the least
- Percentage of total NSW records for the species that occur in the Cumberland subregion
- Species which have been identified by the WTSBR expert panel

Species with both greater than 10 per cent of records affected by fires in NSW and greater than 10 per cent of total NSW records within the Cumberland subregion, or species which have been identified by the WTSBR expert panel are highlighted in blue. For these species, further comment is made about:

- The risk of impacts of the Plan on the species, drawing on the assessments in this Assessment Report
- The significance of the impacts of the fires on the species
- The adequacy of the commitments in the Plan to helping address the impacts of the fires

These species are:

- *Petauroides volans* (Greater Glider)
- *Petaurus australis* (Yellow-bellied Glider)
- *Calyptorhynchus lathami* (Glossy Black-cockatoo)
- *Dasyurus maculatus maculatus* (SE pop) (Spotted-tailed Quoll)
- *Callocephalon fimbriatum* (Gang-gang Cockatoo)
- *Hoplocephalus bungaroides* (Broad-headed Snake)
- *Scoteanax rueppellii* (Greater Broad-Nosed Bat)
- *Grevillea parviflora* subsp. *parviflora* (Small-flower Grevillea)
- *Pomaderris brunnea* (Brown Pomaderris)
- *Persoonia bargoensis* (Bargo Geebung)
- *Heleioporus australiacus* (Giant Burrowing Frog)
- *Acacia bynoeana* (Bynoe's Wattle)
- *Eucalyptus benthamii* (Camden White Gum)

- *Commersonia prostrata* (Dwarf Kerrawang)
- *Myotis macropus* (Southern Myotis)
- *Anthochaera phrygia* (Regent Honeyeater)
- *Pteropus poliocephalus* (Grey-headed Flying Fox)
- *Phascolarctos cinereus* (Koala)

5.2 TECS

Table 5-2 shows TECs which have been identified as both priority TECs by the WTSBR expert panel and TECs potentially impacted by the Plan. TECs included within the list of priority matters both for funding under Tranche 1 of the Wildlife and Habitat Bushfire Recovery Program and management intervention in at least one fire-affected NRM region are highlighted in blue. For these TECs, further comment is made about:

- The risk of impacts of the Plan on the TEC, drawing on the assessments in this Assessment Report
- The significance of the impacts of the fires on the TEC
- The adequacy of the commitments in the Plan to helping address the impacts of the fires

These TECs are:

- Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion
- Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland ecological community
- Turpentine-Ironbark Forest of the Sydney Basin Bioregion

Table 5-1: Analysis of implications for species relevant to the Plan which have been identified as being impacted by the 2019/20 fires

<table>
<tr><th rowspan="2">Scientific name</th><th rowspan="2">Common name</th><th rowspan="2">Cth status</th><th rowspan="2">NSW status</th><th colspan="3">Records/habitat affected by fires</th><th rowspan="2">Species identified for urgent management by WTSBR expert panel?</th><th rowspan="2">Comments on implications of the fires for the Plan</th></tr>
<tr><th>% of NSW records affected</th><th>% of NSW records that occur in the Cumberland subregion</th><th>% distribution affected by fires at national scale</th></tr>
<tr><td>Petauroides volans</td><td>Greater Glider</td><td>V</td><td>-</td><td>82.28%</td><td>0.16%</td><td>10-30%</td><td>Yes</td><td>The risk of residual adverse direct impacts on this species from the Plan is as follows (see Chapter 30):
• Very low with regards to the loss of potential foraging habitat
• Very low with regards to fragmentation
The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted. An area of mapped potential habitat will be fragmented, although there are no species' records in the vicinity of this habitat
While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 9,661 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species
Given the Plan will only have a very low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires</td></tr>
<tr><td>Petaurus australis</td><td>Yellow-bellied Glider</td><td>-</td><td>V</td><td>59.49%</td><td>0.1%</td><td>No data</td><td>Yes</td><td>The species is an ecosystem credit species that is examined in this Assessment Report in terms of impacts to associated PCTs (see Chapter 21). Under the BAM assessment, it is predicted to occur in Wilton and GMAC only. However, it is recognised that a record of this species occurs in GPEC.
The species occurs in tall mature eucalypt forest, in areas with high rainfall and nutrient rich soils, and dens in hollows of large trees. The majority of suitable habitat for this species is restricted</td></tr>
</table>

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								to the gorges and gullies mainly on the edges of the nominated areas. The urban capable lands generally occur outside these areas and no major roads directly cross these areas as part of the development. There are a small number of records of this species within the Strategic Assessment Area. Of these, only one record occurs within the nominated areas, within the OSO development footprint in GPEC. This record is associated with the South Creek riparian corridor. The Plan includes a commitment (Commitment 3) to avoid and minimise impacts to the Yellow-bellied Glider and its habitat within certified major transport corridors through detailed planning and design. This includes avoiding areas of potential habitat connectivity within riparian corridors where possible for specific species including the Yellow-bellied Glider. This commitment will minimise potential impacts to the species' habitat and maintain habitat connectivity for the species. The majority of records occur outside the Plan Area to the north-east and south-west. The comparatively small number of records of the species within the Strategic Assessment Area reflects the largely unsuitable habitat for the species across most of the area. Overall, the Plan is considered to adequately address impacts to this species in the context of the fires
Persoonia hirsuta	Hairy Geebung	E	E	57.28%	7.2%	30-50%	No	-
Calyptorhynchus lathami	Glossy Black-cockatoo	-	V	49.20%	0.5%	No data	Yes	There are some records for this species within the Cumberland subregion. However, there is a much higher density of records in vegetated areas surrounding the subregion, indicating that the subregion contains less suitable habitat for the species across most of the area. It is considered unlikely that the Strategic

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								Assessment Area would be important for the species' post-fire recovery and persistence Potential habitat for this species has been mapped within GMAC and Wilton, and is associated with vegetated riparian corridors. The vast majority of habitat within nominated areas for this species (over 99 per cent) has been avoided by development under the Plan. Impacts occur to the edges of potential habitat and will not result in habitat fragmentation Although small areas of potential habitat for this species will be impacted under the Plan, it is noted that the Plan commits to protecting SCA which contain substantial areas (8,728 ha) of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Overall, the Plan is considered to adequately address impacts to this species in the context of the fires
Falsistrellus tasmaniensis	Eastern False Pipistrelle	-	V	45.96%	4.9%	No data	No	-
Tyto novaehollandiae	Masked Owl	-	V	42.83%	1.4%	No data	No	-
Dasyurus maculatus maculatus (SE pop)	Spotted-tailed Quoll	E	V	40.27%	0.5%	10-30%	Yes	The risk of residual adverse direct impacts on this species from the Plan is <u>low</u> (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted There is potential for the Plan to fragment habitat in two locations as a result of development within transport corridors. Consequently, the Plan includes a species-specific measure to

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								design the transport corridors to avoid and minimise impacts to Spot-tailed Quoll populations and habitat and connectivity, particularly along riparian corridors. This measure is considered to sufficiently mitigate the risk of fragmentation and protect the species from impacts The Plan includes commitments to protect land within the SCA that contains 11,894.9 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Callocephalon fimbriatum	Gang-gang Cockatoo	-	V	36.63%	1.8%	No data	Yes	There are some records for this species within the Cumberland subregion. However, there is a much higher density of records in vegetated areas surrounding subregion, indicating that the subregion contains less suitable habitat for the species across most of the area. It is considered unlikely that the Strategic Assessment Area would be important for the species' post-fire recovery and persistence Potential habitat for this species has been mapped within GMAC, Wilton and GPEC. In GMAC and Wilton, potential habitat and is associated with vegetated riparian corridors. In GPEC, mapped habitat occurs in the vicinity of Orchard Hills and Wianamatta Regional Park. The vast majority of habitat within nominated areas for this species (over 99 per cent) has been avoided by development under the Plan. Given the wide-ranging nature of the species, it is unlikely that development would result in fragmentation impacts

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								Although small areas of potential habitat for this species will be impacted under the Plan, it is noted that the Plan commits to protecting SCA which contain substantial areas (15,376 ha) of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Overall, the Plan is considered to adequately address impacts to this species in the context of the fires
Ninox strenua	Powerful Owl	-	V	31.08%	6.6%	No data	No	-
Maundia triglochinoides		-	V	30.04%	0.4%	No data	No	-
Persoonia glaucescens	Mittagong Geebung	V	E	28.75%	2.1%	30-50%	No	-
Hoplocephalus bungaroides	Broad-headed Snake	V	E	27.19%	1.3%	50-80%	Yes	There will be no direct impacts to this species as a result of the Plan. Indirect impacts to the species under the Plan will be managed and mitigated through a range of generic management strategies in the Plan It is further noted that the Strategic Assessment Area contains only one record of the species, which reflects the largely unsuitable habitat for the species across most of the area. It is considered unlikely that the Strategic Assessment Area would be important for the species' post-fire recovery and persistence Overall, the Plan is considered to adequately address impacts to this species in the context of the fires
Petroica boodang	Scarlet Robin	-	V	26.38%	1.9%	No data	No	-

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
Scoteanax rueppellii	Greater Broad-Nosed Bat	-	V	25.41%	11.1%	No data	No	The species is an ecosystem credit species that is examined in this Assessment Report in terms of impacts to associated PCTs (see Chapter 21). It is predicted to occur in Wilton and GMAC only. The species generally roosts in tree hollows and is more common in tall wet forests. These areas are generally limited within the nominated areas to avoided lands along the edges of Wilton and through the edges and middle of GMAC (associated with gullies and waterways) and will not generally be impacted under the Plan While no species-specific offset is provided for this species under the Plan, the Plan includes commitments (through offset targets for each impacted PCT/NSW TEC) to protect land within the SCA that contains substantial areas of potential habitat for the species Given the Plan has a low likelihood of impacts to the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	V	23.98%	21.3%	No data	No	The risk of residual adverse direct impacts on this species from the Plan is <u>low</u> (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted or fragmented While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 2,924.3 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	23.83%	4.3%	10-30%	No	-
Petroica phoenicea	Flame Robin	-	V	21.32%	0.6%	No data	No	-
Cynanchum elegans	White-flowered Wax Plant	E	E	21.02%	4.9%	30-50%	No	-
Cercartetus nanus	Eastern Pygmy-possum	-	V	20.99%	0.9%	No data	No	-
Miniopterus schreibersii oceanensis (= M. orianae oceanensis)	Large (Eastern) Bent-winged Bat	-	V	20.78%	9.2%	No data	No	-
Miniopterus australis	Little Bent-winged Bat	-	V	19.07%	1.8%	No data	No	-
Pomaderris brunnea	Brown Pomaderris	V	E	18.64%	64.4%	50-80%	Yes	The risk of residual adverse direct impacts on this species from the Plan is low (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted or fragmented

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								The species occurs within the footprint of the OSO and Metro Rail Future Extension tunnels. The Plan contains a species-specific commitment (Commitment 4.2) to avoid and minimise impacts to this species as a result of tunnel construction, which is considered adequate to protect the individuals within the footprint While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 6,954.3 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species. Furthermore, three known populations of the species occur within the proposed Georges River Koala Reserve Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat and several populations, the Plan is considered to adequately address impacts to this species in the context of the fires
Daphoenositta chrysoptera	Varied Sittella	-	V	17.93%	5.9%	No data	No	-
Persoonia bargoensis	Bargo Geebung	V	E	17.86%	70.9%	10-30%	No	The risk of residual adverse direct impacts on this species from the Plan is low (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted or fragmented While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 5,222.1 ha of potential habitat for the species. While it is unclear the how much of this habitat will be

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Heleioporus australiacus	Giant Burrowing Frog	V	V	17.10%	1.2%	30-50%	Yes	The risk of residual adverse direct impacts on this species from the Plan is very low (see Chapter 30). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted or fragmented While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 2,065.6 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Given the Plan will only have a very low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Glossopsitta pusilla	Little Lorikeet	-	V	16.88%	4.0%	No data	No	-
Varanus rosenbergi	Rosenberg's Monitor	-	V	16.27%	1.4%	No data	No	-
Acacia bynoeana	Bynoe's Wattle	V	E	15.73%	16.4%	10-30%	No	The risk of residual adverse direct impacts on this species from the Plan is very low (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								species in the Plan Area and no records are directly impacted or fragmented While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCA that contains 6,321.6 ha of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Given the Plan will only have a very low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Ninox connivens	Barking Owl	-	V	15.13%	1.7%	No data	No	-
Eucalyptus benthamii	Camden White Gum	V	V	13.73%	84.1%	30-50%	No	The risk of residual adverse direct impacts on this species from the Plan is low (see Chapter 29). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area and no records are directly impacted, although a small area of potential habitat connected to records will be fragmented The species occurs within the footprint of the OSO and Metro Rail Future Extension tunnels. The Plan contains a species-specific commitment (Commitment 4.2) to avoid and minimise impacts to this species as a result of tunnel construction, which is considered adequate to protect the individuals within the footprint While no species-specific offset is provided for this species under the Plan, the Plan includes commitments to protect land within the SCAs that contains 1,442.5 ha of potential habitat for the

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires
Petaurus norfolcensis	Squirrel Glider	-	V	13.00%	0.8%	No data	No	-
Commersonia prostrata	Dwarf Kerrawang	E	E	12.94%	12.4%	No data	No	There is no risk of residual direct impacts on this species from the Plan (see Chapter 29). There will be no direct impacts or fragmentation of potential habitat for the species As there are no risks of impacts to the species, the impacts of the fires on this species are not relevant to the Plan
Myotis macropus	Southern Myotis	-	V	11.53%	10.7%	No data	No	Many records for the species occur in the Plan Area and relatively large areas of potential habitat are impacted by the Plan (see Chapter 23), including water bodies (see Chapter 24) While the fires have affected large areas of habitat containing records, it is important to note that high record density for the species in the Cumberland subregion is likely to be a result of high survey effort rather than an indication of substantial reliance on the subregion The Plan recognises the potential impacts to this species from development under the Plan and includes several commitments to reduce these impacts. These commitments include a species-specific offset to secure 1 offset location for the species, as well as several other measures to minimise impacts to habitat features that the species relies on (see Chapter 8 and Chapter 15)

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								Furthermore, the Plan includes other commitments to protect land within the SCA that contain substantial areas (16,234.6 ha) of potential habitat for the species. While it is unclear the how much of this habitat will be secured within the SCA, it is likely that the final distribution of protected areas will contain areas of habitat for the species These commitments are substantial and are considered to adequately address impacts to this species in the context of the fires
Melithreptus gularis gularis	Black-Chinned Honeyeater	-	V	10.95%	2.6%	No data	No	-
Anthochaera phrygia	Regent Honeyeater	CE	CE	10.94%	5.2%	10-30%	Yes	The risk of residual adverse direct impacts on this species from the Plan is low (see Chapter 30). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area. Given the wide-ranging nature of the species, it is unlikely that development would result in fragmentation impacts There is no species-specific offset provided for this species under the Plan. However, it is worth noting that mapped habitat prepared for this project for Regent Honeyeater and the Swift Parrot are the same. And that the offsets that the Plan will provide for Swift Parrot (4,410 ha of potential foraging habitat within the SCA) may provide benefits for the Regent Honeyeater Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires: % of NSW records affected	Records/habitat affected by fires: % of NSW records that occur in the Cumberland subregion	Records/habitat affected by fires: % distribution affected by fires at national scale	Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
Pseudophryne australis	Red-crowned Toadlet	-	V	10.91%	3.6%	No data	No	-
Phascolarctos cinereus	Koala	V	V	10.32%	2.7%	10-30%	Yes	The impacts of the fires on this species are likely to be significant, particularly to populations on the north coast, central and southern tablelands, central coast and the south coast (DPIE, 2020) The fires also increase the significance of the impacts of the Plan on this species. The Southern Sydney Koala population is now likely to be the only population in NSW currently largely unaffected by disease that also remains unaffected by the fires The Plan already recognises the significance of the Southern Sydney Koala population and includes a broad range of commitments to ensure the population persists and the condition of habitat improves in the areas within the Cumberland subregion most likely to support long-term viability (see Sub-Plan B, and Chapter 30). The commitments have been specifically designed to ensure consistency with advice provided by the Office of the NSW Chief Scientist & Engineer with regards to protection of the population. These commitments include: • Avoiding the vast majority (92%) of important Koala habitat (primary, secondary and tertiary corridors) within the nominated areas • Establishing a large reserve specifically for Koala to secure the north-south movement corridor along the Georges River between Appin and Kentlyn • Funding to restore up to 80 ha of Koala habitat

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								• Constructing Koala exclusion fencing within Wilton and GMAC to protect Koalas from vehicle strike and dog attacks • A range of other measures to manage threats These commitments are substantial and are considered to adequately address impacts to this species in the context of the fires A detailed assessment of the adequacy of the commitments under the Plan for Koala is provided in Chapter 30. The detailed assessment specifically considers the advice provided by the Office of the NSW Chief Scientist & Engineer, and finds that the Plan's commitments and other measures are adequate for protection of Koala
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	4.26%	18.7%	10-30%	Yes	The risk of residual adverse direct impacts on this species from the Plan is <u>low</u> (see Chapter 30). The area of potential habitat impacted is a small proportion of available habitat for the species in the Plan Area. Given the wide-ranging nature of the species, it is unlikely that development would result in fragmentation impacts There is no species-specific offset is provided for this species under the Plan. However, it is worth noting that the Plan's conservation program will provide substantial offsets for native vegetation. Much of which will provide potential foraging habitat for the species. Key components of the conservation program that will benefit Grey-headed Flying-fox include: • Commitment 8 which will lead to the protection of at least 5,325 ha of native vegetation in the Cumberland subregion. At least 75 per cent of this target will be achieved by protecting existing native vegetation, and up to 25 per cent will relate to ecological restoration

Scientific name	Common name	Cth status	NSW status	Records/habitat affected by fires			Species identified for urgent management by WTSBR expert panel?	Comments on implications of the fires for the Plan
				% of NSW records affected	% of NSW records that occur in the Cumberland subregion	% distribution affected by fires at national scale		
								• A range of commitments that will help manage landscape threats across the Strategic Assessment Area. These will help maintain and improve the condition of foraging habitat for the species across the landscape over the life of the Plan and include commitments to manage weeds (Commitment 15), pest animals (Commitment 16), fire (Commitment 17), disease (Commitment 18), and support adaptation to climate change (Commitment 19) Ecological restoration will be particularly beneficial to the species given the loss of potential foraging habitat Given the Plan will only have a low risk of impacts on the species and will lead to the protection of substantial areas of potential habitat, the Plan is considered to adequately address impacts to this species in the context of the fires

Table 5-2: Analysis of implications for TECs relevant to the Plan which have been identified as priority matters by the WTSBR expert panel

Name	Cth status	NSW status	% within fire affected areas	Priority matter for funding in Tranche 1 of the Wildlife and Habitat Bushfire Recovery Program?	Priority for recovery action in Greater Sydney NRM region?	Comments on implications of the fires for the Plan
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion	E	V	10 - 30%	Yes	Yes	This TEC is not mapped to occur within any of the nominated areas or transport corridors, and subsequently there will be no direct impacts or fragmentation of this TEC under the Plan Indirect impacts to the TEC which may be exacerbated by the Plan (including inappropriate fire regimes, weed invasion, inappropriate habitat disturbance, diseases, pathogens and dieback and invasive fauna) will be managed and mitigated through a range of management strategies in the Plan Overall, the Plan is considered to adequately address impacts to this TEC in the context of the fires
Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland ecological community	E	E	10 - 30%	Yes	Yes	Implementation of the Plan will lead to the loss of a small area (8 ha) of the TEC, which is a small proportion (3 per cent) of the TEC within the Strategic Assessment Area. Only patches in thinned or scattered condition will be impacted, with no impacts to intact patches, and impacts generally occur on the edge of isolated patches which are already fragmented. As such, impacts will not result in fragmentation To compensate for the predicted direct impacts to the TEC, the Plan includes a commitment to secure 20 ha of the TEC as part of the conservation program. This would: • Lead to the protection and management of an additional 7.4 per cent of the ecological community within the Strategic Assessment Area • Increase the level of protection and management of the ecological community by approximately 125 per cent on top of what is currently secured in the Strategic Assessment Area

Name	Cth status	NSW status	% within fire affected areas	Priority matter for funding in Tranche 1 of the Wildlife and Habitat Bushfire Recovery Program?	Priority for recovery action in Greater Sydney NRM region?	Comments on implications of the fires for the Plan
						Further, potential indirect impacts to the TEC under the Plan will be mitigated through a number of commitments and actions under the Plan Overall, the Plan is considered to adequately address impacts to this TEC in the context of the fires
Turpentine-Ironbark Forest of the Sydney Basin Bioregion	CE	CE	10 - 30%	Yes	Yes	This TEC is not mapped to occur within any of the nominated areas or transport corridors, and subsequently there will be no direct impacts or fragmentation of this TEC under the Plan Further, given the limited extent of the TEC in the Strategic Assessment Area and the distance that it occurs from the nominated areas, it is considered unlikely that the Plan would exacerbate threats and result in indirect impacts to this TEC As there are no risks of impacts to the TEC, the impacts of the fires on this TEC are not relevant to the Plan
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion	CE	E	10 - 30%	Yes	No	
Shale Sandstone Transition Forest of the Sydney Basin Bioregion	CE	CE	10 - 30%	Yes	No	
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest	CE	CE	< 10%	No	No	
Western Sydney Dry Rainforest and Moist Woodland on Shale	CE	E	< 10%	No	No	

References

DAWE (2020a) *Final list of plants requiring urgent management intervention*.

DAWE (2020b) *Priority list of threatened ecological communities affected by 2019-20 bushfires*. Retrieved October 2, 2020, from https://www.environment.gov.au/biodiversity/bushfire-recovery/priority-tecs

DAWE (2020c) *Provisional list of animals requiring urgent management intervention*. Retrieved from http://www.environment.gov.au/biodiversity/bushfire-recovery/research-and-resources

DAWE (2020d) *Wildlife and threatened species bushfire recovery research and resources* Department of Agriculture, Water and the Environment. Retrieved from https://www.environment.gov.au/biodiversity/bushfire-recovery/research-and-resources

DPIE (2020) *NSW Fire and the Environment 2019–20 Summary: Biodiversity and landscape data and analyses to understand the effects of the fire events* Environment Energy and Science.

EES (2020) *Understanding the impact of the 2019-20 fires* NSW Environment, Energy and Science. Retrieved from https://www.environment.nsw.gov.au/topics/parks-reserves-and-protected-areas/fire/park-recovery-and-rehabilitation/recovering-from-2019-20-fires/understanding-the-impact-of-the-2019-20-fires

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document H – Response to submissions following public exhibition

Cumberland Plain Conservation Plan

What We Heard

Public exhibition of the draft Cumberland Plain Conservation Plan

October 2021

NSW GOVERNMENT

www.dpie.nsw.gov.au

Find out more:
www.dpie.nsw.gov.au

Title: What We Heard

Subtitle: Public exhibition of the draft Cumberland Plain Conservation Plan

First published: October 2021

Acknowledgements

Cover image: Joshua Tredinnick, Department of Planning, Industry and Environment

Acknowledgement of Country

The development of the Cumberland Plain Conservation Plan acknowledges more than 60,000 years of continuous Aboriginal connection to the land that makes up NSW.

This Plan recognises that, as part of the world's oldest living culture, traditional Aboriginal and Torres Strait Islander owners and custodians of the Australian continent and adjacent islands share a unique bond to Country — a bond forged through thousands of years of travelling across lands and waterways for ceremony, religion, trading and seasonal migration.

Aboriginal peoples maintain a strong belief that if we care for Country, it will care for us. The area covered by the Cumberland Plain Conservation Plan is custodially cared for by 3 Aboriginal groups: the Darug, Dharawal and Gundungurra. Others, such as the Eora, Darkinjung, Wiradjuri and Yuin, maintain trade or other obligatory care relationships with the area. The Deerubbin, Gandangara and Tharawal local Aboriginal land councils also have local land holdings and responsibilities towards Aboriginal peoples living in the area.

This significant connection to Country has played an important part in shaping this Plan.

For Traditional Owners, Country takes in everything within the physical, cultural and spiritual landscape–landforms, waters, air, trees, rocks, plants, animals, foods, medicines, minerals, stories and special places. It includes cultural practice, kinship, knowledge, songs, stories and art, as well as spiritual beings and people past, present and future.

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Ministerial foreword

The NSW Government's vision is for a thriving and liveable Western Parkland City. We want people to love where they live and enjoy a lifestyle that allows them to get outside, be active and enjoy their great green spaces and local environments.

Western Sydney is a biologically diverse landscape with a rich variety of unique plants and animals, some of which are found nowhere else in the world. It is also home to a koala population that is the largest in the Sydney region and one of the healthiest in NSW.

The Cumberland Plain Conservation Plan (the Plan) will protect large areas of significant habitat for threatened plants and animals while supporting the delivery of housing, jobs and infrastructure in the Western Parkland City. The Plan is an exciting opportunity to protect the best of the remaining woodland habitat in Western Sydney and to enhance the connectivity of a fragmented landscape.

The Plan is one of the largest strategic conservation plans to be undertaken in Australia and delivers on a commitment under the Western Sydney City Deal. The draft Plan and Explanation of Intended Effect (EIE), on exhibition from August to November 2020, provided an opportunity to get your feedback. We received a variety of feedback from the community, landholders, and other stakeholders about the draft Plan and EIE.

We have heard your concerns and are making several changes in the final Plan. In response to community and landholder views, we are:

- taking an alternative approach to environmental conservation zoning on avoided land to better balance land use and conservation outcomes
- revising the Plan's mapping to remove smaller streams from the avoided land
- adding some new lands and key corridors to the strategic conservation area
- working with landholders to encourage biodiversity stewardship sites around Razorback to protect Cumberland Plain Woodland

The Honourable Robert Gordon Stokes MP
Minister for Planning and Public Spaces

- working with NSW National Parks and Wildlife Service to begin gazettal in the first stage of the Georges River Koala Reserve by the end of 2023
- partnering with Transport for NSW to complete a fauna crossing across Appin Road by 2023
- increasing the number of compliance officers to support councils in the Plan area
- collaborating with local councils to ensure unexplained clearing and other implementation matters are managed promptly and effectively.

In addition to the above, the NSW Government has increased its funding commitment in the first 5 years from $84 million to $114 million since the Plan was exhibited. This will fund the restoration of around 80 hectares of habitat, with a focus on koala habitat in the Georges River Koala Reserve, installing koala-exclusion fencing and taking other measures to protect koalas, as well as establishing biodiversity stewardship sites and purchasing land for future reserves.

I am committed to successfully finalising the Plan as a priority. It will streamline the delivery of housing and infrastructure while protecting regionally important land for conservation and publicly accessibly green space in Western Sydney. The Plan will ensure we strategically balance the needs of sustainable development with continued protection of our natural environment.

Top: *Grevillia Juniperina*

About this report

The Cumberland Plain Conservation Plan is an important part of delivering the Western Parkland City. The plan will support the delivery of housing, jobs and infrastructure while protecting the region's important biodiversity such as threatened plants and animals.

The draft Cumberland Plain Conservation Plan was on public exhibition from 26 August 2020 to 2 November 2020. The documents exhibited included:

- Highlights of the Draft Cumberland Plain Conservation Plan
- Draft Cumberland Plain Conservation Plan
- Sub-Plan A: Conservation program and implementation
- Sub-Plan B: Koalas
- The Explanation of Intended Effect
- Summary Assessment Report
- The Draft Cumberland Plain Assessment Report.

We received valuable feedback from community, landholders, local councils, environment groups and other stakeholders. This report summarises the feedback and explains how we have considered and responded to this feedback in finalising the plan.

Thank you for having your say and your continued involvement in developing the Cumberland Plain Conservation Plan and shaping the future of the Western Parkland City.

Photography: Marie-Claire Demers/ DPIE

The Cumberland Plain Conservation Plan

We project the Western Parkland City will grow from 740,000 people in 2016 to 1.1 million by 2036, and to well over 1.5 million by 2056. A thriving, liveable Western Parkland City must be well planned to meet that growth. It should include dedicated areas to protect the many unique native plants and animals in the region, and publicly accessible, open and green spaces that local communities can enjoy.

Our department is developing the Cumberland Plain Conservation Plan to support biodiversity and future growth in the Western Parkland City. The Plan will protect the region's important conservation values through the creation of new reserves, conservation areas and green spaces for local communities.

The Plan has been developed to meet requirements for strategic biodiversity certification[12] under the *Biodiversity Conservation Act 2016 (NSW)* (BC Act) and strategic assessment[13] under the *Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (EPBC Act).

The Plan is one of the largest strategic conservation plans to be undertaken in Australia and is the first strategic biodiversity certification to be undertaken under the BC Act.

The Plan area covers some 200,000 hectares, extending from north of Windsor to south of Picton, and from the Hawkesbury–Nepean River in the west to the Georges River near Liverpool in the east. The Plan will support the delivery of new housing and infrastructure across four areas, which are collectively referred to in this report as 'nominated areas':

- Greater Macarthur Growth Area
- Wilton Growth Area
- Western Sydney Aerotropolis
- Greater Penrith to Eastern Creek Growth Investigation Area.

The Plan spans 8 local government areas and includes four major transport corridors that will allow for future construction of road and rail infrastructure in Western Sydney.

The Cumberland Plain Assessment Report, which was exhibited along with the Plan, assesses the potential impacts of the proposed development under the Plan on biodiversity values in accordance with the BC Act and EPBC Act.

12 NSW Government (2021) Biodiversity certification https://www.environment.nsw.gov.au/topics/animals-and-plants/biodiversity-offsets-scheme/about-the-biodiversity-offsets-scheme/biodiversity-certification

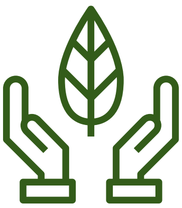
13 NSW Government (2021) Strategic assessment, https://www.environment.gov.au/epbc/publications/strategic-assessment-under-epbc-act-brochure

Key changes to the Plan

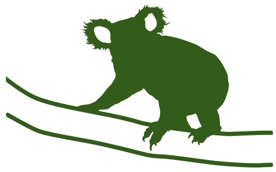
We heard your concerns and are proposing an alternative approach to balance land use and conservation outcomes.

We are reviewing mapping to exclude smaller streams.

We are proposing to add new lands and key corridors to the strategic conservation area. We are reviewing mapping to consider lands subject to development applications.



We heard your feedback about the importance of protecting Cumberland Plain Woodland. We will prioritise working with landholders to encourage biodiversity stewardship sites around Razorback to protect Cumberland Plain Woodland.



We are working with NSW National Parks and Wildlife Service to begin gazettal in the first stage of the reserve by the end of 2023.

We are partnering with Transport for NSW to begin work on a fauna crossing of Appin Road to ensure safe koala movements. The crossing is due for completion in 2023.

We will increase the number of compliance officers embedded into councils from 3 to 6 staff to monitor and report on illegal clearing of native vegetation.

We are proposing to establish a council implementation and compliance working group to ensure illegal clearing activities are managed timely and effectively.

Public exhibition snapshot

In 2020, COVID-19 meant we had to change the way we consulted on the plan. Despite its challenges, the department raised awareness of the plan and encouraged community and stakeholders to make a submission.

Public exhibition ran for 9 weeks from 26 August to 2 November in line with the requirements in the BC Act and EPBC Act. We extended the exhibition from the original closing date of 9 October in response to requests from the community and other stakeholders for more time to make a submission. The community and stakeholders were able to engage on the plan through numerous channels, and we published a range of materials to help understand what was being proposed and what it might mean for them.

Consultation materials

We prepared a range of materials to raise awareness of the draft plan and support the public exhibition. This included:

- direct mail to developers and landholders effected by the plan
- emails sent to community, local councils and other stakeholders
- dedicated staff to respond to enquiries through a hotline and email mailbox
- dedicated webpage and supporting materials such as fact sheets and FAQs
- a spatial viewer to help landholders understand the plan mapping and proposed zoning
- a social media advertising campaign
- newspaper advertising, which also targeted culturally and linguistically diverse groups.

Engagement events

During the plan's exhibition we undertook a variety of engagement events to gain an understanding of the values of the community, council and stakeholders. These included:

- a webinar to inform the community about public exhibition
- a webinar and briefings with eight local councils in western Sydney
- briefings with Tharawal and Gandangara Aboriginal Land Councils and NSW Aboriginal Land Council
- meetings and site visits with landholders
- community meeting with Orchard Hills residents
- briefing with the Urban Development Institute of Australia.

Engagement snapshot

34,500+
department website views

2,902
e-newsletters sent by the department

307,671
people reached via social media within the Western Sydney area

202
people attended the community webinar

2,822
clicks to the spatial viewer

20
council and stakeholder meetings and briefings

926
letters posted

379
phone and email enquiries replied to

Photography: Marie-Claire Demers/DPIE

Submissions analysis

We received 508 individual submissions and numerous campaign emails during the public exhibition period. These came from a range of stakeholders including landholders and developers, community and environment groups, industry, local councils, Aboriginal Land Councils and residents in and outside the Plan area.

Around 80% of submissions were from individuals, with most being landholders potentially affected by the Plan. We reviewed each submission individually, considering all information and additional maps, notes and photos with our own data. This helped us understand key themes that were expressed in submissions, as well as specific concerns about individual sites. This information was used in updating the Plan.

We received additional submissions through 6 campaigns that encouraged responses to the public exhibition. We reviewed the key points and issues resulting from these campaigns and considered them along with all other submissions.

Some landholders included ecological data and assessments to support their submission. The department engaged accredited ecological consultants to review all supplementary reports and information. We used the information to inform updates to the Plan's vegetation and land category maps where needed.

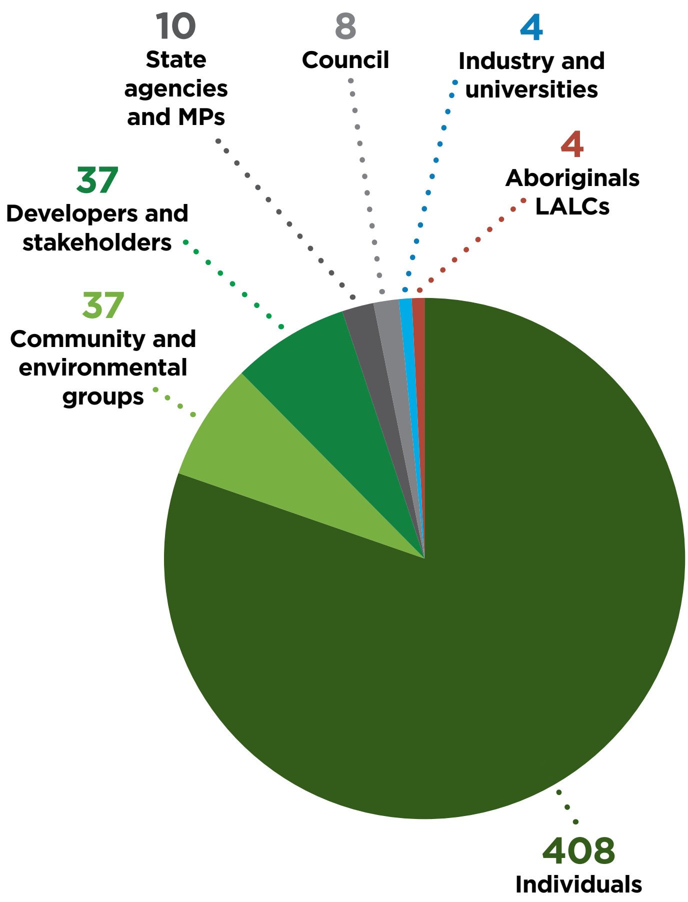


Figure 1 Breakdown of submissions

Figure 2 Campaign responses received

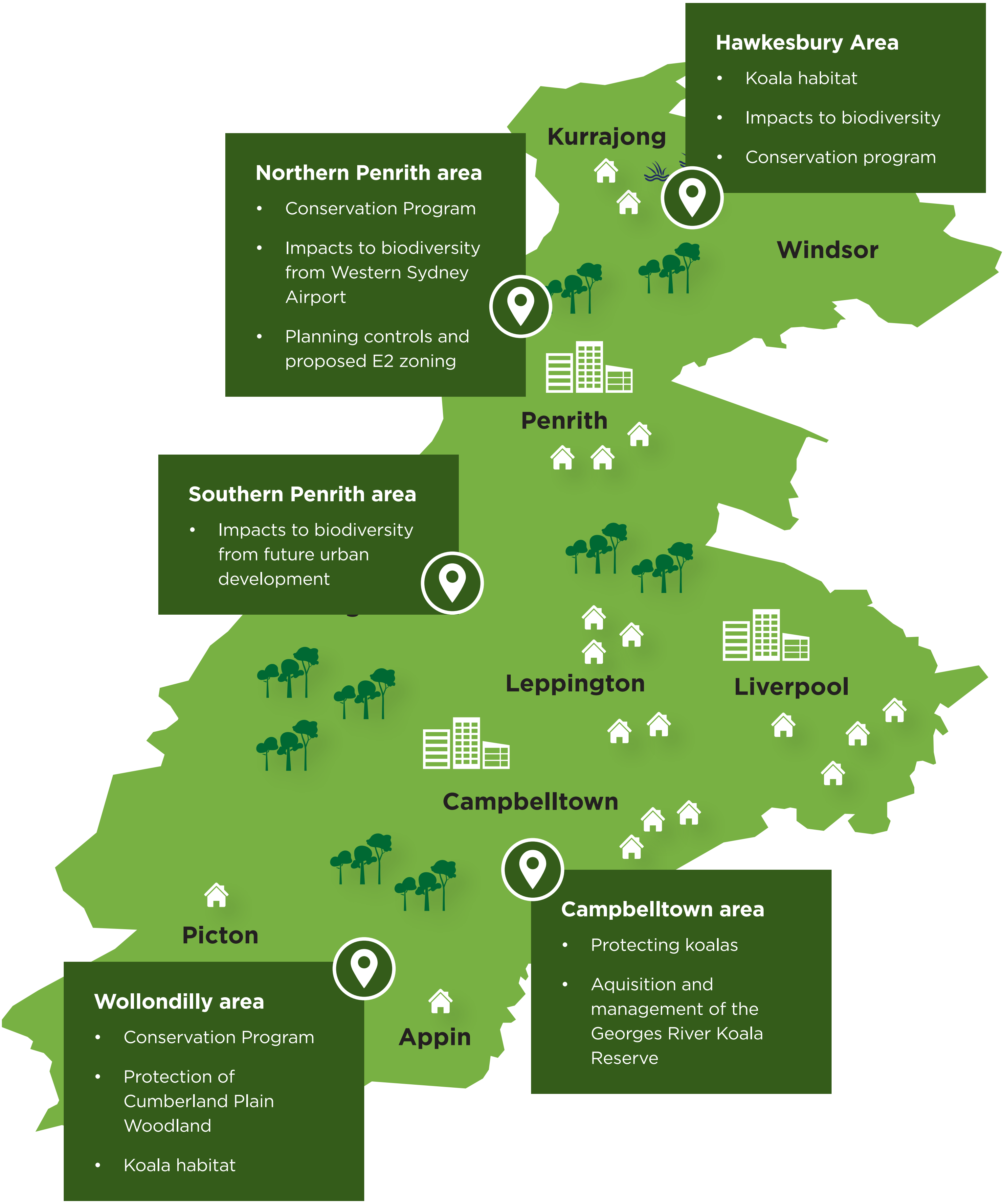


Figure 3 What we heard across the Plan area

Key themes

1. E2 Environmental Conservation zone

Many landholders were concerned about restrictions on future land use and potential impacts on property value because of the proposed E2 Environmental Conservation zone. Some landholders also expressed concerns about the accuracy of the vegetation mapping used to identify avoided land.

2. Impacts to biodiversity

Submissions confirmed that avoiding and managing impacts to biodiversity from urban and transport development was important. There was strong sentiment that all remaining Cumberland Plain Woodland should be preserved. The need to protect biodiversity from climate change and bushfire threats was also considered important.

3. Conservation program

Some people raised questions about the process of identifying conservation lands and how and where the Plan will create new reserves. Some people expressed concerns about the effectiveness of biodiversity offsetting and the ability of the Plan to meet its offset targets. Others were pleased to see an emphasis on long-term private land conservation.

4. Ecological restoration

There was a strong preference for conserving bushland rather than replanting created areas. Some had concerns with how Cumberland Plain Woodland will be restored and advocated for more research into restoration methods.

5. Protecting koalas

Questions were raised about the proposed koala-exclusion fencing. Many people are concerned that the Plan does not go far enough to protect koala movement corridors as recommended by the Office of the NSW Chief Scientist & Engineer koala report (2020), NSW.

6. Funding and implementation

Some people wanted to know more about how the long-term governance and funding arrangements will work. There were some concerns about the reliance on infrastructure contributions from developers to fund the conservation program.

7. Culture and heritage

Many respondents valued the semi-rural lifestyles in the less urbanised parts of the Plan Area and were concerned about losing agricultural land. There was strong support for incorporating Aboriginal knowledge and partnerships into implementing the Plan.

Table 1 Key Themes

1. Proposed E2 zone and other planning controls

Protecting threatened biodiversity is a critical legislative step to reduce impacts of proposed development. The draft Plan proposed planning controls to protect biodiversity values on avoided land. These included applying the E2 Environmental Conservation zone, applying consistency between land categories identified in precinct plans and land covered by the Plan's biodiversity approvals, and guidelines to manage essential infrastructure on avoided land.

The strategic conservation area represents large remnants of native vegetation with high connectivity or areas with potential to improve landscape connectivity if restored. This comprises of approximately 27,200 hectares of the Plan area of regional biodiversity significance. Planning controls are proposed for new developments in the strategic conservation area to protect or enhance native vegetation and minimise development impacts. This will support the future conservation of land under the Plan and improve management of biodiversity to protect threatened ecological communities and species across the region.

What you told us

The E2 zone will unfairly affect my property

- There were concerns about restrictions on future land use and potential impacts on property value as a result of the proposed E2 zone.
- Small landholders and farmers feel they would pay the price for developers to clear vegetation and develop land.
- Existing land use zones should remain unchanged (such as RU1 and RU2).
- Environment protection zones such as E3 Environmental Management and E4 Environmental Living are less restrictive than the proposed E2 zone.
- Protection of vegetation through an E2 zone will increase bushfire risk to existing homes and new development.

There was inadequate consultation with landholders about the E2 zone

- Landholders affected by proposed E2 zoning did not feel they were consulted or given adequate notice of the proposed changes to their land prior to public exhibition.
- Some landholders in Orchard Hills and Wilton were surprised by the proposed actions in the Plan and felt they were not adequately consulted about the Plan or the broader planning arrangements for Western Sydney.
- Some stakeholders felt that the public exhibition was not long enough to seek specialist advice, consider the complex Plan package and provide detailed submissions.

The proposed E2 zone is confusing and applied inconsistently

- There was some confusion about the differences between the proposed E2 zone and strategic conservation area.
- There was concern that application of the proposed E2 zone was sometimes inconsistent across local areas and neighbouring properties.
- The permissible uses of the proposed E2 zone were inconsistent with the permissible uses of E2 zones under existing environmental planning instruments.
- The proposed E2 zone was applied to some properties with existing development applications in place.
- Some stakeholders felt that the restrictions of the proposed E2 zone would not lead to successful biodiversity conservation over current protections.

- Some stakeholders considered that the proposed E2 zone was sometimes inconsistent with land use zones in other environmental planning instruments and government plans such as Wilton 2040 and Greater Macarthur 2040.

The E2 zone and strategic conservation area were based on inaccurate mapping

- Some stakeholders expressed concerns that the vegetation mapping was done from satellite imagery without adequate ground-truthing.
- Many landholders requested field-based vegetation assessments or review of the vegetation mapping on their properties, especially those affected by the proposed E2 zone.
- Landholders questioned the biodiversity value of their properties and their inclusion in the strategic conservation area.
- There was confusion about why some land with high biodiversity value was not included in the strategic conservation area.
- For specific properties, riparian zones do not reflect existing vegetation. Landholders questioned why these should be categorised as having biodiversity value.

Campaigns

Cawdor Residents Group

The group objected to properties in Cawdor being rezoned to E2 and sought to amend the urban-capable boundary. They were concerned that the assessment had been done remotely using information that was not up to date and therefore not reflecting recent or current land uses.

Orchard Hills Resident Group

The group expressed concerns that the review of the Orchard Hills area had not resulted in an accurate portrayal of the environment.

They advocated that the Plan should be withdrawn until an on-site assessment is conducted on all affected properties. conducted on all affected properties.

Kemps Creek Flood Impacts Group

The group objected to the flood study that was used to inform the extent of flooding along Kemps Creek and South Creek. They consider that the proposed environmental conservation zone is not suitable as large areas that are proposed for conservation are of low biodiversity value.

Moreton Park Road Owners Group

Moreton Park Road Owners Group. The group expressed concerns the strategic conservation area would impact their properties. They considered their land as potentially prime employment and services land.

Further information

Development controls in the strategic conservation area

Some stakeholders wanted to understand what development controls will be applied to the strategic conservation area.

The aim of the strategic conservation area is to minimise impacts on areas of regionally significant biodiversity, maintain or enhance ecological function and protect or enhance koala habitat and koala corridors. The development controls proposed for land in the strategic conservation area do not change a property's current land use zone or the permissible land uses under that zone. Development controls provide additional environmental matters for a consent authority such as a council to consider before they give consent or approval for a new development.

Vegetation mapping for avoided areas

Accredited ecological consultants engaged by the department mapped the vegetation and threatened ecological communities in 2019. This mapping used a mix of detailed on-site assessments on public and private land across all four growth areas. This also included desktop analysis, satellite imagery, review of existing threatened species records, modelling work and export reports. The consultants undertook this work in accordance with legislative requirements of the BC Act and EPBC Act, including requirements under the Biodiversity Assessment Method. The work exceeded the minimum requirements for site-based sampling. The mapping was a mix of on-site and desktop analysis.

We wrote to landholders seeking permission to access lands to conduct survey work. We mostly contacted landholders in areas that were likely to be certified as urban capable. In some areas, we were given approval to access more lands than needed, so we did not always access every site available. In some cases, landholders did not respond or were not comfortable providing access. This level of access for survey work allowed the department to prepare vegetation mapping that meets the requirements under Biodiversity Assessment Method for a strategic biodiversity assessment.

Lands excluded from the strategic conservation area

Several submissions asked why we did not include certain areas or reserves in the strategic conservation area. There are many reasons why we excluded some lands with valuable biodiversity from the strategic conservation area. These included that:

- the land does not support the vegetation types needed to offset development under the Plan
- the existing zoning or land use is incompatible
- the lots are too small (less than 5 hectares)
- the lots are too isolated to provide a strongly connected landscape
- the land is already protected and/or used as an offset, such as national park estate or is under an existing biodiversity stewardship agreement
- the land already protected separate to Commonwealth land such as the Air Services site and Shanes Park)

Our response:

The E2 zone will not be applied and an alternative approach to protect biodiversity will allow existing land uses to remain	We acknowledge some landowners were concerned about the development restrictions with the proposed land use zoning. Zoning will remain for land that has already been zoned E2 as a result of the precinct planning process. In response to feedback during public exhibition we have removed the proposed Environmental Conservation Zone (E2 zone). We have revised our approach to use planning controls to address this feedback while still conserving biodiversity and other important environment values within the Plan area. This means, landowners will retain current and permitted land use zones on their land. Planning controls will instead apply to avoided land. These planning controls will provide opportunities for landholders to develop and use their land in a way that is sympathetic to biodiversity. These planning controls will be included in the new Strategic Conservation Planning State Environmental Planning Policy (SEPP). Further information on the planning controls is available on the DPIE website. Any new development applications will require detailed consideration of biodiversity values. A consent authority will consider this when determining a development application on avoided land. The approach aims to protect biodiversity such as threatened ecological communities, threatened species and their habitats.
Revision of vegetation mapping	Some landholders provided vegetation mapping or ecological reports to support their submission. We have considered all reports and data provided through the exhibition period to update the Plan's vegetation and land category maps. This additional information was reviewed by the department's accredited ecological consultants and resulted in some minor changes to vegetation communities. This includes woodland previously identified as Cumberland Plain Woodland, now identified as Shale Gravel Transition Forest.
Revision of riparian mapping	The *Water Management Act 2000* protects water sources in NSW. We have revised the riparian mapping where no significant vegetation was present. This will be included in the final Plan. This includes removing second order streams from the avoided land category, except where they have high biodiversity value. In some instances, we have also removed third order streams where this is no biodiversity values present. Any development near watercourses will need to comply with the *Water Management Act 2000* and *Fisheries Management Act 1994*.

<table>
<tr><td>Updates to the strategic conservation area</td><td>We have reviewed the strategic conservation area based on advice and feedback provided in submissions. Some of the key changes include:

Adding land to the strategic conservation area where:

high biodiversity value areas support strategic landscape connectivity
habitat supports koala corridors
dwellings were previously surrounded by the strategic conservation area.

Removing land from the strategic conservation area where:

an approved development application was raised by landowners
land was changed to urban capable or excluded in the nominated areas

</td></tr>
<tr><td>Feedback from public authorities</td><td>Some infrastructure providers were concerned about the proposed policy to seek approval or consent for development that can be carried out without consent under existing planning pathways, for example, under State Environmental Planning Policy (Infrastructure) 2007. An example of this was the proposed policy to obtain approval or consent for native vegetation clearing on avoided land and in the strategic conservation area.

In response to this feedback, we propose the consent to clear native vegetation on avoided land or in the strategic conservation area would not apply to public authorities. To protect biodiversity in Western Sydney from the impacts of infrastructure development, DPIE will introduce infrastructure guidelines that require infrastructure providers to avoid or minimise impacts on biodiversity on avoided land and in the strategic conservation area.</td></tr>
</table>

2. Impacts to biodiversity

The draft Plan identified strategically important biodiversity areas that can offset the biodiversity impacts resulting from residential development and transport infrastructure in the Western Parkland City. The draft Plan aimed to balance the protection of biodiversity with urban and transport development.

The Plan's objective is to improve ecological function and resilience over the long term. It will focus efforts on new conservation lands to ensure management is active, targeted and holistic. Avoiding and minimising impacts on biodiversity at a landscape scale is an important and required part of the strategic planning process. The total area of avoided land in the draft Plan is 4,795 hectares, which contains threatened ecological communities and species habitat. This is across the four nominated areas of approximately 40,000 hectares. Both the BC Act and EPBC Act require avoidance as a first step in the assessment process.

The draft assessment report identifies all the potential direct, indirect and cumulative impacts of future development in the nominated areas and transport corridors on threatened biodiversity. It also provides an assessment of the adequacy of the conservation program in meeting the requirements of the BC Act and EPBC Act. It concludes that the proposed conservation program is adequate to address all impacts of future development from the Plan on biodiversity.

What you told us

Balancing urban development and conservation is important

- Long term residents were concerned about over-development of semi-rural areas.
- Industry stakeholders were concerned the Plan may constrain housing supply in Western Sydney.
- Increasing the population puts pressure on existing infrastructure.
- Further development should stop until there is adequate protection for native plants and animals in place.
- The Plan seemed to favour urban development over the protection of native vegetation in conservation land.
- Cumulative impacts of development in western Sydney on biodiversity values of the Cumberland Plain need to be better addressed.

Transport corridors will affect existing conservation areas

- Proposed transport corridors will have an impact on established nature reserves, in particular Wianamatta Regional Park, Shanes Park and Colebee Nature Reserve.
- The Outer Sydney Orbital should go through a tunnel under Wianamatta Regional Park to avoid impacts to this important area of biodiversity.
- Land that has been gazetted for conservation or established as a previous offset should not be excised for development.
- The Outer Sydney Orbital and Ropes Crossing Link Road will reduce connectivity between Wianamatta Regional Park, Colebee Nature Reserve and Shanes Park by isolating these reserves from each other.
- The proposed Camden Tunnel will have impacts on bushland of the Cobbitty Hills and a previously identified corridor – EMAI to Razorback Wildlife Corridor – and should be extended 6 kilometres northwards and 4 kilometres southwards to avoid impacts.

Impacts to Cumberland Plain Woodland are too high

- The amount of impact to Cumberland Plain Woodland would be too high – this threatened community should be protected.
- Important areas of remnant Cumberland Plain Woodland need to be protected in areas such as Razorback, Cobbitty, Camden and the Cumberland Conservation Corridor.
- The Plan should adopt the recommendations of the Cumberland Plain Recovery Plan.
- Some reserve investigation areas such as The Confluence do not provide suitable offsets for Cumberland Plain Woodland.

Climate and bushfire threats need to be considered

- Mitigation measures are needed to reduce the urban heat island effect in western Sydney.
- Retaining bushland on and around properties (in avoided land) will increase bushfire risk for landholders.
- Consideration of the impacts of urban heat and climate change and how these might affect the outcomes of the Plan.

Further information

Impacts to Cumberland Plain Woodland

The draft Plan proposed urban development to occur on predominantly cleared and degraded land. Avoiding and minimising impacts on threatened biodiversity is a critical step in reducing overall impacts of development. The draft Plan has avoided a substantial area of Cumberland Plain Woodland. It avoids impacts to 96.3% of the intact NSW-listed Cumberland Plain Woodland in the nominated areas.

The draft Plan commits to protecting and managing 3,170 hectares of Cumberland Plain Woodland to secure its protection in the future and includes a program of ecological restoration of Cumberland Plain Woodland. The outcomes of Plan on Cumberland Plain Woodland are supported by the trend analysis undertaken by RMIT University as part of the assessment report[12]. This analysis examined one component of Cumberland Plain Woodland over the life of the Plan under various scenarios. It suggested restoration would have the potential to address the decline of Cumberland Plain Woodland due to landscape threats.

The report has assessed the impacts of the Plan on both the Commonwealth-listed and NSW-listed Cumberland Plain Woodland and the outcomes are considered acceptable.

12 NSW Government (2020), The Draft Cumberland Plain Assessment Report https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

Our response:

Balancing urban development and conservation	The population of western Sydney is growing, and the Plan plays an important role in balancing social, economic and environmental values. The Plan is part of a coordinated approach to delivering the Western Parkland City, managing future development in a way that helps protect areas that are important to long-term conservation and that provide access to nature. Avoiding and minimising impacts during the planning stage has been a critical step in minimising the effects of development on biodiversity. The Western City District Plan recognises that the district's natural landscape is a great asset, sustaining and supporting a liveable parkland city. Development focuses on certified urban-capable land in the nominated areas where land use and infrastructure implementation plans will guide precinct development. Precinct plans help identify the proposed land uses, associated development and infrastructure at a finer scale.
Transport development	Transport infrastructure is needed to support future urban development in western Sydney. The assessment report has evaluated the impacts of the included transport corridors on threatened species and ecological communities and the conservation program includes offsetting impacts within transport corridors. A range of mitigation measures has been developed specifically for the construction of transport infrastructure facilitated by the Cumberland Plain Conservation Plan. This includes activities such as undertaking pre-construction surveys, pest control, establishing minimum setbacks, and weed management[12]. Transport for NSW is working to minimise impacts to existing reserves such as Wianamatta Regional Park. Tunnels are not the first choice for avoiding on-ground impacts due to their considerable expense and technical considerations. Transport for NSW is proposing an elevated viaduct to pass over the reserve. Through the Cumberland Plain Conservation Plan they will be offsetting all vegetation within the corridor. However, if a viaduct is used, clearing will be limited to construction sites and pylons. This will allow continuing connection of habitat beneath the viaduct. We have passed feedback on the suggested extensions to the Camden tunnel onto Transport for NSW for its consideration in future planning for the corridor.
Protecting Cumberland Plain Woodland	Much of the Cumberland Plain Woodland that has been certified for development comprises of native grassland or grassland with scattered trees. When determining the certified - urban capable land, we avoided 96.3% of intact Cumberland Plain Woodland. In response to feedback that the three priority reserves investigation areas did not include substantial areas of Cumberland Plain Woodland, we are proposing to prioritise working with landholders to encourage biodiversity stewardship sites in the Razorback area. The Razorback area is rich in Cumberland Plain Woodland and other threatened ecological communities that we need to offset through the Plan.

12 NSW Government (2020) Cumberland Plain Conservation Plan, Sub Plan A https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

Climate threats and urban heat

Climate change is likely to introduce additional threats and exacerbate existing ecosystem stressors over the coming decades. Although the fires of 2019–20 had limited impact on the native species in the Plan area, they are a reminder of the threats that bushfires pose to biodiversity.

We are committed to funding research that will help to identify the most at-risk species and ecological communities in the Cumberland subregion. This includes identifying priority locations such as climate refugia. The Plan's evaluation program will help measure how well we are enabling plants and animals to adapt and survive in a changing climate.

In the first 5 years of the Plan, we will prepare a fire management strategy for the strategic conservation area. We will work closely with key agencies and delivery partners to identify the fire management priorities, including fire-sensitive species and ecological communities. Aboriginal specialists in Indigenous fire management techniques will also train and support land managers.

While the Plan's conservation program is focused on the protection of biodiversity, the Plan will also contribute to wider government efforts to increase green canopies and mitigate the urban heat island effect. One way we are doing this is by introducing development controls to protect biodiversity (such as hollow-bearing trees) and other habitat features in new urban developments in the nominated areas. Restoration projects will also contribute to expanding the area of green space over the coming decades.

3. The conservation program

The Plan's conservation program will focus on identifying and protecting conservation lands to offset impacts to biodiversity from development facilitated through the Plan.

We will select conservation lands from areas identified within the strategic conservation area. This area contains large remnants of native vegetation with good connectivity or are areas with the potential to enhance connectivity. The strategic conservation area comprises of habitat for 49 threatened flora and fauna species and 8 threatened ecological communities listed under either the BC Act or EPBC Act, or both.

We will establish conservation lands as new national parks or additions to existing national parks, public reserves and biodiversity stewardship sites. Conservation lands can also include areas of degraded habitat where it provides connectivity and can be enhanced through a restoration project.

Under the draft Plan, the establishment of conservation lands will protect a minimum of 5,475 hectares of threatened native vegetation in perpetuity to offset development. More than double this area – around 11,000 hectares – is likely to be protected to support the establishment of conservation land.

What you told us

Adequacy of the conservation program

- The Plan has been designed to facilitate urban development that will result in unacceptable impacts to important habitat for threatened species and ecological communities.
- The Plan is an offset program for development not a holistic conservation program for the Cumberland Plain.
- The plan does not adequately consider cumulative impacts of future development in western Sydney.
- The Plan does not consider other impacts of development such as changes in hydrology and water quality
- The full impact of development under the Plan is unknown because infrastructure routes through 'avoided land' have not been determined.

Environmental corridors need protection

- There is strong support for preserving corridors and enhancing connectivity for the survival of habitat and key threatened species.
- Additional corridors should be included in the strategic conservation area and protected through the Plan including Kingshill Corridor, Blaxland Creek, the Cumberland Connection Corridor, Ropes Creek Corridor, and the EMAI-Razorback Wildlife Corridor.
- Corridors described in the Plan for protection are not continuous, like-for-like or wide enough and do not incorporate wildlife crossings.
- The priority reserves do not support connectivity.

Biodiversity offsetting is complex and not effective

- Offsets must not be selected from public reserves or already protected sites.
- All offsetting should occur on the Cumberland Plain – vegetation protected outside the subregion will not result in like-for-like offsets.
- Biodiversity offsetting is not an adequate trade off or compensation for development.
- Some properties will not be able to participate in protecting biodiversity due to minimum lot sizes recommended by the Biodiversity Conservation Trust.
- Engagement is needed with landholders and developers to support the Plan's biodiversity offset program.

Campaigns

Action Network Group

This campaign raised concerns about the overall adequacy of the plan and the protection of conservation lands. Participants considered that the plan did not adequately protect remaining Cumberland Plain Woodland or the local koala population.

Nature Conservation Council

This campaign of submissions expressed their concern that in its current form the plan would result in fragmentation and clearing of significant areas of habitat and threatened ecosystems.

They were concerned that there was not enough funding to ensure that the offsets are delivered. Submissions did not want offsets created on existing public reserves and emphasised the importance of staging development to keep pace with offsets.

Further information

Biodiversity offsets

The conservation program will avoid, mitigate and offset impacts on biodiversity. Biodiversity offsetting will maintain biodiversity values by seeking to conserve, protect or establish conservation lands in the strategic conservation area, and where necessary, in suitable sites across Western Sydney or adjacent regions. These lands will be established in accordance with legislative requirements that prioritise direct and like-for-like offsets. If they are established outside of the strategic conservation area, they will be selected according to a strict ecological criteria and capped to a maximum of 20 per cent of the Plan's offset targets.

Biodiversity offsets will not be 'double counted'. Existing conservation reserves such as the NSW National Parks and Wildlife Service estate, cannot be used for offsetting. These existing conservation sites were not considered as part of developing the Plan's strategic conservation area.

We will enable the purchase of credits (as offsets) from existing stewardship sites if they meet the Plan's criteria for offsets and contain the Plan's target species and threatened ecological communities. For example, we could consider sites if they adjoin the strategic conservation area and would otherwise meet the criteria for conservation land. This could benefit all land holders with suitable stewardship sites, not just those established after the Plan commences. It could also lead to an improved ecological outcome in the Plan area, where the purchase of credits could transition a site from passive to active management.

Biodiversity stewardship sites

The Biodiversity Conservation Trust generally advises not all landholdings will be suitable for biodiversity stewardship sites. Smaller landholdings (e.g. holdings less than 10 hectares) may not be suitable because of the cost of managing the site may be greater than the value of credits generated from the biodiversity stewardship site. The factors that determine whether a biodiversity stewardship site is viable is specific to the landholding and the landholder. Therefore, we encourage individual landholders to contact the Biodiversity Conservation Trust with any enquiries.

We are working with the Biodiversity Conservation Trust to develop a community engagement program to consult with landholders about the benefits of biodiversity stewardship sites and to maximise the uptake of stewardship agreements.

Our response:

Adequacy of the conservation program	The potential impacts to biodiversity values have been assessed in detail, as per the requirements of the Biodiversity Assessment Method and the terms of reference for the strategic assessment. The assessment report describes the Plan's approach to avoid and minimise impacts, and measures to avoid, mitigate and offset the residual impacts through a strategic conservation program. The Plan is not intended as a complete conservation program for the Cumberland Plain but aims to be consistent with other broader conservation plans in the region such as the Cumberland Plain Recovery Plan and NSW Koala Strategy. The Plan's offset targets for biodiversity were developed to meet legislative requirements for strategic biodiversity certification (NSW) and strategic assessment (Commonwealth). We will meet targets by securing large areas of habitat in perpetuity for protection as conservation lands. The advantage of strategic conservation planning is that it allows the establishment of a larger network of connected conservation lands. In addition to conserving large areas of habitat, the conservation program identifies mitigation measures to protect habitat and manage indirect impacts to threatened ecological communities and species from development in the Plan's nominated urban development areas. For example, the conservation program includes development controls to retain large trees during precinct planning in all nominated areas. This will address potential residual risks to several species including microbats, flying foxes and nectivorous birds, and owls and raptors.
Indirect and cumulative impacts	Indirect impacts of development, such as upstream and downstream hydrological processes have been considered in the assessment report[12] The Plan commits to mitigating these impacts on threatened ecological communities and species habitat to best-practice standards by implementing development controls through the NSW planning system. Where standard controls were not considered to adequately minimise these impacts, the Plan proposes additional specific mitigation actions. The Plan cannot account for all future essential services and local roads that may need to pass through land that we have avoided for biodiversity values. However, we have prepared guidelines for essential infrastructure development that will ensure that the impacts from these projects are acceptable. The guidelines will constrain the types of infrastructure that may be constructed and set out what is required to protect biodiversity in terms of planning, assessment and implementation. Additional infrastructure projects may also need to seek their own biodiversity offsets under NSW biodiversity legislation (the BC Act). The assessment report examines the cumulative impacts and conservation benefits of current and foreseeable major development in the Cumberland subregion, where data on the extent and location and impacts of future development was available. The assessment of cumulative impacts informed the Conservation Program measures and offset targets for threatened species and ecological communities protected under the Plan. We acknowledge that future development will occur, however development controls have been designed as part of the Plan to minimise additional cumulative impact to biodiversity in the nominated areas.

12 NSW Government (2020), The Draft Cumberland Plain Assessment Report https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

Corridors for protection	We considered some additional corridors suggested through submissions. This has resulted in updating the strategic conservation area to include Kingshill and Blaxland Creek Corridors to ensure long term corridor viability. We will review the strategic conservation area every five years and update it to reflect any new opportunities for conservation in the Plan area. The impacts of future development on habitat connectivity and movement are considered in the Assessment Report. The report demonstrates that impacts are acceptable because most of the most important areas of connectivity (BIO Map regional corridors and core areas) have been avoided and will not be directly impacted by development. Commitments are in place to protect priority habitat corridors in the Cumberland subregion, including for koalas.
Managing biodiversity offsets	Managing biodiversity impacts and offsets for a conservation program of this scale is a complex task. We are working on several methods to select, establish and track conservation land to ensure that biodiversity offsets are delivered over the life of the Plan. We proposed that the Plan includes some flexibility in reaching targets through the conservation lands selection steps[13]. These steps will guide the conservation program to allow for alternative offsets in case like-for-like species and threatened ecological community offsets cannot be secured. Our priority will be to select offsets from within the Plan's strategic conservation area. We will source offsets outside the Cumberland subregion only as a last resort and these will be capped at 20% of the overall offset target for native vegetation over the life of the Plan. We have introduced this flexibility to ensure that offsets are secured, and a conservation benefit is realised. The selection steps and flexibility mechanisms are consistent with the Biodiversity Conservation Regulation (NSW). The Plan will also establish a reconciliation accounting process to continually track offsets secured against development impacts. If offsets are not keeping pace with development, the department will introduce additional measures, for example compulsory acquisition, or temporarily constraining development (a pause point) until the offsets program is back on track.

13 NSW Government (2020), The Draft Cumberland Plain Conservation Plan, Sub Plan A https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

4. Ecological Restoration

Much of western Sydney's environment is degraded. Ecological restoration will play a critical role in delivering conservation lands, expanding native vegetation and creating new habitats within the Plan area. This will also assist in the recovery of ecosystems that have been degraded through erosion, weeds or past land uses. Ecological restoration also has the potential to enhance connectivity between fragmented habitats and replace some areas of over-cleared vegetation communities.

The Plan commits that a maximum of 25% of the Plan's offset target for threatened ecological communities will be delivered through restoration of habitat. Restoration will target threatened ecological communities such as Cumberland Plain Woodland, Shale Gravel Transition Forest and Swamp Oak Forest that is needed to help meet offset targets. Restoration of these threatened ecological communities will also contribute to restoration of koala habitat protected under the Plan in Georges River Koala Reserve, the Ousedale Creek corridor, and other priority areas of habitat.

What you told us

Protecting existing bushland should be the priority

- We need to conserve existing remnant bushland first rather than restore degraded areas.
- Planting seedlings will take decades to provide useful habitat.
- Replanting should only be used as a last resort.
- The Confluence does not have high biodiversity value and should not be a priority reserve.

More knowledge is needed for effective restoration

Replanting Cumberland Plain Woodland has a low success rate and should not be relied on to deliver conservation lands.

- More research is required before ecological restoration in the plan area is undertaken.
- Traditional and scalp and seed restoration methods are not successful in Cumberland Plain Woodland.

There is limited capacity for restoration and seed production

- There is limited regional capacity to supply seeds and propagate the plants that are needed to support a project of this scale.
- Community education and engagement is one way of increasing involvement in ecological restoration activities.

Our response:

The Confluence reserve investigation area	The Confluence reserve investigation area offers opportunity to link with existing NSW nature reserves in Windsor Downs and Londonderry, and with Wianamatta (South Creek Corridor). This corridor has been identified as a priority corridor in the Sydney Green Grid[12] due to its proximity to several existing reserves. It provides an opportunity for significant restoration of threatened ecological communities, including the River-flat eucalyptus. We chose this site as an early priority for the Plan because of the large sized lots that are not suitable for urban development. Protecting this site will contribute to the enhancement of terrestrial–aquatic linkages between South Creek and Eastern Creek.
Restoration strategy	Our commitment to actively restore vegetation is an important part of restoring ecological function and delivering against commitments for some plant communities, particularly those that are part of the Cumberland Plain Woodland. We acknowledge that there are concerns around the success and effectiveness of restoration to create new habitat. We want to ensure that restoration carried out as part of the Plan is recognised as best practice, so we will be providing funding for research into techniques for best practice restoration and land management. The Plan draws on best ecological restoration practice case studies such as Scheyville National Park, where direct seeding of Cumberland Plain groundcover to reconstruct plant communities in a highly fragmented landscape is currently being trialled in partnership with Greening Australia.. Trend analysis that was undertaken as part of the Plan's assessment report[13] has modelled the effectiveness of restoration as part of the conservation program. The modelling involved recognised experts in the management of Cumberland Plain Woodland and used ecological information on how one of the plant communities that makes up Cumberland Plain Woodland responds to management. The analysis showed that high-intensity management of conservation lands, such as active restoration or reconstruction, has significant potential to improve Cumberland Plain Woodland even when the ecological community is in poor condition. It demonstrated that active restoration would deliver greater gains in the long term when compared to lower-intensity vegetation management combined with early implementation of offset sites. The analysis supports our view that restoration has an important role in achieving the conservation outcomes of the Plan. We will develop a restoration and weed control implementation strategy in consultation with key stakeholders and delivery partners. This strategy will provide principles-based guidance on best-practice restoration of Cumberland Plain Woodland ecosystems. It will include guidance on restoration techniques and how to identify the restoration potential of lands that are within and adjacent to conservation lands. A working group will support the development and implementation of the strategy. Members will provide advice on suitable restoration methods based on their on-ground experience.

12 Government Architect New South Wales (2017) Sydney Green Grid, https://www.governmentarchitect.nsw.gov.au/projects/sydney-green-grid

13 NSW Government (2020), The Draft Cumberland Plain Assessment Report https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

Seed supply and production

The restoration strategy will identify best-practice restoration techniques and provide guidance best suited to Cumberland Plain Woodland species for restoration that delivers genetically diverse, self-sustaining and climate-resilient ecosystems. Evidence to inform restoration implementation will be enhanced by the Cumberland Plain Knowledge Infrastructure project, which is led by the Royal Botanic Gardens and Domain Trust. It will identify suitable areas where seeds can be sourced for restoration, guidelines for establishing seed production areas, and guidelines for seed sampling and collection for priority species. We will also be partnering with councils to help them to establish or expand seed banks and community nurseries.

We have established an initial panel of restoration service suppliers to spread opportunities across the Plan Area, minimise risks and maximise access to seed and plant stock.

5. Protecting Koalas

While koala numbers are in decline across much of NSW, western Sydney has one of the healthiest koala populations in NSW. A koala population occurs in south western Sydney around Campbelltown and Wollondilly local government areas. The protection of these koalas is at the forefront of the Plan to ensure they continue to grow and thrive..

The conservation program for koalas will establish new conservation lands including reserves and biodiversity stewardship sites to protect koala habitat protected under the Plan in perpetuity. Under the draft Plan, this includes establishing the Georges River Koala Reserve to protect and manage up to 1,885 hectares of koala habitat[12]. The Georges River Koala Reserve will protect 3 times the required offset target for koalas (around 80 hectares to restore by replanting). Ecological restoration will aim to expand the area's native vegetation and maximise ecological connectivity for koalas. The conservation program will restore up to 83 hectares of koala habitat in the Georges River Koala Reserve over the life of the Plan.

To mitigate against urban threats, koala-exclusion fencing will be installed between koala habitat and urban-capable land, and along the western boundary of the Georges River Koala Reserve. This includes up to 10 kilometres of koala-exclusion fencing along Appin Road to mitigate the impacts of vehicle strike on koalas. Transport for NSW will be fencing an additional five kilometres of Appin Road. Two fauna crossings under Appin Road will provide safe access (under Kings Falls Bridge) and east-west connectivity between the Georges and Nepean rivers (Ousedale corridor). As part of the Plan, we have prepared model clauses that can be used in development control plans to address threats to koalas and their habitat from increased development.

The conservation program will deliver education and a targeted stakeholder and community engagement program to build awareness among residents about koala conservation and key threats. Research will enhance our knowledge of koalas, allow for conservation initiatives and monitor populations as development occurs in western Sydney. We will also be providing funds to the NSW Koala Strategy and its NSW Volunteer Wildlife Rehabilitation Sector Strategy to support koala health and welfare in south-western Sydney.

12 The area comprising of the Georges River Koala Reserve currently includes publicly and privately owned land.

Photography:
Sarah Puling/
Bear Hunt Photography

What you told us

Greater protection is needed for east–west koala corridors

- All six of the east–west koala corridors that connect the Nepean and Georges rivers should be protected (many submissions cited the Office of the NSW Chief Scientist & Engineer Advice 2020.
- The Plan should incorporate the Office of the NSW Chief Scientist & Engineer Advice 2020 recommendation for habitat corridors to have an average width of 390 to 425 metres. There are also specific requirements for buffers and asset protection zones.
- More than one crossing point needs to be in place to allow koalas to safely move across Appin Road.

Koala-exclusion fencing has both benefits and impacts

- There is support for fencing both sides of Appin Road to mitigate koala vehicle strikes.
- The construction of koala-exclusion fencing will isolate and fragment the southern Sydney koala population.
- Koala-exclusion fencing will have a visual impact on new developments and along Appin Road.
- The proposed koala-exclusion fencing will require ongoing maintenance.

Mapping and protecting koala habitat is critical

- Protecting koala habitat in southern Sydney is critical to the survival of this koala population.
- There is not enough dedicated land being protected for koalas and their movement in south-western Sydney
- The Plan needs to consider the Campbelltown Koala Plan of Management and associated habitat mapping.
- Cleared land and properties where no koalas have been sighted have been identified as koala habitat protected under the Plan.
- It is unclear how the Plan relates to other koala planning instruments such as the Koala SEPP.

The Georges River Koala Reserve must be established as soon as possible

- There is widespread support for the establishment of the Georges River Koala Reserve.
- The proposed timeframes for establishing the reserve are too long and it needs to be established as soon as possible before any more koala habitat is lost.
- The reserve proposal does not protect enough of the koala habitat in south-western Sydney and is less than historic proposals and recommendations by government.
- The Georges River Parkway falls within the proposed reserve and should be removed from all planning instruments.
- Some landholders within the reserve are concerned about acquisition of their properties.

Further information

Office of the NSW Chief Scientist & Engineer Advice 2020

The Office of the NSW Chief Scientist & Engineer Advice on the protection of the Campbelltown Koala population (2020) (Office of the NSW Chief Scientist & Engineer Koala Advice 2020) is a report by an independent, expert panel advising on the protection of the Campbelltown koala population. It included several recommendations relating to the Plan that have been addressed in the conservation program for koalas.

The feedback in many submissions assumed that the Office of the NSW Chief Scientist & Engineer Koala Advice 2020 recommended the protection of all six east–west koala corridors for koala movement. However, the report recognises that some of these corridors are too fragmented and that not all of them are necessary for koala movement. The report identifies which of these corridors should be a priority for koala movement. For further information on the recommendations and an analysis of how we have addressed these, see the Sub Plan B[13].

In April 2021, the Minister for Planning & Public Spaces and Minister for Energy & Environment sought advice regarding the adequacy of the Plan's koala-specific measures to support a long-term strategic landscape-scale outcome for koalas across the Wilton and Greater Macarthur growth areas. Provided a second report titled Advice regarding the protection of koala populations associated with the Cumberland Plain Conservation Plan (Office of the NSW Chief Scientist & Engineer Koala Advice 2021), which provides principles to be applied in the region for the protection of the South Western Sydney koala population, and an assessment of the Plan's proposed protection measures and how they relate to the principles.

Koala-exclusion fencing

Koala-exclusion fencing has been recommended by the Office of the NSW Chief Scientist & Engineer Koala Advice 2020, Office of the NSW Chief Scientist & Engineer Koala Advice 2021, and the Conserving koalas in Wollondilly and Campbelltown LGAs report (Office of Environment and Heritage 2018) as a best-practice method to separate koalas from future urbanised areas.

Urban development in proximity to koala habitat poses several threats to koalas. Threats include domestic dogs, cars and swimming pools, particularly in the Wilton and Greater Macarthur growth areas. Without specific mitigation actions, threats to koalas near urban areas will increase as the population grows.

Cleared land as koala habitat

There was some confusion about why the Plan mapped some areas of cleared land as koala habitat. Cleared land may be identified as koala habitat protected under the Plan if it is part of an important koala movement corridor and a potential restoration area.

The Conserving Koalas in Wollondilly and Campbelltown LGA's Report (OEH 2018) recognises these cleared areas informally as a primary koala corridor. We have identified these cleared areas for potential ecological restoration as part of the Plan based on the EES mapping. If restored, these areas have the potential to become koala habitat. Nevertheless, koalas do cross these cleared areas to reach suitable areas of habitat, and in this context, cleared areas adjacent to primary koala corridors could be informally considered part of a koala corridor. The Office of the NSW Chief Scientist & Engineer Advice 2020 also recognises koala corridors with cleared areas such as the Georges River Koala Reserve as essential to the persistence of the Southern Sydney koala population.

13 Office of the NSW Chief Scientist & Engineer Advice 2020

Koala SEPP and plans of management

The State Environmental Planning Policy (Koala Habitat Protection) 2021 (Koala SEPP) provides local councils with a pathway for assessing development applications. This also enables councils to create koala plans of management (KPOMs). There are currently 9 approved KPOMs in NSW. There are requirements for development applications in areas with or without an approved KPOM. Campbelltown Council have an approved KPOM which needs to be considered when assessment development applications.

The draft Plan has been developed to meet requirements for strategic biodiversity certification under the BC Act and strategic assessment under the EPBC Act to deliver strategic conservation planning across Western Sydney.

The Koala SEPP is a separate regulatory process that reinstates the policy framework of Statement Koala Habitat Protection 2019. Accordingly the department considers and provides feedback about any potential consistency issues for the draft Plan as a KPOM is finalised or approved.

Our response:

Koala corridors and movement

During development of the draft Plan, we met with the expert panel that prepared the Office of the NSW Chief Scientist & Engineer Advice 2020 to gain their insights and ensure that the Plan was consistent with their recommendations. See the previous section’s clarification on the Office of the Office of the NSW Chief Scientist & Engineer Advice 2020.

Some of the existing 6 east–west corridors in the Greater Macarthur Growth Area are too fragmented and not wide enough to support koalas over the long term. Updated advice from the Office of the NSW Chief Scientist & Engineer Koala Advice 2021 recommends an average width of 390 to 425 metres and management of key threats for a safe koala corridor.

The Plan’s koala measures have been developed in recognition of the regional context. We are committed to securing at least one east west corridor for koala movement. The Ousedale Creek to Appin North corridor is recommended by the Office of NSW Chief Scientist & Engineer Advice 2020 as the most suitable for koala movement because of the condition and width of the existing vegetation. We are proposing one fauna crossing of Appin Road to support east-west connectivity between Georges and Nepean rivers. Another fauna crossing is proposed under Kings Falls Bridge, which will enhance north-south connectivity along Georges River.This will ensure safe koala movement across Appin Road near Brian Road. We are working with Transport for NSW to scope out the design of the crossing. This will take into account current scientific evidence and lessons learnt from other fauna crossing projects.

Fragmented or narrow corridors will be fenced off to exclude koala access to these areas that are considered to be not viable for safe koala movement (as identified by the Office of NSW Chief Scientist & Engineer Advice 2020). However, all these corridors have been mapped as avoided land and will have development controls applied to protect them from clearing. They provide habitat and movement opportunities for other wildlife and are still immensely important for this reason. If any of these corridors were to be enhanced through acquisition and future revegetation, this may allow them to become safe koala movement corridors in the future.

The Plan does not implement the Office of NSW Chief Scientist & Engineer Advice 2020 recommendation on corridors that fall within the Mount Gilead Stage 2 development, as it is not within the scope of the Plan. However, the approval for that development requires the construction of at least one crossing point of Appin Road to a suitable koala corridor.

Koala-exclusion fencing	We have begun a feasibility study to determine the exact location and design of exclusion fencing in the Greater Macarthur and Wilton growth areas, along Appin Road, and the Georges River Koala Reserve. We will deliver best-practice design to support the safety and longevity of the southern Sydney koala population. The fencing will be delivered in stages, as development progresses. The logistics and requirements for ongoing maintenance of the fencing will be considered as part of the feasibility study. The fencing will be maintained as part of reserve management or as agreed management actions on biodiversity stewardship sites, or as agreed on a case-by-case basis with relevant landholders. A comprehensive community engagement program will support the design and construction of the fencing. This will include targeted engagement with landholders along the fence boundary and with broader stakeholders and the local community to ensure their views and knowledge are considered.
Georges River Koala Reserve	The reserve is a commitment for the NSW Government. In response to your feedback to establish the reserve as soon as possible, we are working with NSW National Parks and Wildlife Service to start gazetting government-owned land within stage 1 of the reserve by the end of 2023. We will continue working with the Office of Strategic Lands and NSW National Parks and Wildlife Service to purchase, transfer and gazette future properties so that stage 1 is complete by year 10 of the Plan and stage 2 is complete by year 20 of the Plan. Land within the koala reserve is a priority for voluntary purchase at market value. We will be working with NSW National Parks and Wildlife Service and councils to develop a concept design plan for the Georges River Koala Reserve that will identify intended uses of the reserve, proposed infrastructure and visitor facilities, and optimal boundaries and access points. Planning for the reserve will help inform koala-exclusion fencing locations including locations for grids and gates. The concept planning will take account of restoration projects within the reserve. We are continuing to work with Transport for NSW to determine the future of the Georges River Parkway, which was exhibited as part of the koala reserve. The minimum offset target for koala habitat protected under the draft Plan is 610 hectares. The Georges River Koala Reserve will protect 3 times the required offset target. In addition to the Georges River Koala Reserve, around 7,345 hectares of important koala movement corridors and habitat have been identified within the Plan's strategic conservation area, so there is an opportunity to protect significantly more koala habitat.

6. Funding and implementation

The department will have long-term responsibility for implementing, and reporting on the Plan and reporting on its progress to stakeholders and the community. An implementation and assurance framework will ensure the success of the conservation program and provide confidence to stakeholders we will meet the commitments of the Plan.

At the time of exhibition, the NSW Government had committed $84 million to implementing the Plan's commitments and actions for the first 5 years. Since the end of the exhibition period, this funding commitment has increased to $114 million. We propose to recover costs of the conservation program from industry through contributions from developers in the 4 western Sydney nominated areas.

What you told us

Secure funding is needed for the plan

- The funding secured for the Plan is inadequate given the scale of offsets required under the Plan and the associated timeframes.
- More upfront funding is needed to achieve conservation commitments and outcomes.
- There is no certainty about future funding after the first 5 years of the Plan.
- Funding needs to be in place to ensure offsets are secured prior to development.
- There are concerns about the role of a special infrastructure contribution, who will pay for biodiversity offsets, and what land categories will be subject to a special infrastructure contribution.

Timeframes for implementing the plan are unclear

- There needs to be clarity on the timeframe for development contributions and offsets.
- Development should be staged appropriately to ensure offsets keep pace with development.
- The Plan does not identify a timeframe to protect lands of high biodiversity value.
- Timeframes for acquisition of lands are too long.

Ensure appropriate governance is in place

- More detail is needed on how developers will apply the Plan within the context of the NSW planning system.
- More information is needed on the governance framework, constitution, terms of reference and representation.
- There should be a role for community and stakeholder groups to help implement the plan and provide feedback on its progress.
- The role of local councils in the governance structure needs to be clearer.

Compliance is important

- Local councils are stretched for resources and need support for further compliance work.
- The Plan relies heavily on planning instruments that can easily be amended or repealed in the future, such as SEPPs and development control plans.
- Many commitments are worded in a way that will make progress with implementation difficult to measure, and compliance and enforcement difficult to undertake.

Our response:

Funding	In April 2020, Hon. Rob Stokes MP, Minister for Planning and Public Spaces in April 2020 requested the NSW Productivity Commissioner undertake a review of the infrastructure contribution system in New South Wales. The Commissioner made 29 recommendations for reform in the Final Report released 3 December 2020. The review recommended creating a new category of developer contributions specific to strategic biodiversity offsetting. In March 2021, the government accepted all 29 recommendations in principle and the Department of Planning, Industry and Environment is progressing the recommendations with legislative and regulatory amendments to be in place and effective from 1 July 2022. The Minister will be the decision maker to consider a range of development contribution amounts, including full cost recovery prior to determining the approach to funding the Plan.
Timeframes	The proposed timeframes for all commitments and actions under the Plan can be found in Appendix A of Sub-Plan A.[12] The timeframes for acquiring and establishing new reserves may seem long. This is because they are based on voluntary acquisition, which allows property owners to sell if and when it is convenient to them. Compulsory acquisition will be used only as a last resort, to ensure the Plan's commitments will be achieved. We are establishing a reconciliation accounting process that will continually track offsets secured under the Plan against impacts to biodiversity from development. If offsets are falling behind, the adaptive management framework for offsets will be triggered which would enable the department to consider options such as compulsory acquisition and temporarily constraining development (a pause point) on further development of precincts.
Governance	An executive implementation committee will support and drive the delivery of the Plan including governance arrangements and an evaluation program. This will be made up of executive-level representatives from key government agencies who will guide implementation actions and raise issues for ministerial attention. Specialised working groups will be formed to advise the executive implementation committee and oversee implementation of some commitments and actions. In October 2020 we established a Koala Working Group, which is providing guidance on koala-exclusion fencing and restoration of koala habitat. Other working groups will be established in 2021 to focus on weed control, restoration, pest animal control and compliance.

12 NSW Government (2020) Cumberland Plain Conservation Plan, Sub Plan A https://www.planningportal.nsw.gov.au/draftplans/under-consideration/draft-cumberland-plain-conservation-plan

Reporting	We acknowledge the Plan's vision is ambitious. The Plan's evaluation program will ensure the conservation program stays on track to meet its commitments and outcomes. The evaluation program will establish processes to support how we will be reporting on to government and the community. The results from evaluation will be used to support adaptive management and governance to ensure continuous improvement in implementing the Plan. The NSW Government will commission a comprehensive and independent review on the status of implementation of the Plan and its outcomes every five years over the life of the Plan. Annual reporting will also be undertaken and made publicly available on the department's website and remain available through the life of the Plan.
Compliance	Local councils are a key delivery partner and play a critical role in implementing the Plan. We are committed to working with local councils to ensure they have the resources they need to carry out compliance associated with the Plan. A compliance and implementation working group will be established. This will have representatives from all eight local government areas in the Plan area. We will also provide funding such as competitive grant programs so councils can help deliver actions such as weed and pest control, other threat management activities and community education and engagement programs. Based on council feedback we are proposing to increase the number of compliance officers from three to six to monitor and report on illegal clearing of native vegetation in the Plan Area. These roles will identify threats to the Plan's conservation program and coordinate investigations and remedial actions to address threats such as illegal dumping and vegetation clearing. We are proposing to manage a compliance program to identify illegal activities, provide some coordination and reduce the burden for councils. A Compliance Implementation Strategy will be prepared in partnership with councils.
Community engagement in the plan	We will be preparing a Communications and Engagement Strategy to guide the implementation of the Plan. This strategy will be updated every five years following the independent review of the Plan's progress. The strategy will identify ways that the community can be involved in implementing some of the actions in the Plan and be involved in reviewing and providing input into the Plan as it progresses. The Plan's education and engagement program will provide many opportunities for to learn about biodiversity, get involved in conservation and restoration activities, and participate in citizen science programs.

7. Culture and heritage

Conserving rural landscapes and European and Aboriginal heritage is an important part of recognising the western Sydney's unique culture and heritage. Strategic conservation planning aids forward planning of open spaces and protects sensitive bushland that contributes to rural character.

The development of the Plan acknowledges more than 60,000 years of continuous Aboriginal connection to the land that makes up NSW. Aboriginal people hold a profound knowledge, understanding, obligation and custodianship of the landscape, often referred to as 'connection to Country'. Through this connection, Aboriginal people have developed their own system of knowledge and understanding of ecology and biodiversity. Through the Plan we want to support Aboriginal communities to care for Country and receive economic benefits from implementing the Plan.

What you told us

Partnering with the Aboriginal community is important

- Indigenous knowledge and land management should be incorporated into the Plan
- There is strong support for the proposed Aboriginal Engagement and Implementation Strategy for Western Sydney and gearing up Aboriginal businesses and organisations to deliver services under the Plan such as ecological restoration.
- There is a role for Aboriginal education officers or rangers to support biodiversity conservation.
- Formal partnership agreements between the department and Aboriginal Land Councils would be beneficial to implement components of the Plan
- It is unclear how the Plan might affect undetermined Aboriginal land claims.
- Impacts to Aboriginal burial sites have been identified due to the proposed M9 (Outer Sydney Orbital) route.

Agriculture and rural heritage is valued

- Further development in south-west Sydney will have impacts on agricultural land and food production and supply to Greater Sydney.
- Rural and agricultural land is an important part of the cultural landscape and heritage, especially in the southern part of the Plan area.
- Some people enjoy semi-rural lifestyles in parts of the Plan area and fear the rural character of villages such as Wilton and Mulgoa will be lost.

Our response:

Partnering with Aboriginal communities	We are committed to ongoing engagement with Aboriginal communities in western Sydney to provide economic opportunities from the Plan. We are currently developing a 10-year Aboriginal Engagement and Implementation Strategy. This will be developed in collaboration with Traditional Custodians, community, Aboriginal Land Councils, Aboriginal services providers and businesses as well as other Aboriginal groups in Western Sydney. This will involve creating partnerships that encompasses co-design and collaboration principles. It will ensure Aboriginal people are at the forefront of implementing the Plan and can benefit from the economic and cultural opportunities. The strategy will also guide the best practice approaches to ongoing engagement with Aboriginal people in the Plan area. If Aboriginal land claims exist on potential reserve sites, reserve proposals will not proceed until the claim is resolved. As part of the Aboriginal strategy we propose to work with the department's Crown Lands branch to support the speedy resolution of Aboriginal land claims under the Aboriginal Lands Right Act 1983 (NSW) for areas within potential conservation lands.
Protecting Aboriginal culture and heritage	We will work with the Aboriginal community and landholders to protect Aboriginal heritage on new reserves and stewardship sites. We will help use these sites to raise awareness of Aboriginal culture and relationships to Country. We have forwarded submissions that raised concerns about the potential destruction of Aboriginal burial sites in the Outer Sydney Orbital corridor to Transport for NSW for further investigation. Transport for NSW has confirmed they were not previously aware of these sites and will engage with the Aboriginal community and other stakeholders to seek further information.
Agriculture and rural heritage	Western Sydney is in a transition from an agricultural landscape to a thriving but sustainable urban city. Future growth in western Sydney is guided by the Greater Sydney Commission's A Metropolis of Three Cities and the Western City District Plan. These documents set out the planning priorities and actions as the district grows and changes over the next 20 years. Regional planning within the western Sydney district acknowledges the importance of its Aboriginal and European heritage in connecting people and shaping the regions identity. As precinct planning commences, areas of heritage and landscape value will be identified early in the planning process. Much of the land that will be zoned urban capable is currently vacant or used for low-intensity grazing. The Western Sydney International (Nancy-Bird Walton) Airport presents additional opportunity to invest in agriculture and agribusiness in western Sydney. These areas can support the development of intensive plant agriculture, horticulture and viticulture where these meet airport safety guidelines. This will support new agricultural and food production industries alongside urban and industrial development.

Next steps

The department has reviewed all submissions received during the public exhibition period and is currently finalising the Plan based on your feedback to submit for approval.

Figure 4 Submissions timeline

In late 2021, the following documents will be submitted for approval to the NSW Minister for Environment under the BC Act and the Commonwealth Minister for Environment under the EPBC Act:

- The final Cumberland Plain Conservation Plan and its associated documents
- the final Cumberland Plain Assessment Report
- ministerial direction under section 9.1 of the EP&A Act to prevent the avoided land and the strategic conservation area being rezoned to more intensive land uses
- State Environmental Planning Policy for strategic conservation planning.

Contacting the department

The department is committed to engaging with the community and industry as we continue to develop and implement the plan for protecting Western Sydney's biodiversity.

If you have any questions or wish to raise any issues, contact the department by email on:

CPCP@planning.nsw.gov.au

Phone

TBC

NSW GOVERNMENT

dpie.nsw.gov.au

2021

CUMBERLAND PLAIN ASSESSMENT REPORT

Supporting document I – Survey report for the Green and Golden Bell Frog at Ropes Creek

19 February 2021

Laura Torrible
Department of Planning Industry and Environment
Environmental Infrastructure Planning and Resilient Places
Level 17, 320 Pitt Street
Sydney NSW 2000

Dear Laura,

Re: Green and Golden Bell Frog targeted surveys for Western Sydney Strategic Assessment

Project no. 33824

Biosis Pty Ltd was commissioned by Department of Planning Industry and Environment to complete targeted surveys for Green and Golden Bell Frog *Litoria aurea* [Endangered, NSW *Biodiversity Conservation Act 2016* (BC Act) and Vulnerable, Commonwealth *Environment Protection and Biodiversity Conservation Act 19999* (EPBC Act)] as part of the Western Sydney Strategic Assessment (WSSA).

The WSSA will guide the development of the Western Sydney area through the identification of the highest areas of biodiversity value and integrate these findings to deliver positive outcomes for the environment and development. The WSSA covers seven Local Government Areas including Penrith, Liverpool, Camden, Campbelltown, Wollondilly and Hawkesbury.

The WSSA has identified potential habitat for Green and Golden Bell Frog along Ropes Creek, north-east of Penrith. Ropes creek is adjacent to areas proposed for development and as such, targeted surveys have been identified as a required action. This action is part of a commitment relating to managing indirect impacts of development. The targeted surveys will inform the finalisation of commitments and actions in relation to the Green and Golden Bell Frog under the Cumberland Plain Conservation Plan.

Background

Ropes creek is located approximately 8 kilometres north east of the Penrith CBD. The study area is located adjacent to Wianamatta Regional Park in Ropes Crossing, NSW. Green and Golden Bell Frog has been recorded to the south of the study area within Ropes Creek and habitat associated with Ropes Creek.

A GIS desktop assessment of the Green and Golden Bell Frog species habitat mapping identified four main areas of the development footprint within the Greater Penrith to Eastern Creek (GPEC) Growth Area that intersect with the expert mapped Green and Golden Bell Frog species habitat, including:

- Site 1: Ropes Crossing Boulevard, Ropes Crossing NSW (Lot 3, DP1203565).
- Site 2: Ropes Crossing Boulevard, Ropes Crossing NSW (Lot 3, DP1203565).
- Site 3: Corner of Forrester Road and Boronia Road, North St Marys, NSW (Lot 11, DP 1192443).

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- Site 4: 11 Boronia Road, North St Marys, NSW (Lot 11, DP566394).

The most recent sightings occurred in 2012 (DPIE 2021) (Table 1). There are also historical records including three occurrences from 1998 and one occurrence from 1966 (DPIE 2021). Other sightings in the greater area occurred in 2001 and 2005.

Method

Targeted Green and Golden Bell Frog survey

Targeted surveys were conducted in accordance with the *NSW Survey Guide for Threatened Frogs* (DPIE 2020).

Surveys were conducted during the designated survey period, specifically:

- September to March (breeding and larval period for the species).
- After 50 millimetres of rainfall over a 7-day period.
- During warm and windless nights (optimal conditions).

Field teams of two ecologists undertook the surveys over a minimum of four nights with the first and last night not being less than 14 days apart. Each waterway was surveyed four times in total (Table 1).

Table 1 Green and Golden Bell Frog targeted survey effort

Site	Site address	Approximate size of feature(s) to survey	Description of feature(s) to survey	Most recent BioNet records	Survey undertaken
1	Ropes Crossing Blvd, Ropes Crossing NSW.	50 m stretch of ephemeral creekline (tributary of Ropes Creek).	Typha habitat present, narrow, broad channel, ephemeral.	**1966** – Identified in a slow flowing section of creek full of reeds, ephemeral (Wells, R).	• 1 December 2020 • 3 December 2020 • 11 January 2021 • Could not be completed on 12 January 2021 as planned due to survey interruptions. • 28 January 2021
2	Ropes Crossing Blvd, Ropes Crossing NSW.	50 m stretch of perennial creekline (Ropes Creek).	Typha habitat present, wood debris, emergent vegetation, narrow, defined channel, perennial creek.	**1966** – Identified in a slow flowing section of creek full of reeds, ephemeral (Wells, R).	
3	Corner of Forrester road and Boronia Rd, Nth St Marys, NSW.	One Large dammed waterbody (0.45 ha in size, perimeter 300 m). One small dam (0.03 ha, 80 m) with Typha and other riparian vegetation.	Large dam areas with riparian vegetation.	**1998** – Identified in ponded area northeast of former driving range (now stadium), towards Ropes Creek (White, A). **2012** – Identified in Tregear Reserve, Blacktown, near Ropes Creek	• 9 December 2020 • 15 December 2020 • 13 January 2021 • 14 January 2021

Site	Site address	Approximate size of feature(s) to survey	Description of feature(s) to survey	Most recent BioNet records	Survey undertaken
4	11 Boronia Road, Nth St Marys, NSW.	50-m stretch of perennial creekline (Ropes Creek).	Connectivity and dispersal habitat to Site 3 (records previously found in this locality).	**1998** – Identified in ponded area northeast of former driving range (now stadium), towards Ropes Creek (White, A). **2012** – Identified in Tregear Reserve, Blacktown, near Ropes Creek	

Targeted searches were undertaken as follows:

- Visit to a local Green and Golden Bell Frog reference site immediately prior to the survey to confirm Green and Golden Bell Frogs are calling. The Green and Golden Bell Frog population at Sydney Olympic Park was used as a reference site to align surveys with times when frogs are most actively moving within suitable habitat and calling, therefore maximising detection probability at survey sites.
- Static listening period of five minutes at the targeted survey sites (with all head torches turned off) were undertaken. All frog species recorded calling during this time were recorded.
- Green and Golden Bell Frog call-broadcasting for two minutes was undertaken, followed by a two minute listening period. Aural surveys were undertaken every 50 metres along a 500 metre transect. All frog species recorded calling during this time were recorded.
- Visual encounter surveys (active searches), targeting Green and Golden Bell Frog habitat features were undertaken at a pace not greater than 5 minutes per 50 metre section after the listening and broadcasting surveys to identify if any non-calling individuals were present.

Appropriate frog hygiene protocols were implemented by each field team to avoid the accidental transfer or introduction of pathogens and diseases to frog species (DECC 2008).

Results

Two waterways were surveyed as part of the investigations both flowing from a southeast to northwest direction. In the west of the study area is Ropes Creek, a fourth order waterway. Ropes Creek occurs as a concrete-lined drain approximately 4 metres deep with multiple discrete areas containing small islands comprised of silt, woody debris and re-growth of native and exotic vegetation. These areas often contained exotic grasses on the edge of the islands providing potential shelter habitat for fauna. Water flow within Ropes creek was approximately 10-20 centimetres deep and steady during the investigations with some pooling occurring where debris and vegetation occurred. To the east of this lies a naturally formed second order waterway consisting of slow flowing pools with occasional subsurface flow through silt. The main substrate of this waterway is sandy clay with occasional accumulations consisting of sand. Aquatic vegetation was limited within the waterway with one pooling area approximately 5 metres by 3 metres wide containing floating macrophytes. Another pooling area to the north contained limited emergent vegetation consisting predominantly of sedges and exotic grasses growing on the banks. Occasional fallen tree branches provided habitat features within the creek and the dominant vegetation growing on the banks occurs as thick stands of Privet *Ligustrum* sp.

No Green and Golden Bell Frogs were recorded during field investigations. Table 2 outlines weather conditions during each survey. Frog species recorded during frog survey are shown in Table 3.

Table 2 Weather observations during targeted surveys (Penrith, NSW)

Survey date	Temperature (°C)		Rain (mm)	Rain past 7 days (mm)
	Min.	Max.		
1 December 2020	17.2	38.5	0.2	1.4
3 December 2020	16.6	23.5	6.4	15.8
9 December 2020	11.7	29.3	0.0	11.6
15 December 2020	18.4	25.5	3.4	5.4
11 January 2021	15.3	31.4	0	15.2
13 January 2021	20.3	32.4	0	4.2
14 January 2021	19.1	39.6	0	3.2
28 January 2021	18.3	22.7	0.8	1.2

Information from the Australia Government Bureau of Meteorology website.

Table 3 Frog species recorded during targeted Green and Golden Bell Frog surveys

Common name	Scientific name	Site
Common Eastern Froglet	*Crinia signifera*	1, 2, 3, 4
Striped Marsh Frog	*Limnodynastes peronii*	1, 2, 3, 4
Eastern Dwarf Tree Frog	*Litoria fallax*	1, 3, 4
Broad-palmed Rocket Frog	*Litoria latopalmata*	1, 2
Peron's Tree Frog	*Litoria peronii*	1, 2, 3, 4
Spotted Marsh Frog	*Litoria tasmaniensis*	3, 4
Tyler's Tree Frog	*Litoria tyleri*	3

The study area has potential to provide shelter and dispersal habitat for Green and Golden Bell Frog. It is unlikely to contain habitat suitable for breeding given the un-named waterway is highly sheltered by native canopy and weedy understorey species and lacks complexity of habitat features such as dense stands of emergent vegetation and vegetated banks.

Conclusion

No Green and Golden Bell Frog were recorded during targeted survey for the species. No other threatened species were recorded, species encountered included common widespread species. Although historical records exist within the area, the study area does not currently provide suitable breeding habitat for the species and therefore no further action is required.

I trust that this advice is of assistance to you however please contact me if you would like to discuss any elements of this ecological advice further.

Yours sincerely

Dr Caragh Heenan
Project Zoologist

References

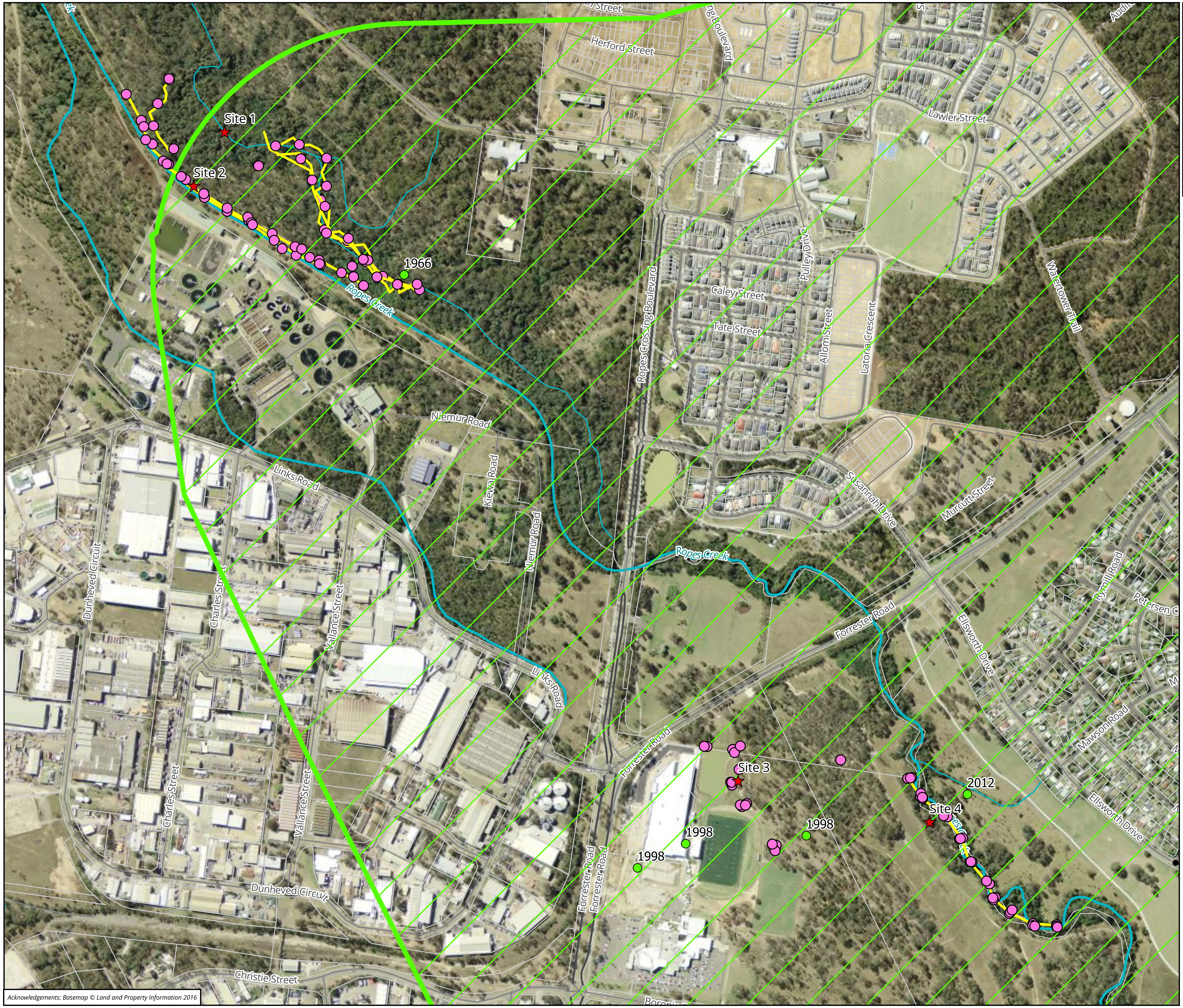
DECC 2008. *Hygiene Protocol for the Control of Disease in Frogs*, New South Wales Government Department of Environment and Climate Change, Sydney, NSW.

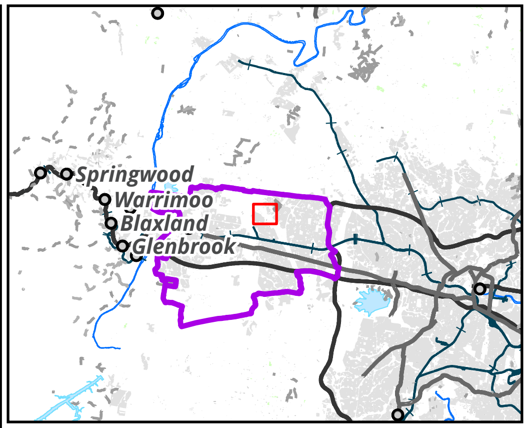
DPIE 2020. *NSW Survey Guide for Threatened Frogs: A Guide for the Survey of Threatened Frogs and their Habitats for the Biodiversity Assessment Method*, Department of Planning, Industry and Environment.

DPIE 2021. *BioNet the website for the Atlas of NSW Wildlife*, http://www.bionet.nsw.gov.au/.

Appendices

Appendix 1 Figures





Legend

- Targeted survey site
- *Litoria aurea* records (BioNet Atlas)
- *Litoria aurea* potential habitat
- Greater Penrith Growth Area
- Targeted frog transects
- Targeted frog call playback points

Figure 1 Green and Golden Bell Frog Survey Effort

0 60 120 180 240 300

Metres

Scale: 1:7,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

biosis.

Appendix 2 Photos

Plate 1 Ropes Creek – facing northwest

Plate 2 Ephemeral tributary East of Ropes Creek – facing northeast