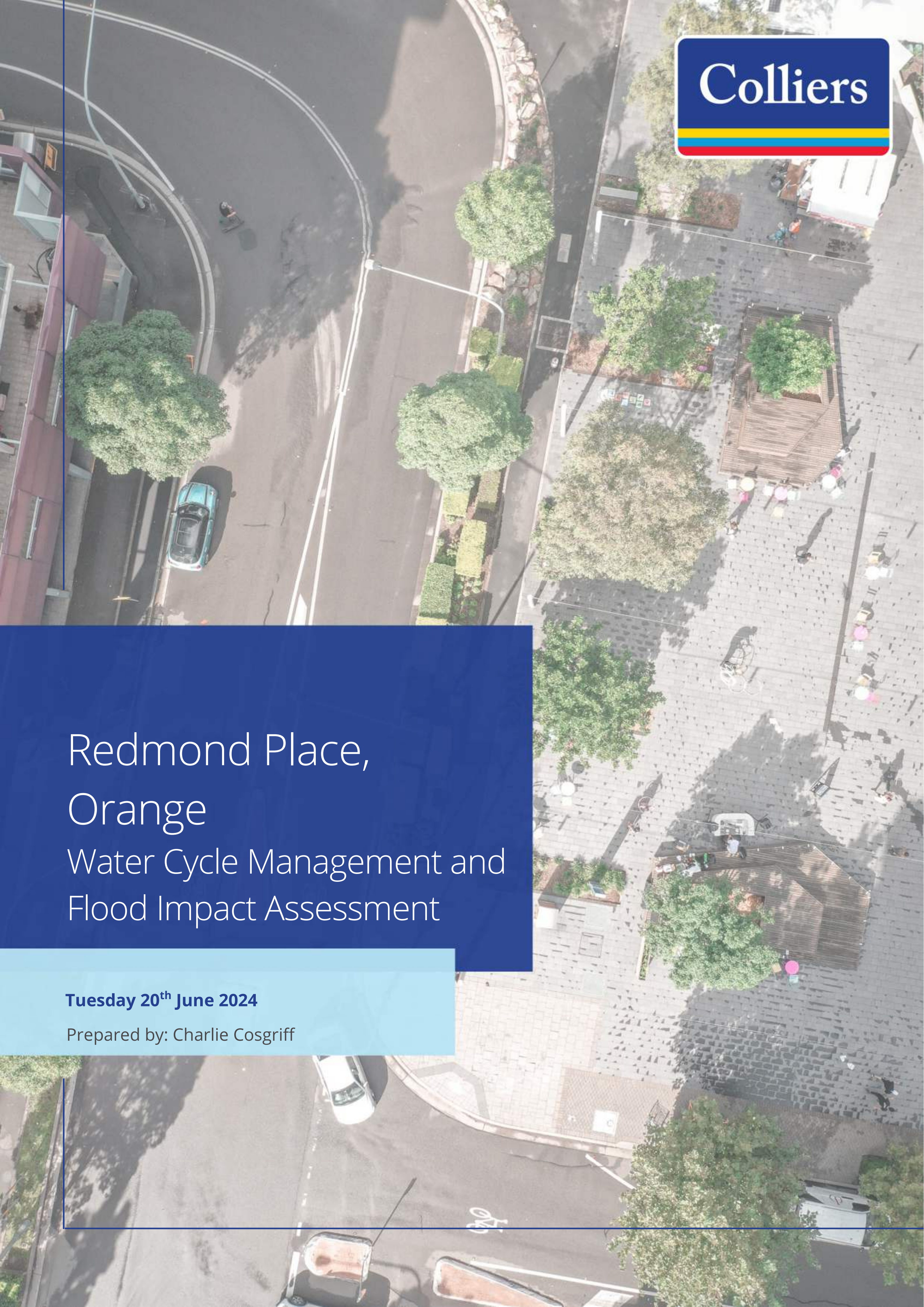

Redmond Place, Orange

Water Cycle Management and Flood Impact Assessment

Tuesday 20th June 2024

Prepared by: Charlie Cosgriff

DOCUMENT CONTROL

Issue	Date	Purpose	Author	Approved
A	20/06/2024	Final Issue	CC	JB

This report has been prepared by Colliers International Engineering & Design (NSW) Pty Ltd and has undergone a quality assurance review. The signatures above confirm review completion.

Acknowledgement of Country

Colliers Engineering & Design (NSW) acknowledges the Wiradjuri people of the Wiradjuri Nation as the Traditional Custodians of the lands and waterways upon which this project is located in the Orange City Council LGA. We also acknowledge the Wangal people of the Eora national as the traditional custodians of the land upon which our Rhodes Office is located.

We pay our respects to the traditional owners for their care and stewardship of these lands for more than 40,000 years and to all Aboriginal and Torres Strait Islander Peoples and the elders past, present and emerging.

Abbreviations

AEP	Annual Exceedance Probability
ARI	Annual Recurrence Interval
CED	Colliers International Engineering & Design (NSW) Pty Ltd
DEM	Digital Elevation Model
GSDM	Generalised Short Duration Method
LGA	Local Government Area
LiDAR	Light Detection and Ranging
OCC	Orange City Council
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QGIS	Quantum Geographic Information System
TIN	Triangulated Irregular Network
WCMS	Water Cycle Management Strategy

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1 Introduction

Colliers Engineering & Design (NSW) have been engaged by Landcom to prepare a Flood Risk and Impact Assessment and Water Cycle and Stormwater Management Assessment for the rezoning of a site at Redmond Place in the Orange City Council Local Government Area (LGA).

It is proposed that the site is rezoned for residential use to enable urban development for a diverse range of housing products, open space and recreation, roads and stormwater management.

Landcom and Orange City Council have signed a Project Delivery Agreement for the purposes of delivering the Redmond Place project. The site is owned by Orange City Council and Landcom are taking the lead in preparing a planning proposal to amend the Orange Local Environmental Plan 2011 (LEP) to rezone the Site for residential uses.

The key objectives of the project are:

- Supply – increase the supply of land to facilitate housing
- Diversity – promote housing diversity
- Affordability – increase the supply of land for affordable housing by delivering at least 20% of all residential dwellings for affordable housing
- Sustainability – develop a climate resilient, healthy and inclusive place, at the forefront of environmental and social sustainability.

The staging strategy for this site will need to take into consideration infrastructure availability, delivery timing, placemaking, and entry point to the area from Mitchell Highway.

The urban design approach for the project focuses on socio-economic activation, innovative sustainability solutions and urban vibrancy through place-making. The masterplan for the future new community of Redmond Place will be based on a landscape-led approach to urban design, informed by the unique qualities of the site and Connecting with Country principles. A thorough community and stakeholder engagement process, including community workshops, a Walk on Country and indigenous stakeholder interviews, will also inform the urban design process.

As part of the Planning Proposal lodgement, a Flood Risk and Impact Assessment and Water Cycle Management Plan is required.

This Water Cycle Management Plan was undertaken for the purposes of supporting a planning proposal for rezoning and provides an overview of the data collated and assessed to date and any additional data required for subsequent stages. The subject site constraints are detailed in relation to flooding and stormwater and a preliminary design response that considers the site constraints is provided.

1.1 Background

The Site is located on the southeast fringe of Orange, the largest city in the Central West Region. It is adjacent to the suburb of Glenroi, 4.4km from Orange City Centre and approximately 3.2km from Orange train station.

The Site has a significant frontage along Mitchell Highway (A32) which runs from east to west from the M4 Motorway in Greater Sydney connecting through Penrith, Katoomba, Bathurst to Orange.

The Site lies on the southern side of Redmond Place, bounded by Bathurst Road / Mitchell Highway (on the northeast), Lone Pine Avenue (on the west) and Dairy Creek Road to the south. It is surrounded by a mixture of land uses with low density residential to the west, retail and large format retail to the north, rural farmland to the south and east, as well as a kart racing track 250m north of the Mitchell Highway.

The Site is approximately 24.2 Ha in size and is currently utilised for agriculture and is otherwise vacant, except for a structure that previously housed an emergency services helicopter hangar.

The site typically grades from northwest to southeast with levels ranging from 903 mAHD down to 886 mAHD and is bounded by the Mitchell Highway to the east, Redmond Place to the north, Dairy Creek Road to the south and Lone Pine Avenue to the west.

Currently, the subject site is zoned C3 – Environmental Management and E3 – Productivity Support and is predominantly rural grass land, with one building footprint located in the north of the site along Redmond Place.

Dairy Creek is located south of the site and flows south to north and then east, where it confluences with Summerhill Creek. It is not anticipated that Dairy Creek will impact the subject site, as the site is located approximately 3-4m above the channel invert, however, along the eastern boundary of the site the terrain is low-lying with a culvert underneath the Mitchell Highway that brings flow into the site from the northeast and it was noted from a site visit that the terrain along the eastern boundary can be somewhat swampy.

The subject site is illustrated in Figure 1 below.

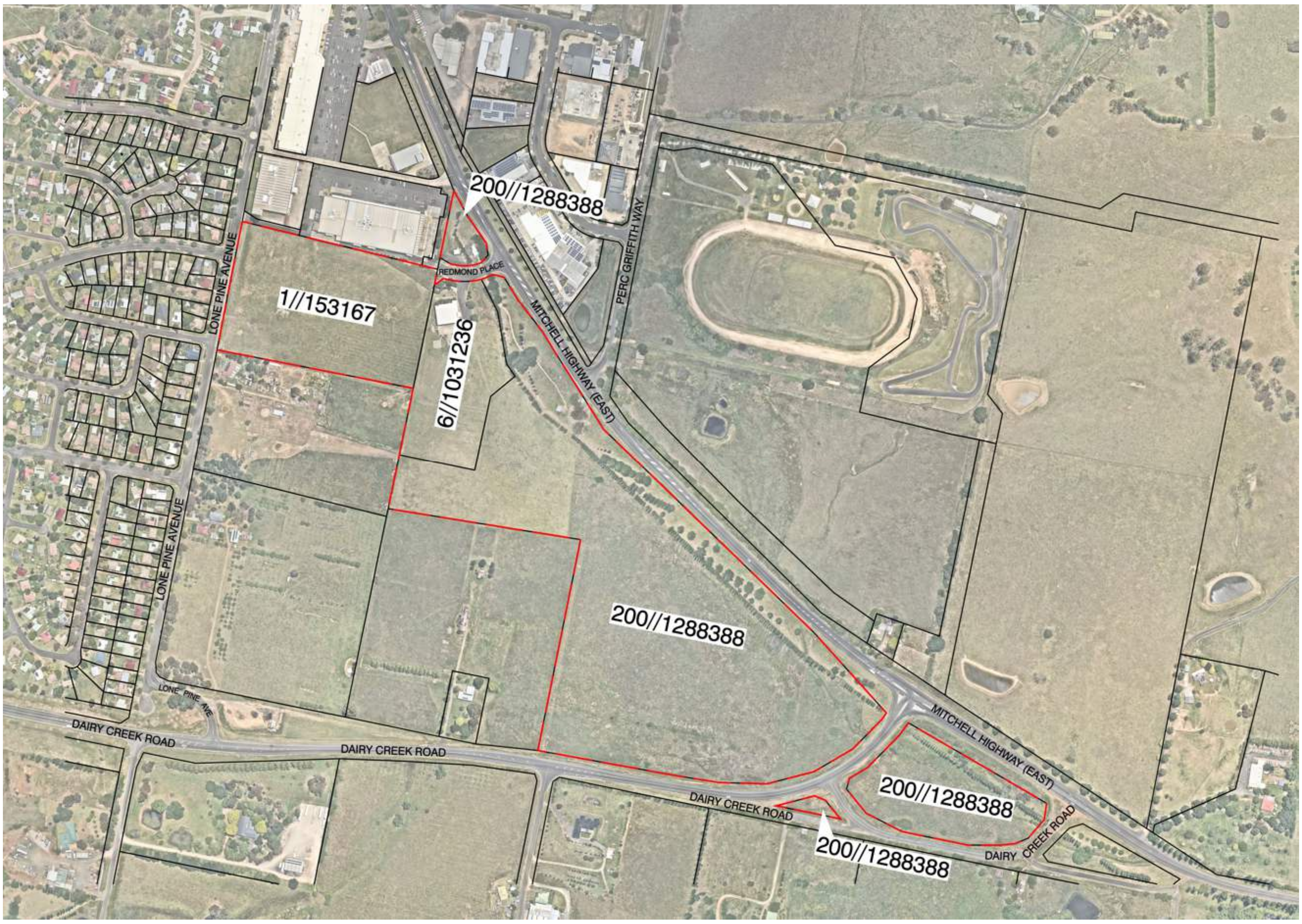


Figure 1 Subject Site (Source: Oculus)

The site comprises three lots identified in Table 1.

Table 1 Lots comprising the Site

Legal description	Address	Area
Lot 1 DP 153167	154 Lone Pine Avenue	4.10 ha
Lot 6 DP 1031236	3 Redmond Place	2.28 ha
Lot 200 DP 1288388	5255 Mitchell Highway	17.85 ha
Total		**24.23 ha**

The land is owned by Orange City Council, who will remain owners throughout the course of the project.

1.2 Objective

The objective of the Water Cycle Management Strategy report at this stage is as follows:

- Collate and review available data in relation to Flooding and Stormwater;
- Determine data gaps;
- Prepare high level modelling and present a stormwater and water cycle management strategy and options to achieve treatment targets and water retention goals for the site.
- Provide a recommendation for bioretention and detention basin layout and sizing.
- Undertake detailed flood study to demonstrate the impact of development on flood conditions on surrounding parcels, including any mitigation measures required.

1.3 Guidelines and available data

1.3.1 Guidelines

The following Guidelines were reviewed as background information to this project:

1. Orange Local Environmental Plan 2011 (NSW legislation)
2. DCP 04A Flood Affected Land 2004
3. Blackmans Swamp Creek floodplain Risk Management Study and Plan (Lyall and Associates, 2009, Volumes 1 & 2)
4. Blackmans Swamp Creek Flood Study Reports (Volumes 1 & 2)
5. NSW Government Floodplain Development Manual (2005)
6. Australian Rainfall and Runoff (2019)
7. NSW SES Orange City Local Flood Plan, 2005
8. DCP 07 Development in Residential Areas (2004) – Planning Outcome 7.7-18 Stormwater
9. Stormwater Management Plan for the City of Orange (2008)
10. State Environmental Planning Policy (Biodiversity & Conservation) (2021)
11. Orange City Council Subdivision Code (2024)
12. Neutral or Beneficial Effect on Water Quality Assessment Guideline (Water NSW) (2022)

1.3.2 Data

The following data was reviewed and utilised for mapping:

1. LiDAR Data: 2019 2km x 2km 1 metre resolution digital elevation model produced using Triangular Irregular Network (TIN) method of averaging ground heights. The data is not hydrologically enforced. Vertical accuracy 0.3m, horizontal accuracy 0.8m.
2. NSW Government Spatial Services Topographic and Cadastral Data that included for example road and rail centrelines, hydrolines and hydro areas, cadastral lot boundaries, suburb and LGA boundaries etc.
3. NearMap Imagery dated 13/12/2023

1.4 Data Gaps

It is anticipated that as the project progresses the following data will also need to be collated where available:

1. Site feature and level survey
2. Survey of hydraulic features such as culverts / bridges
3. Historical rainfall and other flood related data where available
4. Tailwater data at Summerhill Creek where available
5. Orange City Council stormwater drainage network if applicable

2 Development Description

2.1 The Planning Proposal

The Planning Proposal is to amend *Orange Local Environmental Plan 2011* to rezone the site to facilitate delivery of a residential precinct in accordance with a prepared Masterplan.

The objectives of the Masterplan are to:

- Increase the supply of land to facilitate housing through the creation of lots to support a sustainable, innovative and affordable community.
- Promote housing diversity through supporting a diverse mix of product, including houses and townhouses.
- Increase the supply of land for affordable housing by delivering at least 20% of all residential dwellings for affordable housing managed by a community housing provider.
- Develop a climate resilient, healthy and inclusive place, at the forefront of environmental and social sustainability.

A masterplan provided by Landcom (prepared by Oculus) is illustrated in Figure 2 below.

Figure 2 Proposed Site Masterplan (Source: Landcom, prepared by Oculus)

3 Site Constraints

The following constraints were identified for the subject site from the applicable Guidelines.

3.1 Orange Local Environment Plan 2011 (2012 EPI 55)

The LEP is the overarching legal instrument that guides development at this location and the clauses within the LEP are the most important to satisfy to gain consent from the approval authority (Orange City Council).

Part 7.2 Pertains to Flood Planning, Part 7.3 pertains to Stormwater Management and Part 7.5 pertains to Riparian land and watercourse.

3.1.1 Flood Planning

1. It is noted that the site is not identified as a "Flood planning area" on the Flood Planning Map, therefore the LEP Clause- 7.2 Flood Planning (2011) applies only in relation to Part (2) (b) other land at or below the flood planning level. Where the Flood Planning Level is defined as *the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*[1]
2. The LEP (2011) Clause 7.2 Part (3) outlines the items under which the consent authority must be satisfied for development to be granted consent:
    a. Is compatible with the flood hazard of the land, and
    b. Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
    c. Incorporates appropriate measures to manage risk to life from flood, and
    d. Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
    e. is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

    Parts (2) (a) through (2) (c) will form most of the flood risk assessment and part (2) (e) will be satisfied when parts (a)-(c) are satisfied. Part (2) (d) will be considered in how it pertains to the flow outfall into Dairy Creek, as there are otherwise no designated waterways within the site.

3. It is noted that the LEP requires consideration of projected changes as a result of Climate Change. As a response to the significant flooding across NSW over recent years, councils in NSW are typically requesting analysis of the Climate Change and/or the PMF storm events at Planning Proposal stage.

3.1.2 Stormwater Management

It is noted (as per Part 7 (3)) that the consent authority must be satisfied that the development:

a. Is designated to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water, and
b. Includes, where practical, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and
c. Avoids any significant impacts of stormwater runoff on adjoining downstream properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.
d. Additional requirements for the stormwater runoff have been applied to the site given the location with a drinking water reservoir catchment. The site shall adhere to the targets within

[1] It is noted that the use of Average Recurrence Interval (ARI) has been superseded by the notation 1% AEP (annual exceedance probability), where the 1:100 ARI and the 1% AEP different notations for the same storm event.

the Neutral or Beneficial Effect (NorBE) on Water Quality Assessment Guideline (2022). In addition, Orange City Council have designated the performance requirements of the NorBE are to be exceeded by 10% as a sensitivity.

3.1.3 Part 7.5 Riparian land and watercourses

Part 7.5 pertains to land that is identified as "Sensitive Waterways" on the Watercourse Map, or land that is within 40 metres of the top of the bank of a "Sensitive Waterways" identified under paragraph (a).

Figure 3 below illustrates the extent of the "Sensitive Waterways" adjacent to the subject site. It is noted that Dairy Creek is designated as a "Sensitive Waterway", but there is no designated waterway within the subject site. Therefore, Part 7.5 is applicable insofar as the consent authority will need to be satisfied that there is no adverse impact on Dairy Creek pertaining to:

i. the water quality and flows within the watercourse,
ii. aquatic and riparian species, habitats and ecosystems of the watercourse,
iii. the stability of the bed and banks of the watercourse,
iv. the free passage of fish and other aquatic organisms within or along the watercourse,
v. any future rehabilitation of the watercourse and its riparian areas.

The above points (i) through (v) will apply specifically at the flow outfall into Dairy Creek from the subject site.

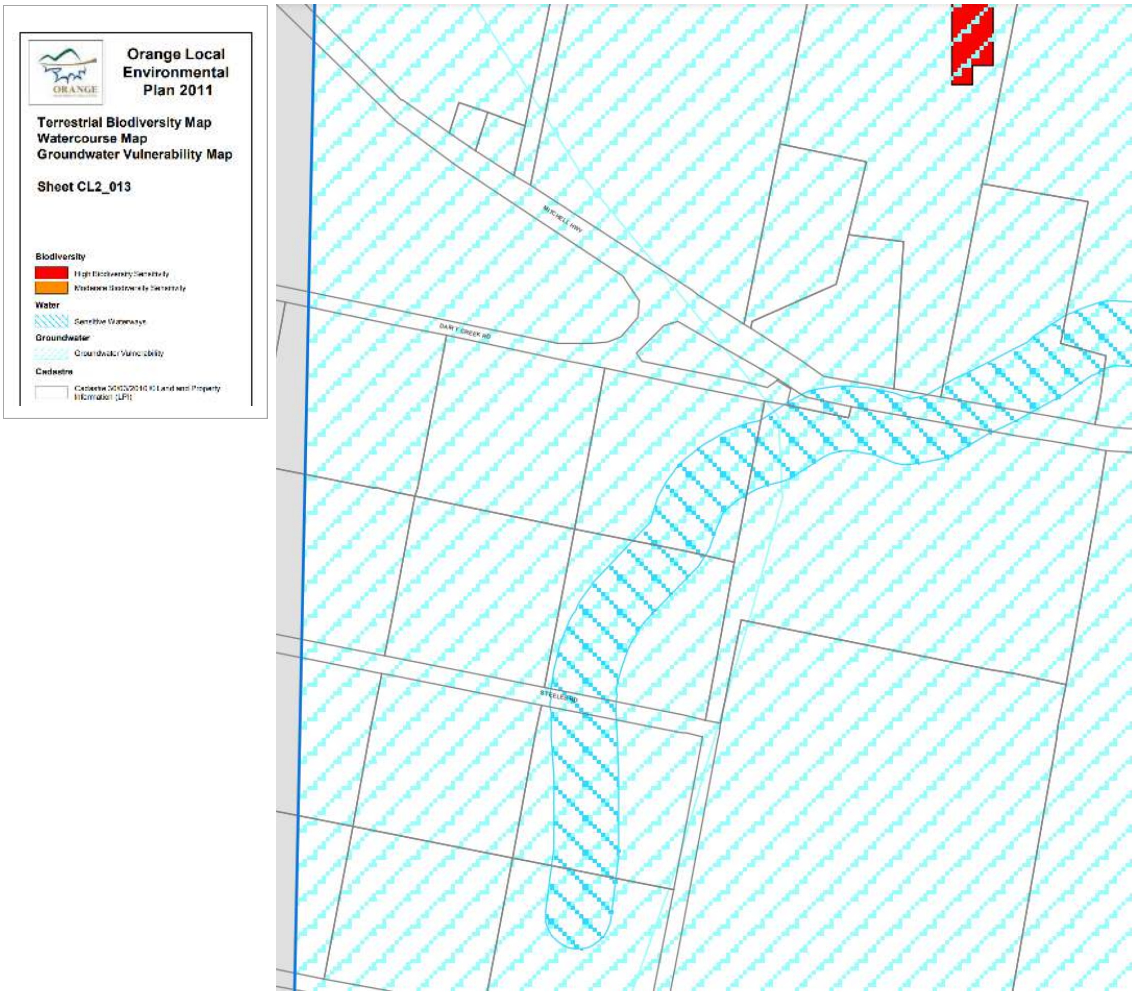


Figure 3 Orange LEP Watercourse Map (excerpt) Source: LEP (2011)

3.2 Orange Development Control Plan 2004

The Orange City Council Development Control Plan includes specific chapters for flooding and development in residential areas, but not for stormwater. Key points from the chapters for flooding and development in residential areas pertaining to stormwater are summarised below.

3.2.1 Chapter 4A Flood Affected Land

Chapter 4A pertains to development controls within flood affected land and incorporates the findings of the 7Blackmans Swamp and Ploughmans Creek Flood Study and the procedures set out in the (now superseded) NSW Floodplain Management Manual, 2005.

The following key points from the DCP Chapter 4A are noted as relevant to this proposed development:

- The DCP applies to all development permissible with the consent of Council on land in Orange City Council that is shown in Annexure 1.0. (An extract of Annexure 1.0 is provided in Figure 4)
- The site is partially located on the periphery of the Blackmans Swamp Creek Catchment
- There is a negligible area of *Land outside Flood Planning Area – Subject to Overland Flow Deeper than 100mm* on the northwest boundary of the subject site as per Figure 4 below.
- The Prescriptive Development Controls – Flood Response Levels for residential development are outlined in Annexure 3 and illustrated in Figure 5 below. These state that:
    - The habitable floor levels are to be equal to or greater than the 1% AEP flood level plus 0.3m freeboard (at the location of the above noted Overland Flow).
    - All structures that have building components below the 1% AEP flood level should be flood compatible.
    - All structures must be able to demonstrate that they can withstand the forces of floodwater, debris & buoyancy up to and including the 1% AEP Flood level.
    - The development is to be consistent with any relevant flood evacuation strategy.
    - Flood affectation will need to comply with both the subdivision and residential categories:
        - Engineers report required to certify that the development will not increase flood affectation elsewhere;
        - Development shall not block the conveyance of flood waters across the floodway or overland flow; and
        - Filling of a maximum of a 1/3 of allotment up to 0.3m above the 1% AEP Flood level permitted provided this does not result in any significant effect on the conveyance of flood waters or flood levels.
    - Management and Design:
        - No external storage of materials below the design floor level which may cause pollution or be potentially hazardous during any flood; and
        - Applicant to demonstrate that at the time of Development Application lodgement that the potential development complies with this DCP as a consequence of a subdivision proposal and any potential dwelling construction can be undertaken in accordance with this Plan.
- As the subject site is only partially covered by an Overland Flow Path in accordance with Annexure 3, the site will be subject to a merit-based assessment.
- Despite the subject site being predominantly outside of the Flood Planning Area, it is expected that Council will require a Flood Impact Assessment for the proposed subdivision and subsequent determination of whether any flooding on the property is considered mainstream or overland flow within this location to inform their consent determination.

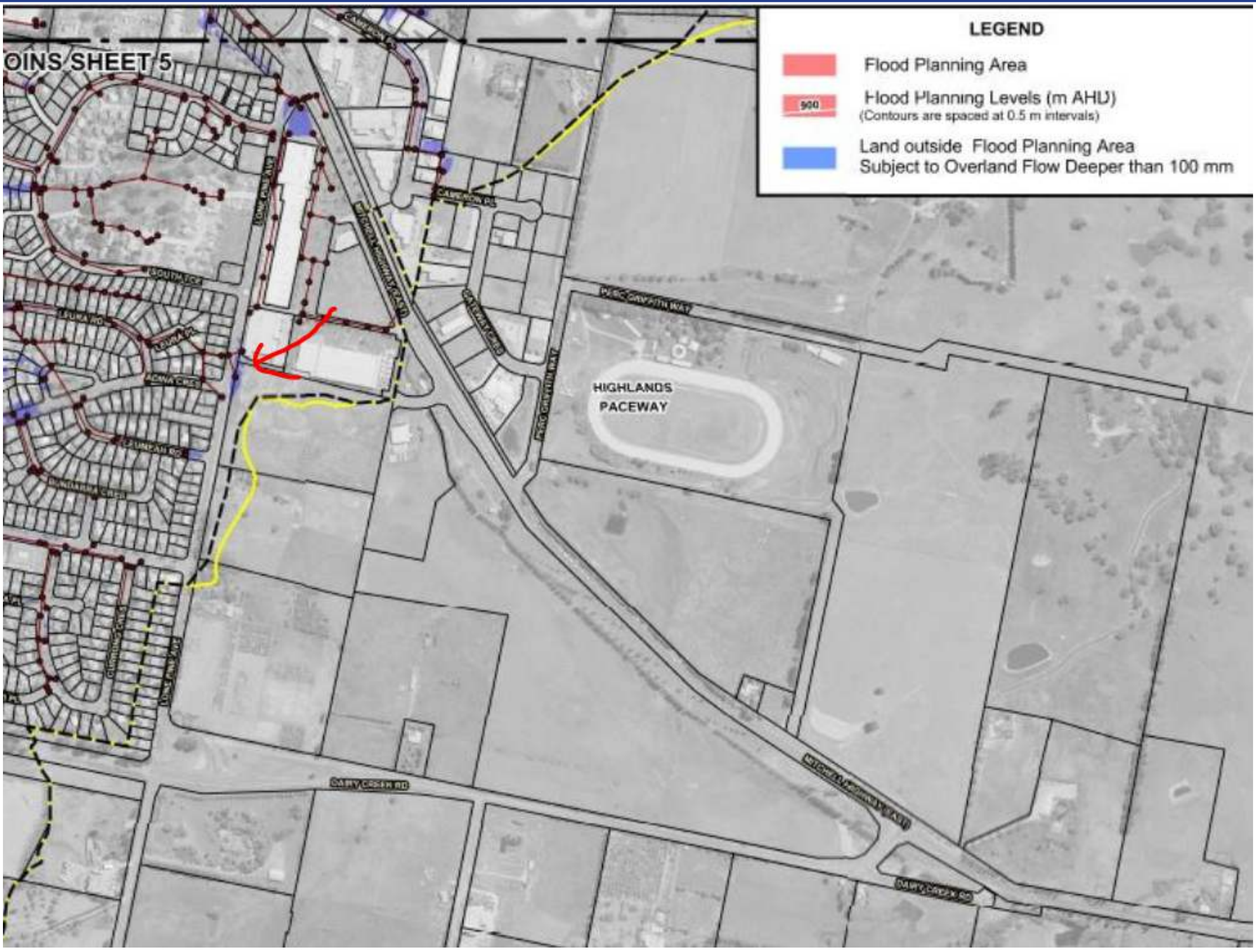


Figure 4 Blackmans Swamp Creek and Ploughmans Creek Flood Study Flood Planning Area and Levels (Source: OCC DCP Annexure 1.0, 2004)

	OVERLAND FLOW FLOODING						
PLANNING CONSIDERATIONS	ESSENTIAL COMMUNITY FACILITIES	CRITICAL UTILITIES	SUBDIVISION AND FILLING	RESIDENTIAL	COMMERCIAL OR INDUSTRIAL	RECREATION OR AGRICULTURE	MINOR DEVELOPMENT
FLOOR LEVELS	1	2		2			
BUILDING COMPONANTS	1	1		1			
STRUCTURAL SOUNDNESS	1	1		2			
EVACUATION	1	1	1	1	1	1	1
FLOOD AFFECTATION	1,2,5		1,2,4	4	1,2		
MANAGEMENT AND DESIGN	1,2	2	2,3	2	1,2	2	2

Figure 5 Annexure 3 - Prescriptive Development Controls - Flood Response Levels for Overland Flow Flooding (Source: OCC DCP, 2004)

3.2.2 Chapter 7 Development in Residential Areas – 7.7 PO 7.7-18 Planning Outcomes – Stormwater

The information pertaining to Stormwater within the DCP is quite brief and the section from Chapter 7 *Development in Residential Areas* is summarised in the extract below, with the main objective being to control and minimise the impact of stormwater run-off and soil erosion on adjoining land and downstream.

PO 7.7-18 PLANNING OUTCOMES - STORMWATER	
1	On-site drainage systems are designed to consider: - downstream capacity and the need for on-site stormwater retention, detention and re-use; - scope for on-site infiltration of water; - safety and convenience of pedestrians and vehicles; - overland-flow paths.
2	Provision is made for on-site drainage which does not cause damage or nuisance flows to adjoining properties.
GUIDELINES These guidelines indicate ways of achieving the planning outcomes. It Is recognised that there may also be other solutions. All design solutions will be considered on merit. Applications should clearly demonstrate how the planning outcomes are being met where alternative design solutions are proposed.	
a	Site drainage permits: - on-site stormwater retention; - on-site stormwater storage for re-use (Note Water tanks may be exempt development.)
b	Landscape design assists on-site infiltration of stormwater run-off by grading, locating and maximising unpaved or unsealed areas of common areas.
c	The developer is responsible for gaining access to neighbouring land if required for the purpose of providing drainage services to the land.

Figure 6 Planning Outcomes Stormwater (Source: OCC DCP Chapter 7, 2004)

3.3 Blackmans Swamp Creek Floodplain Risk Management Study and Plan Volume 1 – Study Report

The following key points that are relevant to the proposed development are noted from the Blackmans Swamp Flood Risk Management Study Plan:

- The nature of flooding within the catchment is short duration flash flooding;
- The subject site is not within a low hazard, medium hazard or high hazard zone;
- The subject site is not within a flood fringe or floodway hydraulic category; and
- The Floodplain Risk Management Study and Plan also refers to the NSW SES Orange City Local Flood Plan.

3.4 Stormwater Management Plan for the City of Orange

The Stormwater Management Plan for the City of Orange was prepared in April 2008 in conjunction with The University of Sydney in consultation with the community to investigate stormwater issues for the Orange Urban Catchment. The following are key points that should be noted as relevant to the subject site from the Stormwater Management Plan:

- The subject site falls within the Upper Summer Hill catchment.
- The primary objective for stormwater management is to *improve water quality and health of waterways within the urban catchment of Orange.*
- The Stormwater Management Plan primarily focuses on the Ploughmans Creek and Blackmans Swamp Creek catchments.
- The geology and topology of the area is part of the Lachlan fold belt, which consists of volcanic basalts that are rich in phosphorous.
- The topography is typically gently undulating.
- The typical soil types are Krasnozems with limited minor erosion.

- The main stormwater objectives for new development is to ensure appropriate erosion and sediment control plans are implemented to prevent environmentally harmful impacts of downstream sedimentation. This can be achieved by:
  - Minimising disturbance of vegetation cover;
  - Regulating surface water flow paths and volumes across development sites;
  - Trapping the mobilised sediment; and
  - Stabilising disturbed lands.
- There are no pollutant reduction targets for water quality treatment outlined within the Stormwater Management Plan (2004). The OCC Subdivision Code does designate targets which have been adopted to inform the Water Cycle Management Strategy, with special consideration to the fact the site is within a drinking water catchment. In consultation with Council, the adopted targets are in accordance with the Neutral or Beneficial Effect (NorBE) guidelines (2022), and include a sensitivity where the guidelines are exceeded by 10% as a sensitivity.

4 Constraints Analysis – Stormwater & Flooding

4.1 Existing site constraints

The existing conditions site constraints for flooding and stormwater were assessed as a desktop-based analysis and the following dot points summarises the findings.

1. Although there are no designated waterways within the subject site there is a low-lying valley / swale along the eastern boundary of the site adjacent to the row of poplar trees. The low-lying valley has been confirmed on site to be “swampy” land suggesting the regular presence of water.
2. There is an open swale from the northeast farmland that crosses under the Mitchell Highway via 2 x 1.5m W x 0.6m H concrete culverts that discharge into the site approximately 160m northeast of Dairy Creek Road.
3. The water from the “swampy” low-lying terrain then flows under Dairy Creek Road into the southeast corner of the site via 3 x 1.05m diameter culverts.
4. At the southeast corner of the site the main flow path along the east confluences with a secondary flow path from the west, which is a minor flow path and may result in shallow overland flow. The magnitude of the flows from the west will be further determined within the existing conditions flooding assessment.
5. There is a row of memorial ‘Poplar Trees’ that front the Mitchell Hwy within the existing flow path which cannot be removed.

The existing conditions sub-catchment delineation and flow paths are illustrated in Figure 7 below.

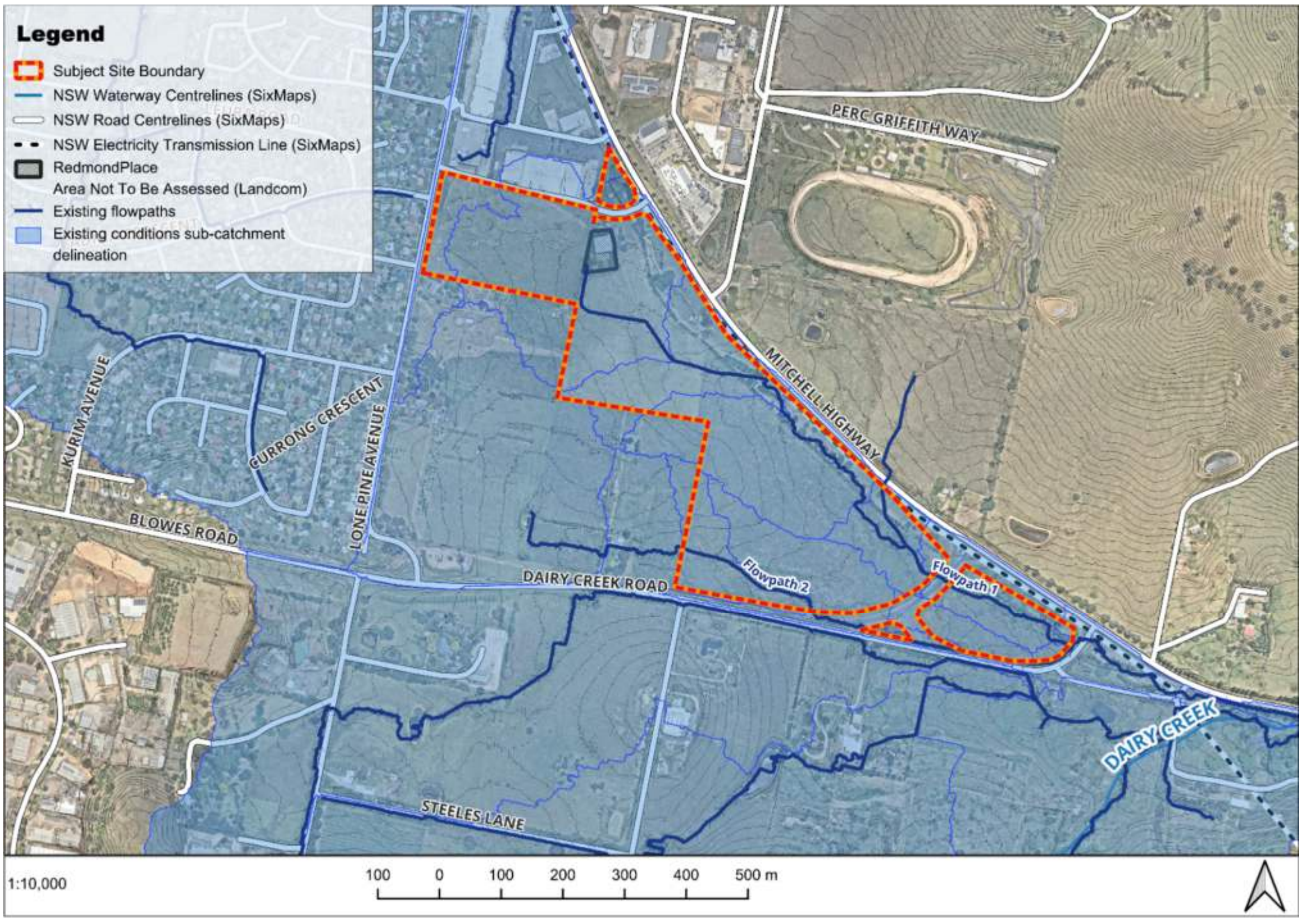


Figure 7 Existing conditions flow paths and catchment delineation

Based on the existing constraints assessment in conjunction with the data collation and review the follow recommendations are outlined in Table 2.

Table 2 Constraints and recommendations

Constraint	Recommendation
Flood Planning • Is compatible with the flood hazard of the land, and • Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and • Incorporates appropriate measures to manage risk to life from flood, and • Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and • Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding. • Consideration of projected changes as a result of climate change • The habitable floor levels are to be equal to or greater than the 1% AEP flood level plus 0.3m freeboard (for overland flow) and 0.5m freeboard for mainstream flooding and detention as per OCC Subdivisional Code • The development is to be consistent with any relevant flood evacuation strategy • Engineers report required to certify that the development will not increase flood affectation elsewhere • Development shall not block the conveyance of flood waters across the floodway or overland flow	• Prepare a Flood Impact Assessment to ensure there are no adverse offsite flood impacts and that the development does not block the conveyance of flood waters. • Include analysis of Climate Change storm events in addition to the 1% AEP to satisfy the requirements of the LEP, at DA stage. • Work in conjunction with the Civil Design Team to ensure that any flood affected land is filled to the 1% AEP + relevant freeboard (0.3m for overland flow and 0.5m for mainstream flooding and detention). • Assess and refine the benefits of the detention basins to reduce downstream flood impacts as the project progresses in conjunction with the Stormwater Management design. • Cross reference the NSW SES Orange City Local Flood Plan to ensure that the proposed subdivision is consistent with any requirements outlined within this document.
Stormwater Management • Remove the additional stormwater pollutnant runoff that would impact downstream receiving waters. • Maximise the use of permeable surfaces • Minimising disturbance of vegetation cover; • Regulating surface water flow paths and volumes across development sites; • Trapping the mobilised target pollutants to have a neutral or beneficial effect on water quality leaving the site when compared to existing conditions pollutant loads; and • Stabilising disturbed lands.	• Convey stormwater runoff through subdivision overland flow paths and underground drainage system. • Incorporate bio-retention and detention basins. • Upgrade existing swale to open channel for better flow conveyance adjacent to proposed basins. • Incorporate flow dissipators prior to the outlet to Dairy Creek to avoid erosion of Dairy Creek. • Incorporate open space, green space and adopt permeable pavement where possible.

Site Constraints

- Low-lying swampy valley along the eastern boundary
- Water entering the site from the northeast
- Restrictions on development in the southeast corner
- Shallow valley along the south boundary
- Existing memorial Poplar trees fronting the Mitchell Highway cannot be removed.

- Set aside land along the eastern boundary as a riparian corridor / open space area for both waterway and aesthetic values.
- Place wetlands / bioretention basins within the riparian corridor where the land is already "swampy".
- Depending upon flow volumes from the west, focus design of stormwater trunk drainage along the south boundary of the subject site to the southern bio-retention basin.
- Utilise the southeast corner for flow detention
- The stormwater infrastructure will avoid or incorporate the Poplar trees and no removal or relocation of the trees will be proposed.

5 Design Response

In response to the above site constraints and recommendations the following preliminary design response is suggested as follows:

- The sub-catchment delineation was reworked considering the proposed masterplan provided by Landcom (Source Oculus).
- Suggested grading/flow directions (green arrows) were determined and overlaid on the plan, based on the existing terrain and for ensuring flows reach the main flow path.
- Design a primary Riparian Corridor / Open Space area along the eastern boundary for waterway, ecological and community values. This alignment is consistent with the provided masterplan.
- Design for a primary trunk drainage corridor along the south boundary to cater for overland flows from the west.
- Provide bio-retention and detention basin located along the primary riparian corridor to cater for runoff from the developed conditions catchment layout.

The recommended preliminary basin layout and sizes are calculated based on the catchment areas and land use fraction impervious.

It is assumed for this development that because it is not within a Flood Planning Area, that flow volumes are unlikely to be significant and therefore the intention is to place one single detention basin at the end of the subject site to retard flows to existing levels prior to the final outfall into Dairy Creek. The modelling performed within RORB and TUFLOW software has demonstrated this is an adequate approach.

The bio-retention and detention basin areas are detailed in Table 3, concept design is illustrated in Figure 8 and the calculations performed are included within Appendix A.

Table 3 Treatment & Detention Basin Recommendations

Basin Id	Placement	Area
B01 **(bioretention)**	Northern basin Adjacent to Mitchell Highway	600 m^2
B02 **(bioretention)**	Central East Cnr Mitchell Highway and Dairy Creek Road	500 m^2
D01 **(detention)**	Southeast lobe of subject site Downstream of Dairy Creek Road	11,000 m^2 (14,900m^3 storage)

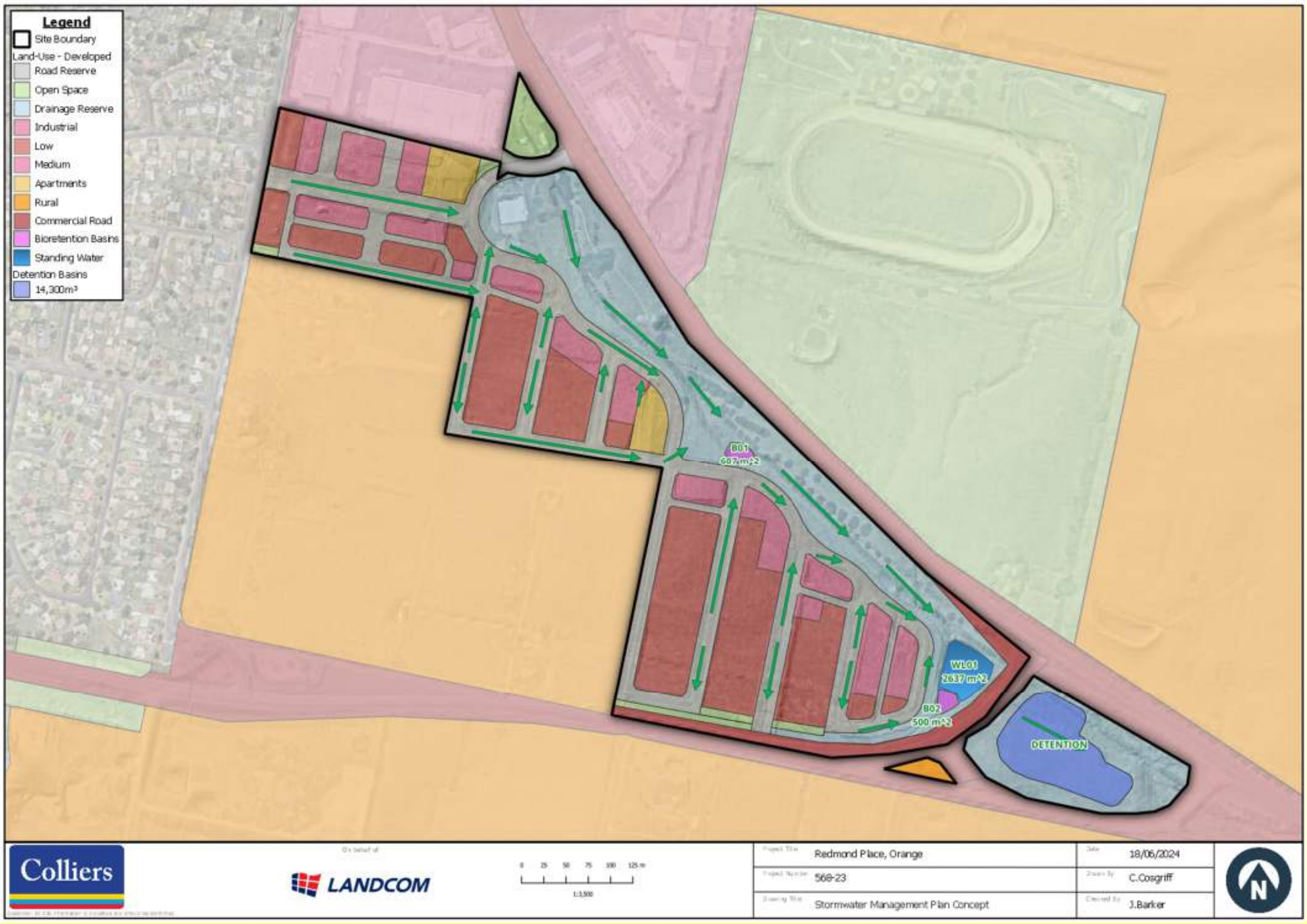


Figure 8 Stormwater Management Concept

A full map of the above Figure 8 is included at Appendix A.

6 Flood Assessment

6.1 Study Area

The Redmond Place development does not lie within the catchment of any previously undertaken flood study that is fit for purpose for the assessment of this rezoning application. The closest study in proximity for reference is the Flood Study (DHI,2005) for Blackmans Swamp Creek which was used to validate approaches to modelling in the region. The Redmond Place Development Proposal Area and the extent of the hydrological and hydraulic assessment can be seen below in Figure 9.

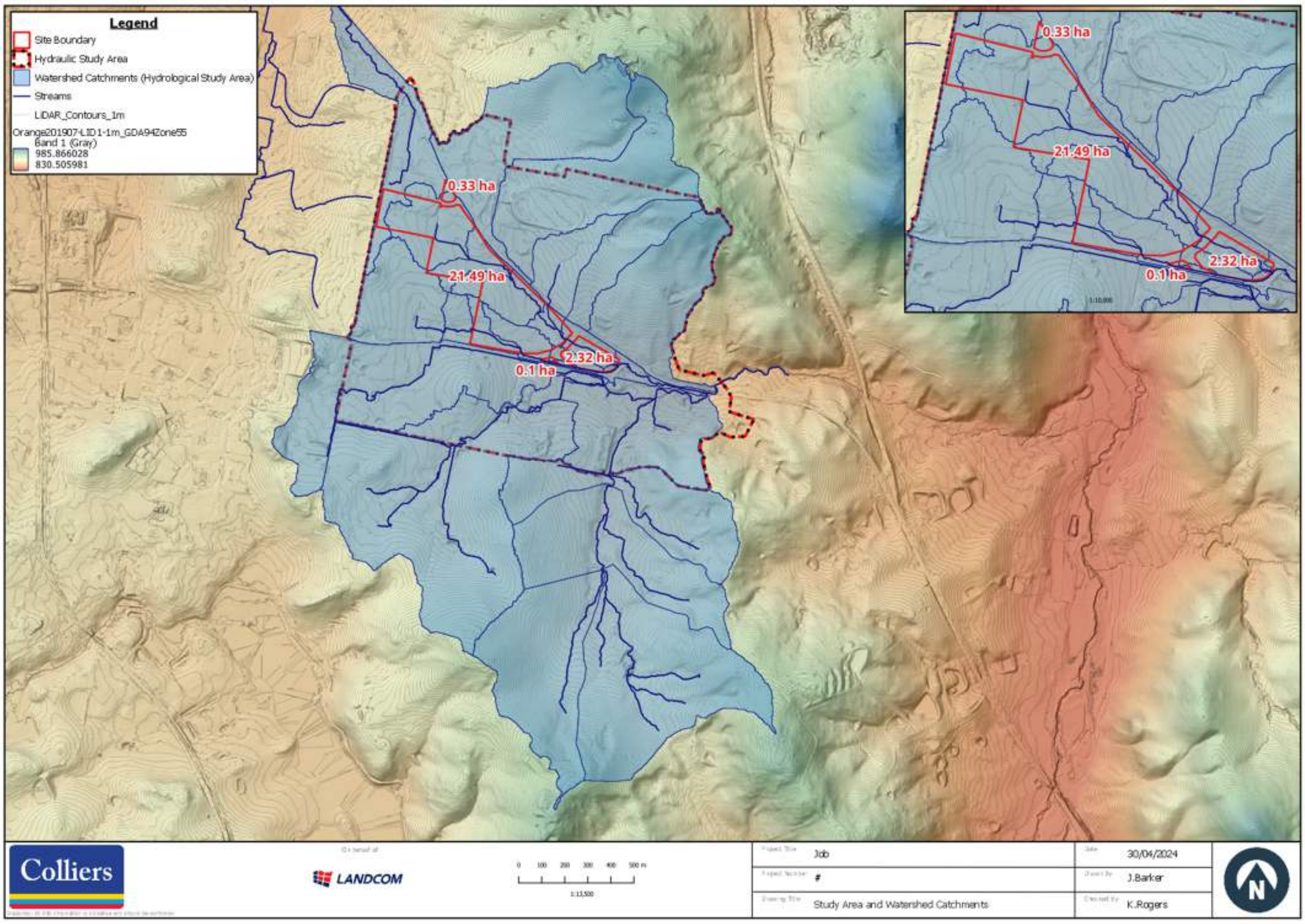


Figure 9 Study Area and Watershed Catchments

6.2 Data Collation and Review

The general data collated for this flood study included cadastral, topographic and LiDAR data. Additional data collated specifically for the flood study is outlined below.

Data relevant to the flood assessment has been collated and reviewed as a data gap analysis. A stat quality analysis is not relevant at this stage, as the acquired data, (eg from SixMaps and Council etc) is assumed to have been reviewed by the relevant authorities, and is the best available data for this level of analysis. Additional information and detail will be included at elevated levels of design. Data prepared by Colliers Engineering & Design (NSW), such as design TIN's, have been quality checked, both by the Civil Design Team and by the Flooding Team.

Specific flood assessment data is listed below.

- Rainfall data was downloaded from the ARR2019 Data Hub and utilised with due consideration for the NSW jurisdiction guidelines.
- Streamflow data was not utilised for calibration of this model. A search was undertaken for nearby streamflow gauges utilising the NSW government data available via the Water Data Online on the Bureau of Meteorology website (2023), with the closest gauges catchment being the Bell River at Malong, a poor-quality gauge, significantly downstream from Orange.
- A 1m resolution design surface representing the Proposed Zoning Plan was developed by Colliers Engineering & Design (NSW) Civil Engineering Department (design_DTM_1m_v3.tif).

The gauging stations that are in proximity to the site can be seen below in Figure 10.

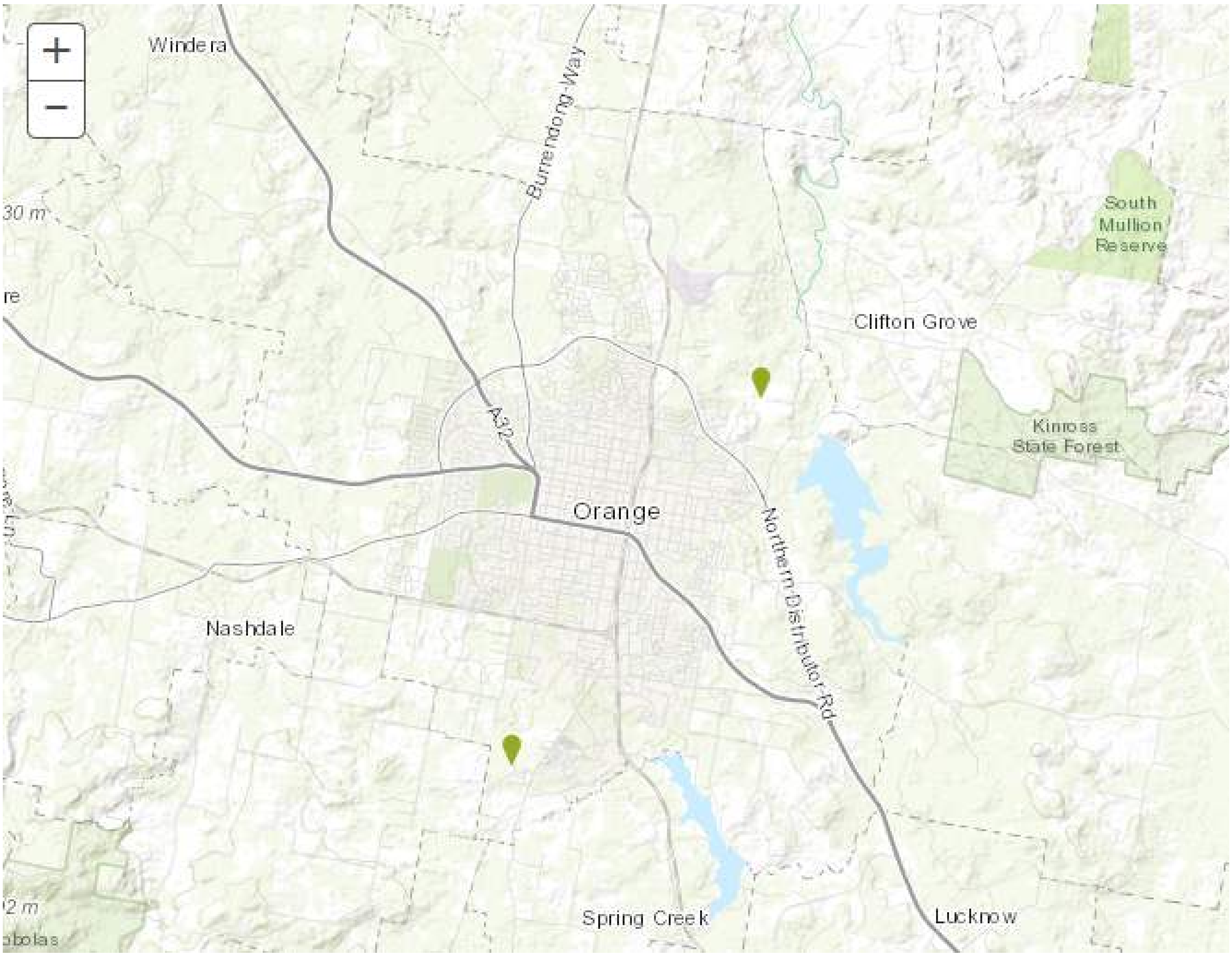


Figure 10 Water Data Online Gauging Stations

6.2.1 Digital Elevation Model

A digital elevation model was prepared from the 1m LiDAR obtained from Elvis (GeoScience Australia, 2021). The resultant Digital Elevation model is illustrated below in Figure 11 below.

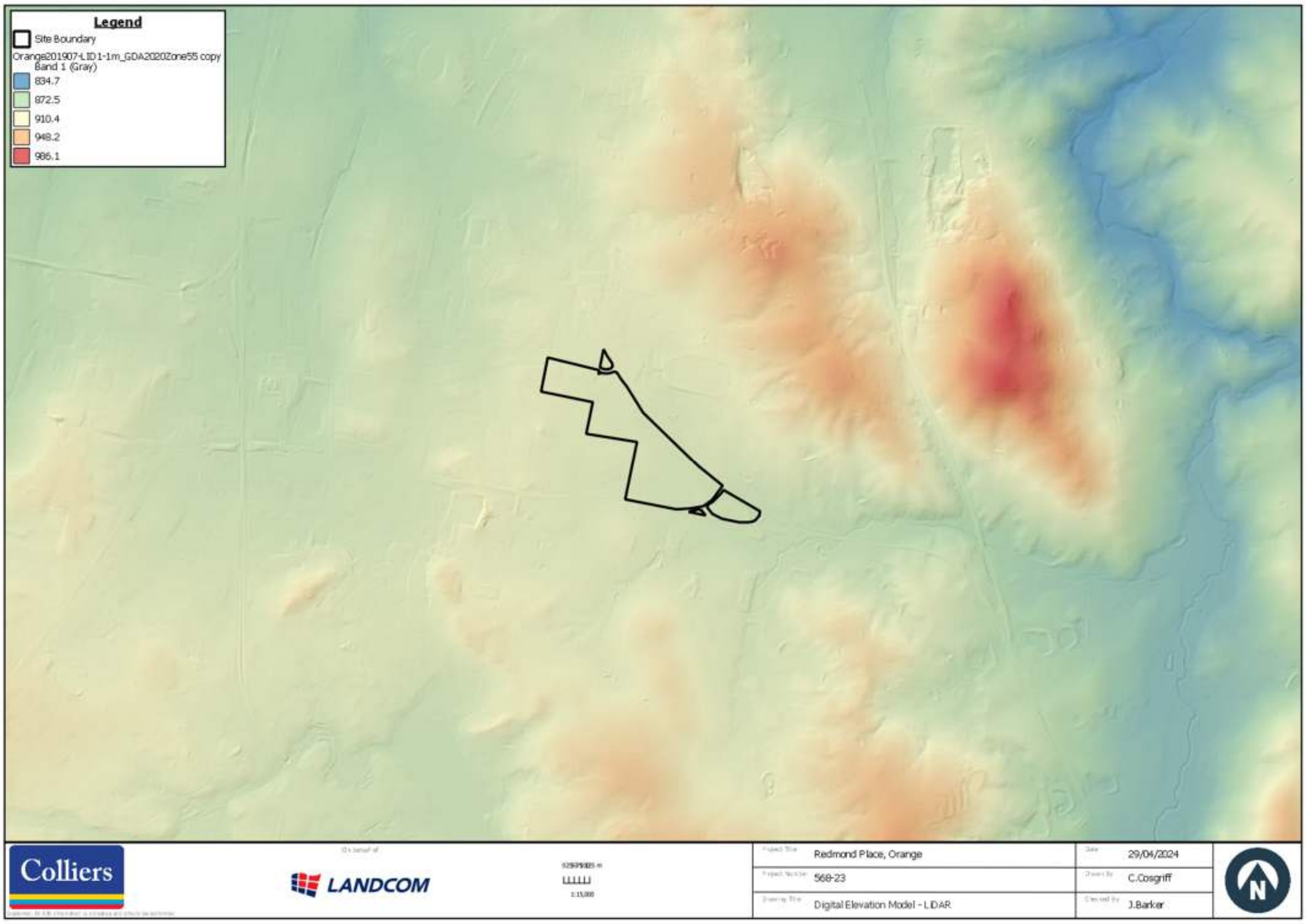


Figure 11 Digital Elevation Model – Existing Conditions.

6.2.2 Existing Farm Dams

Existing farm dams present within the study area were assumed to not act as detention basins and as such, were filled to the dam spillway level. This approach is conservative and ensures that dams do not unnecessarily act to attenuate overland flows. This was done by prewetting the catchment within the hydraulic (TULFOW) model.

6.2.3 Data Gaps

At this stage of analysis there remain several outstanding data gaps. It is expected that these will be obtained and incorporated into the model for subsequent work required at the Development Application (DA) stage. Data gaps are as follows.

- Site feature and level survey.
- Refined details for hydraulic structures such as culverts. Colliers have undertaken a desktop assessment of culvert levels to provide confidence in design.
- Detailed detention basin design was undertaken with indicative storage requirements and earthworks grading prepared for the mitigated scenarios.

6.3 Hydrologic Model

RORB modelling software was used to perform the hydrological analysis of the Site area and external catchment. RORB modelling is a modelling tool used for hydrological modelling and flood prediction. It simulates the hydrological processes of a catchment via rainfall patterns, catchment characteristics and land use information.

The model has been developed in accordance with the latest Australian Rainfall and Runoff (ARR2019) methodology and guidelines. The purpose of the model is to estimate the magnitude of the flows acting on the site in existing conditions and assess the impact of the post development flow rates.

ARR19 datahub extracted rainfall depths, temporal patterns (10-minutes to 168-hours) and areal factors have been utilised within the model.

Table 4. ARR 2016 Data Hub Co-Ordinates

Parameter	Value
Latitude	-33.310
Longitude	149.134
Zone	55
Date Accessed	20/02/2024

6.3.1 Losses

The AR&R Datahub recommends a five-step hierarchy for determination of catchment losses. Steps 1 through 3 rely on available calibration data from either the actual study area or similar adjacent catchments. Step four of the hierarchy uses NSW Flood Frequency Analysis reconciled losses available through the Data Hub.

A review of the Flood Study (DHI.2005) for Blackmans Swamp Creek showed that they utilised a combined hydrologic / hydraulic calibration / validation and validated the RORB model to rational method. The adopted losses were IL 18mm and CL2.5mm/hr. The study found a better fit to downstream gauge using 0mm IL and 2.5mm/hr for CL. This was considered inappropriate to adopt these losses within this RORB model, as the study used XP RAFTS and the modelling was undertaken in 1987 IFD rainfall.

Therefore, the losses were adopted from datahub with the application of probability neutral burst initial losses and a continuing loss multiplied by 0.4 of the DataHub value, as per the DataHub recommendation Hierarchy Level 5. The adopted losses can be seen below in Table 5.

Table 5. ARR 2016 Data Hub Adopted Losses

Parameter	Value
Initial Loss	25mm
Continuing Loss	1.96 mm/hr

6.3.2 Pre-development Hydrologic Model

The pre-development conditions catchment delineation was undertaken using GRASS GIS, following the methodology outlined by Hans van der Kwast (2019). The GRASS GIS tools automate the delineation of catchments and streams usings the underlying 1m LiDAR data. The assessment generated set of maps indicating local drainage direction and streams from which the catchments and sub-catchments were derived.

Sub-catchments were connected by reaches of type 1, 2 or 3, depending on land use and slope. The land use fraction impervious was based on the OCC Subdivision Code (2024). The RORB model can be seen below in Figure 12.

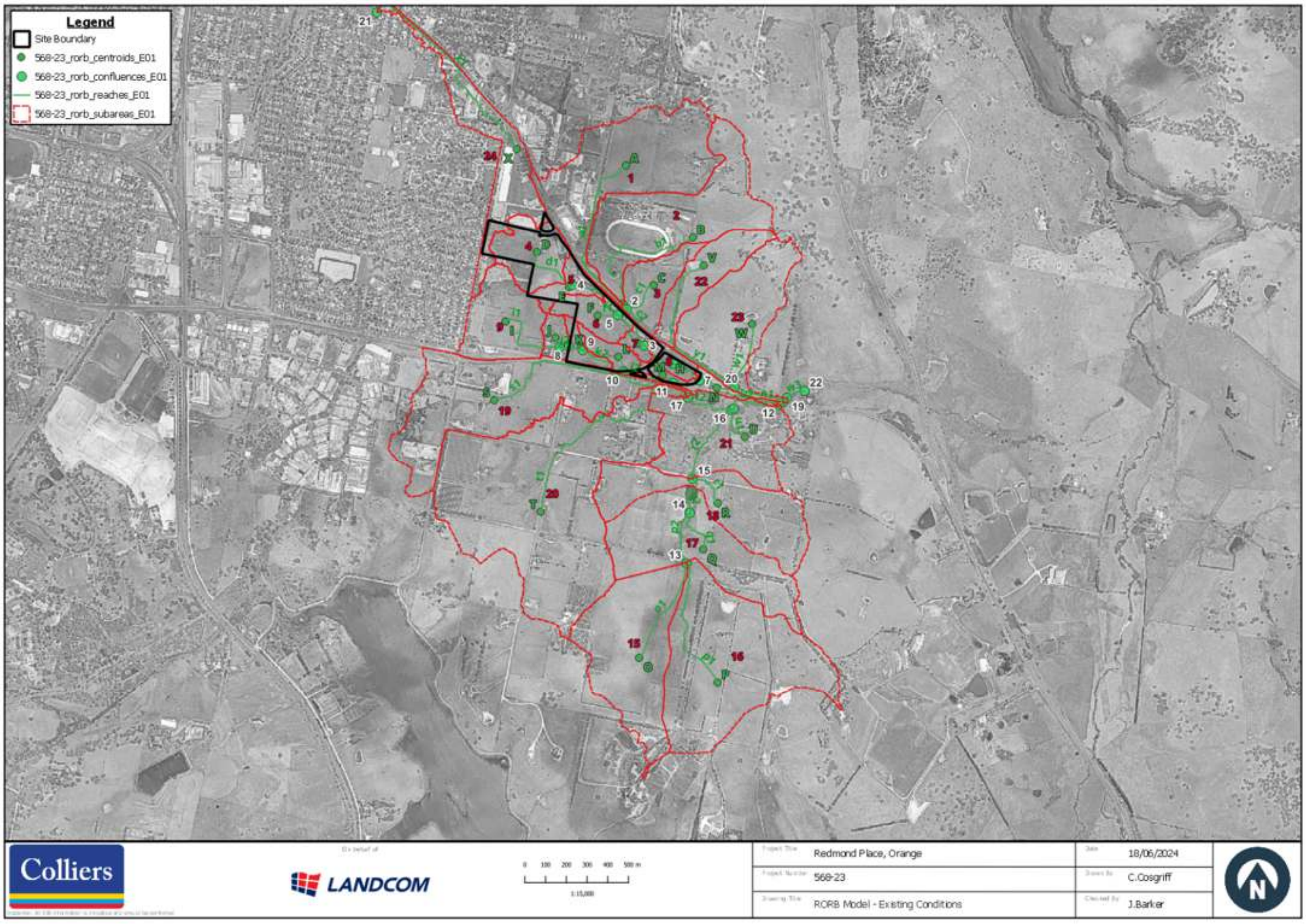


Figure 12. RORB – Existing

6.3.3 Kc Calibration

The routing factor Kc was determined by applying each of the relevant equations as listed below and utilising other flow determination methods to validate the chosen equation in accordance with AR&R2019. The equation for the entirety of NSW was firstly adopted for further calibration / investigation against sanity check methods including RFFE and rational calculations.

Table 6 Kc Calibration

Equation	Kc	Flow
NSW	2.26	23.97
NSW West of Great Dividing Range	1.64	32.22
RFFE		71.60
NSW Rational Method		24.70

The RORB results, indicating a flow ranging from ~24 – 32 m^3/s are on the lower end of the results, but coincides reasonably with the rational value using an average FI from the FI map informing the RORB sub-catchments. The Kc for catchments west of the Great Dividing Range in NSW was selected given the comparison to sanity check flow methods and to ensure a conservative calculation given the results from the RFFE assessment. The RORB parameters are summarised in Table 7 below.

Table 7 RORB Parameters

Parameter	Value
Kc	1.64
Kc (Sub Area X)	0.33
m	0.80
Initial Loss (IL)	25.00
Continuing Loss (CL)	1.94

6.3.4 Simulated Storm Events

An initial assessment of all storm durations (ranging from 10min to 168hours, for all temporal patterns) was run to assess the critical durations throughout the site and relevant catchment in order to assess the critical storm duration at critical locations throughout and downstream of the site. The results were then analysed following the process outlined in Figure 13.

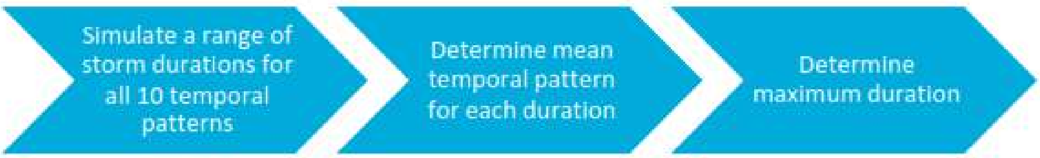


Figure 13 Process for determination of critical storm

The analysis illustrated that the critical storm durations ranged from 15-minutes to 45-minutes. From subsequent simulations five key storm durations and critical temporal patterns were adopted to perform the existing conditions flood impact assessment. The storms which were adopted are outlined below in Table 8.

Table 8 Critical Storm Durations and Mean Temporal Patterns – Existing Conditions.

Storm Duration	Mean Temporal Pattern
15 min	TP5
30 min	TP6
45 min	TP5
60 min	TP5
90 min	TP8

6.3.5 Developed Conditions Hydrology

The model was updated with appropriate routing to represent the impact of development. Kc was updated as a function of D_{av} and land use fraction impervious was updated to represent the various land use and parcel densities through the proposed development. Updated RORB parameters are shown below in Table *9*. The parameters were consistent with the existing model due to a negligible change in D_{av} between scenarios.

Table 9 RORB Parameters – Developed

Parameter	Value
Kc	1.64
Kc (Sub Area X)	0.33
m	0.80
Initial Loss (IL)	25.00
Continuing Loss (CL)	1.94

The developed model can be seen below in Figure 14 with land use fraction impervious values shown in Table 10.

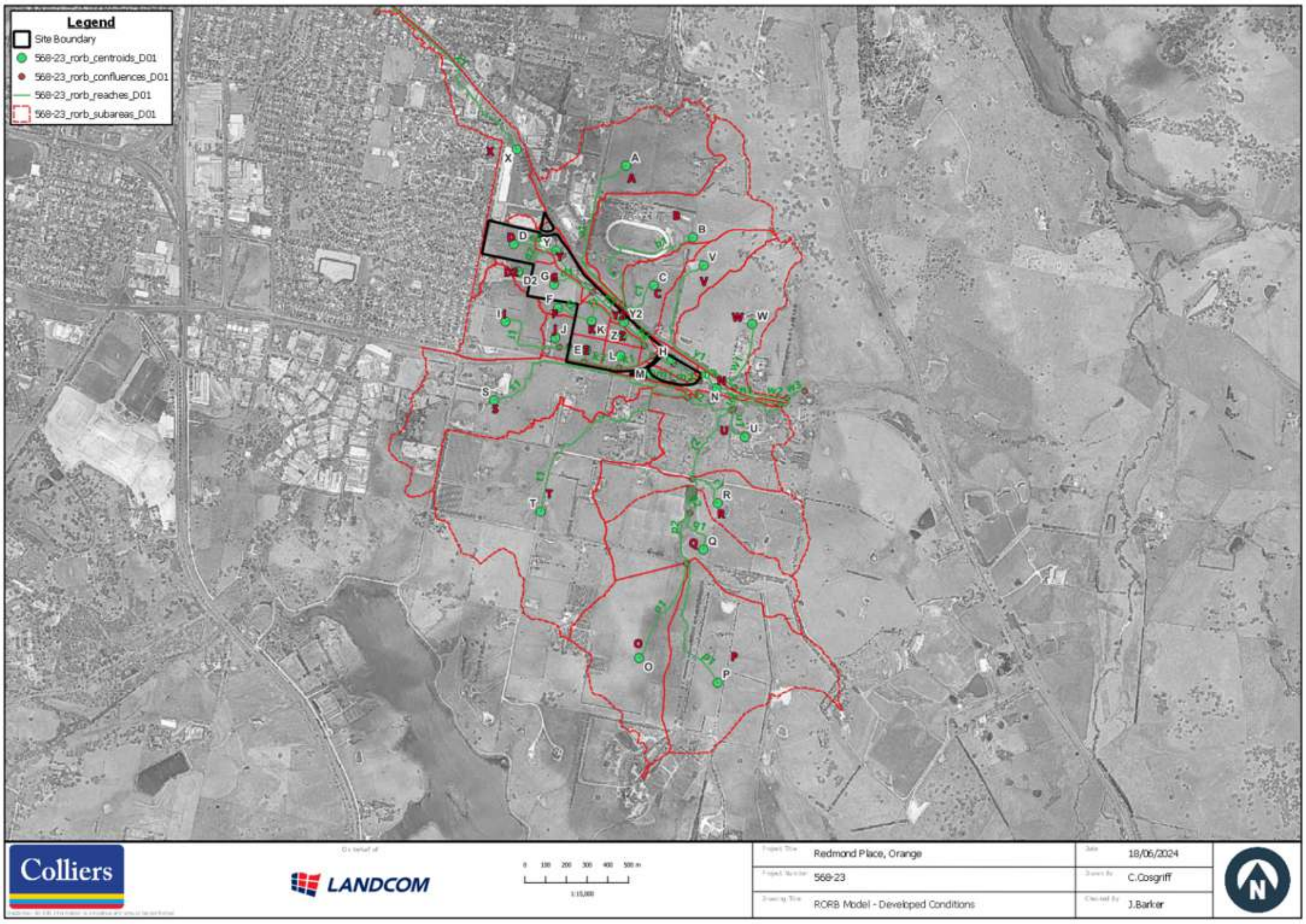


Figure 14. RORB – Developed

Table 10 Land Use Fraction Impervious.

Parameter	Value
Low Density Residential	0.70
Medium Density Residential	0.80
Apartments	0.90
Industrial	0.95
Rural	0.05
Open Space	0.10
Commercial Road	0.98
Subdivisional Road	0.60
Drainage Reserve	0.10.

The simulated storm events were analysed as per section 6.3.4 with the critical duration and mean temporal pattern assessed for critical locations throughout the catchment for analysis. The storms to be analysed for assessment against existing conditions are shown below in Table 11.

Table 11 Critical Storm Durations and Mean Temporal Patterns – Developed Conditions.

Storm Duration	Mean Temporal Pattern
15 min	TP5
30 min	TP6
45 min	TP5
45 min	TP6
60 min	TP5
90 min	TP8

7 Water Quantity Management Strategy

7.1 Introduction

Surface runoff is generally increased as a result of an increased impervious within development, which causes an increase in the peak flow rate exiting the site. This increased flow rate needs to be managed/mitigated to ensure the protection of downstream environments, habitats and communities.

A detention basin is proposed downstream of the development to attenuate peak flows and restrict discharge to below predevelopment rates. RORB modelling was used to initially size the basin, which is located downstream of Dairy Creek Rd and north of the Mitchel Highway.

The basin was initially designed to reduce outflow to the predevelopment rate of 11.89m³/s downstream of Dairy Creek Rd, then downstream and model exit print nodes were checked to ensure the basin did not cause increased flows downstream due to interaction with regional catchments.

7.2 Basin Design

The size of the detention basin outlet and upstream stage storage relationship was iteratively designed until the peak outflow was less than the predevelopment rate of 11.89m³/s. The resultant outlet configuration is described below in Table 12.

Table 12 Proposed Retarding Basin Outlet

Length (m)	Invert (mAHD)	Size (m)	Spillway Elevation
10	887.20	4x1.05	889.10

7.2.1 Height Storage Relationship

The basin was designed in 3d to match into the surrounding proposed development and existing terrain from LiDAR data, to ensure the required storage could fit within the constraints of the site. The Storage – Height relationship was extracted from Civil 3d software and loaded into the RORB model. The relationship can be seen below in Table 13.

Table 13 Height Storage Relationship - Detention Basin

H	S	H	S
887.2	0	888.2	7493.6
887.3	679.7	888.3	8331.3
887.4	1374.4	888.4	9186.5
887.5	2084.4	888.5	10060
887.6	2809.8	888.6	10951
887.7	3550.7	888.7	11862
887.8	4307.2	888.8	12792
887.9	5079.7	888.9	13741
888	5868.1	889	14710
888.1	6672.7	889.1	15700
		889.2	16711

7.3 Basin Performance

The flow measured downstream of the site increased to 18.42m³/s from 11.89m³/s because of development. The detention basin mitigates this increase in flow. The extracted outputs from RORB can be seen below in Table 14.

Table 14 Detention Outputs.

Event	1% AEP
Peak Elevation (mAHD)	889.02
Peak Outflow (m³/s)	11.21
Peak Storage (m³)	14,900

The inflow and outflow hydrographs, against the existing hydrograph at the basin outlet for the detention basin can be seen below in Figure 15.

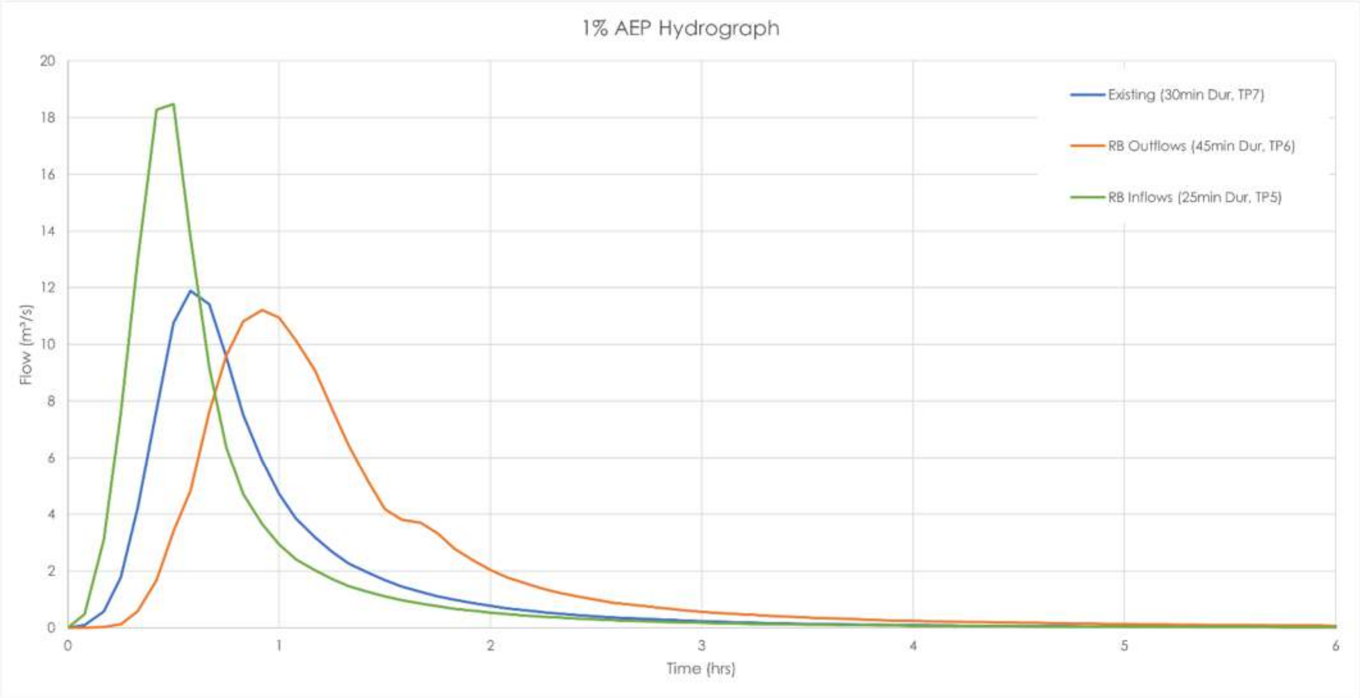


Figure 15 Detention Inflow-Outflow Hydrographs

The above demonstrates that the detention basin successfully reduced the peak inflow of 18.42m³/s (25min TP25) to a peak outflow of 11.21m³/s (45min TP26), less than the predevelopment rate of 11.89m³/s (30min TP27).

The basin design was graded into the 3d terrain of the site using Civil 3d software so it could be applied within the hydraulic model for the post-developed scenario. This will ensure the functionality of the detention basin as per design intent, validating the results achieved in the hydrological model.

7.4 Hydraulic Modelling

7.4.1 Approach and Methodology

The hydraulic model was undertaken using TUFLOW software. TUFLOW is a computational engine that provides one dimensional (1D) and two dimensional (2D) solutions for free-surface flow equations to simulate flood and tidal wave propagation.

The model introduces flow in the form of RORB excess hyetographs via "SA" polygon for each sub-catchment internal and external to the proposed development.

7.4.2 Pre-development Hydraulic Model

The pre-development hydraulic model was developed to assess the current flood conditions surrounding the site to provide a base case scenario. This will allow the assessment of the post developed conditions and the impact of development to be quantified.

The hydraulic model, the parameters adopted, and any assumptions made are outlined in the following sections. The model can be seen visually below in Figure 16.

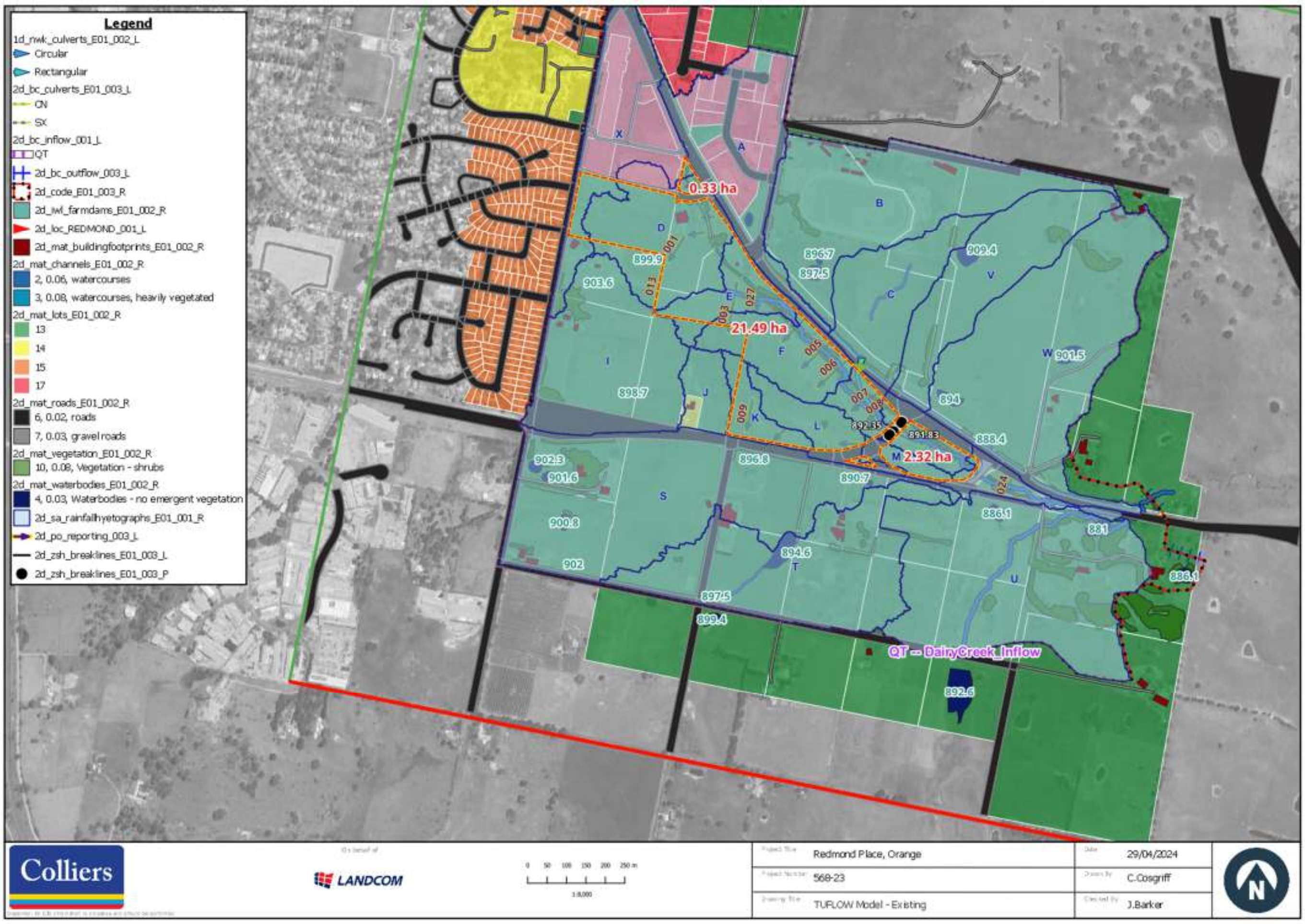


Figure 16 TUFLOW Model - Pre-Development conditions

7.4.2.1 Boundary Conditions

The hydrological model was developed to inform the inflows with a rainfall excess approach taken to input flows to the model. Sub-catchments derived from the hydrological analysis and loaded into RORB were used to extract excess flows after losses are accounted for and applied in the form of a hyetograph applied across the full area of the sub-catchment. Each sub-catchment relating to an inflow can be seen above in Figure 16.

Where the inflow polygon (2d_sa) was trimmed down to reduce the size of the model, a factor was applied within the bc_dbase to ensure scaled inflows were input to the model. The relevant catchment and scaling factors can be seen below in Table 15.

Table 15 Inflow Multiplication Factors

Subarea Trimmed	Original Area (km²)	Area Remaining (km²)	TUFLOW Factor
A	0.333	0.11	0.3303
B	0.300	0.173	0.5767
S	0.379	0.256	0.6755
T	0.703	0.163	0.2319
X	0.171	0.101	0.5906

In addition to the hyetographs, a singular hydrograph has been included as an external flow boundary to capture this inflow from Dairy Creek. There are three outflow boundaries represented to allow flows to exit the site, which have been placed a significant distance downstream as to not impact upon flood condition in the area of analysis. The applied slopes have been measured at each location to give an accurate representation of outflow. All external flow boundaries can be seen below in Table 16.

Table 16 External Boundaries

Type	Name	Slope
HQ	DairyCreek_Out	0.1667
HQ	LonePineAve_Out	0.025
HQ	Eastmodel_outflow	0.05
QT	DairyCreek_Inflow	NA (hydrograph inflow)

7.4.2.2 Mannings 'n' Roughness (Materials Definition File)

A materials definition file was used to define the mannings roughness of the terrain surface. Aerial imagery and SixMaps cadastral data was used to delineate the specific roughness regions. Depth varying mannings 'n' values were adopted due to the distributed rainfall input approach. The roughness map of regions can be seen above in Figure 16, with defined mannings coefficients outlined below in Table 17.

Table 17 Mannings 'n' roughness values

Id	Material	'n' Value (y_1, n_1, y_2, n_2)
1	Impervious Area Rainfall Losses	IL = 1.0 mm CL = 0.0 mm/hr
2	Design ARR2016 Pervious Losses	Probability Neutral Burst Losses
3	Concrete Lined / Irrigation Channels	0.05, 0.04, 0.1, 0.02
4	Watercourses	0.5, 0.1, 1.0, 0.04
5	Waterbodies, no emergent vegetation [assume zero infiltration]	0.03, 0.08, 0.1, 0.03
6	Roads	0.05, 0.06, 0.1, 0.03
7	Gravel Roads	0.03, 0.08, 0.1, 0.025
8	Rail Corridor	0.1, 0.16, 0.2, 0.08
9	Open Space (e.g., Minimal vegetation (grassed))	0.1, 0.06, 0.2, 0.04
10	Moderate vegetation (shrubs)	0.15, 0.16, 0.3, 0.08
11	Heavy vegetation (trees)	0.2, 0.24, 0.4, 0.12
12	Building Footprints	0.1, 0.02, 0.3, 0.3
13	Low density residential lots	0.1,0.12,0.2,0.06
14	Medium Density Residential	0.15,0.2,0.3,0.1
15	Large Residential Lots	0.1, 0.1, 0.2, 0.05
16	Industrial/Commercial (Large significant buildings)	0.15, 0.2, 0.3, 0.1
17	Limestone Quarry	0.05, 0.1, 0.1, 0.025
18	Default Model 'n' value - Rural, generally unmaintained grass, lightly vegetated	0.03, 0.1, 0.1, 0.045
19	Developed Conditions - Parks, Open Space, Minimal Vegetation, neatly maintained grass [assumed pervious]	0.1, 0.06, 0.2, 0.03
20	High Density Residential, slightly increased c.f. Wollondilly Flood Study	0.15, 0.25, 0.3, 0.15
21	Watercourses – heavily vegetated	0.5, 0.15, 1.0, 0.06
22	Used car lots present within the catchment	0.15, 0.06, 0.3, 0.2

7.4.2.3 Structures

Due to insufficient information, a minimal number of existing structures were included in the model, however Colliers has investigated the site allowing the pickup and use of survey data for important hydraulic structures, such as inlet and outlet culverts to the site, to allow more accurate modelling of the flood conditions.

The culverts underneath Dairy Creek Rd will need to be upgraded to avoid the breaching of Dairy Creek Rd in the 1% AEP event. Existing conditions flood modelling demonstrates that the road is inundated in major events in its current state. The existing culverts are described below in Table 18.

Table 18 Existing Dairy Creek Rd Culverts

Length (m)	US Invert (mAHD)	US Invert (mAHD)	Size (m)
10	891.20	890.71	3x1.05

Each structure, input within the 1d_nwk files, can be seen below in Table 19.

Table 19 Existing Scenario Structures

Type	ID	Length	Size	US IL	DS IL	Location
R (Box Culvert)	CULV01	29.40	2x1500x600	893.68	593.37	Mitchell Hwy
C (RCP)	CULV02	32.30	3x1050Ø	891.20	890.71	Dairy Creek Rd

Further detail and certainty will be added to the surrounding structures as the project progresses to the development approval stage.

7.4.3 Post-development Hydraulic Model

The updated model to represent the proposed post development conditions is shown below in Figure 17. The following sections outline the updates to the existing model to represent the proposed development.

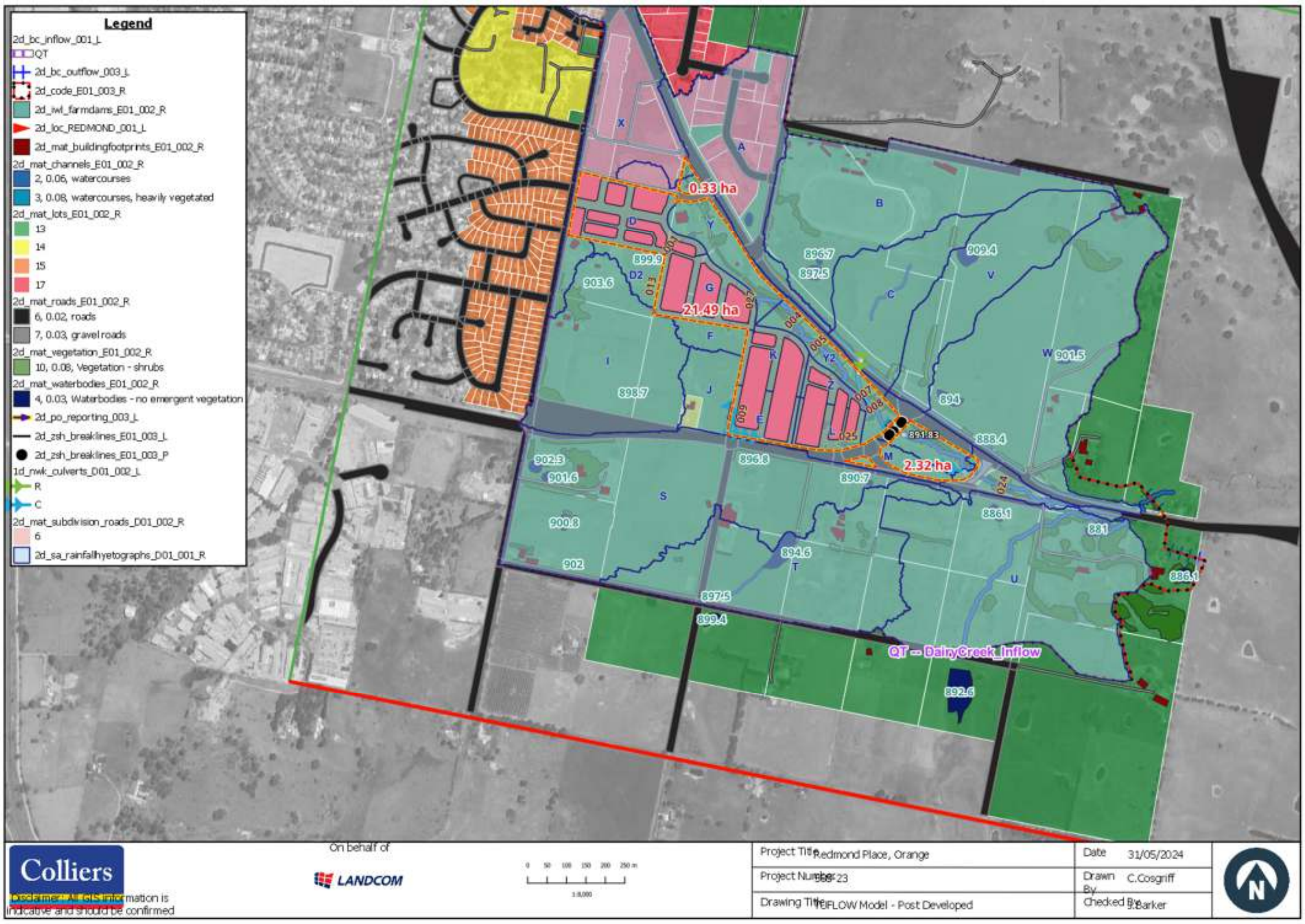


Figure 17 TUFLOW Model - Post-Development conditions

7.4.3.1 Boundary Conditions

The developed case inflows were updated to represent proposed land-use fraction impervious and routing as discussed in section 6.3.5. The updated inflow polygons representing developed conditions can be seen above in Figure 17. The significant change to the developed conditions was removing the lot boundaries from the rainfall catchment. At this stage of analysis, although the underground drainage network has not been designed and is not included in the TUFLOW model, it is assumed the excess rainfall from the lots will be managed by on-site drainage and be directed into the adjacent road corridors. This was considered conservative, and the drainage will be added during the Development Approval (DA) phase. This was achieved by eliminating the portions of the 2d_sa polygons over the designated lot areas.

The external outflow and inflow boundaries throughout the catchment remained the same as those adopted for existing conditions.

7.4.3.2 Terrain

A design tin that represents the grading of the Proposed Zoning Plan was included in the developed case TUFLOW model. The resultant updated terrain is illustrated in Figure 18.

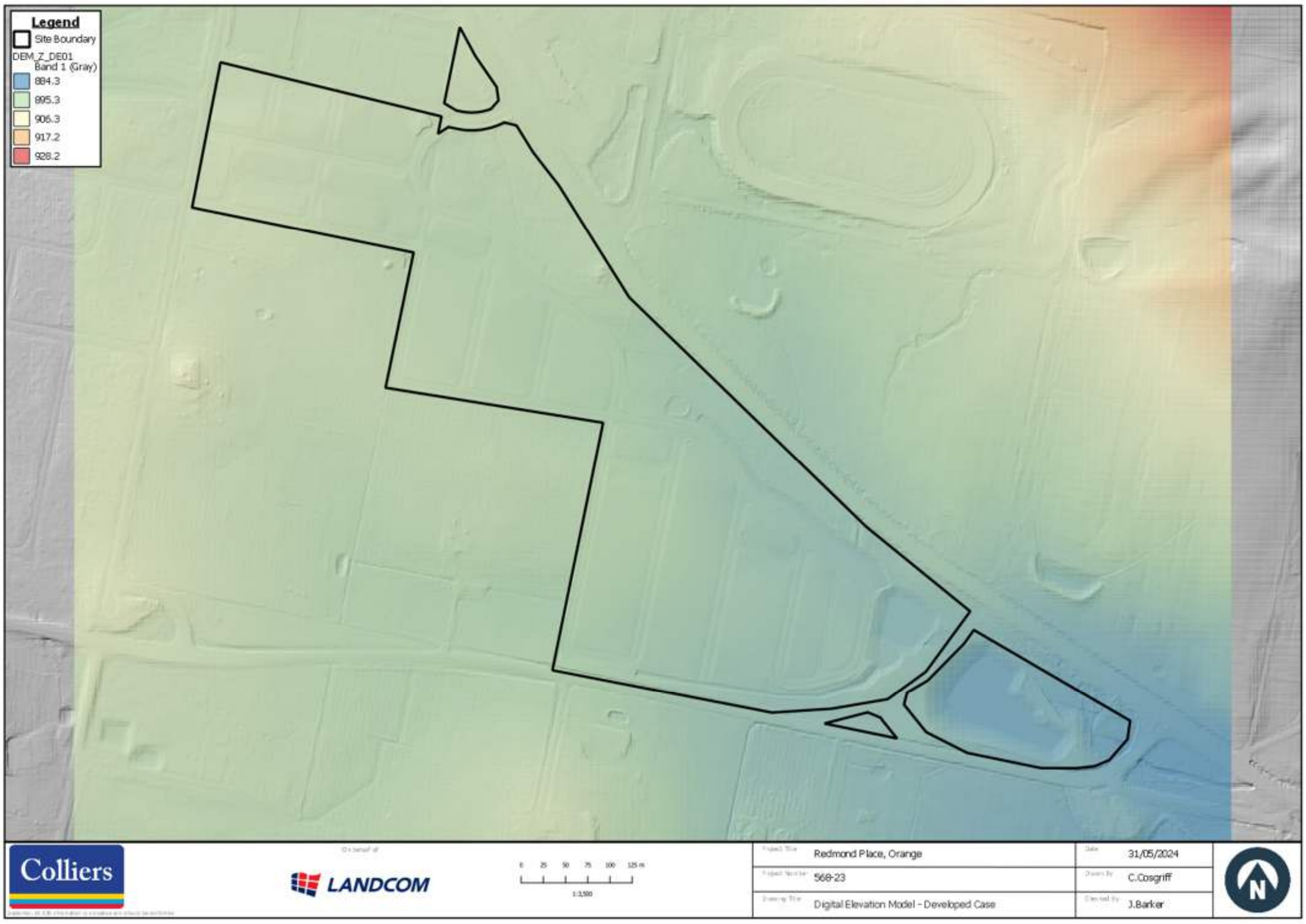


Figure 18 Digital Elevation Model – Developed Case

7.4.3.3 Structures

There are two additional structures required to service the proposed developments flood conditions. The proposed design solutions are listed below.

1. The upgrade of the Dairy Creek Rd culverts. The initial size was calculated using RORB software and validated using TUFLOW within the flood impact assessment. The culverts require upgrading to prevent the inundation of Dairy Creek Rd in major events and pass the 1% AEP flow.
2. Underground pipeline to connect the external catchments to the west (sub-catchments I & J) to the swale though the site.
3. The retarding basin outlet, to ensure site discharge does not exceed predeveloped levels and there is zero impact on external flood conditions.

The updates to the 1d_nwk file can be seen below in Table 20.

Table 20 Developed Case Structures

Type	ID	Length	Size	US IL	DS IL	Location
C (RCP)	BP	72.00	1050Ø	893.68	593.37	Internal
C (RCP)	CULV02	32.30	8x1050Ø	891.00	890.71	Dairy Creek Rd
C (RCP)	CULV02	32.30	4x1050Ø	889.10	888.90	Retarding Basin

All other structures were consistent with the existing case scenario.

7.5 Flood Modelling Results

The results of the existing case and developed case modelling are detailed in sections 7.5.1 & 7.5.2, with the impact of the proposed development on flood conditions discussed in section 7.5.3.

7.5.1 Pre-development Flooding Results

Being at the top of the catchment, the overland flow is generally restricted to sheet flow across rural areas in existing conditions, with flow directed towards defined gullies and eventually Dairy Creek. The deepest areas of flood depth illustrated on the map are the farm dams, where the depth exceeds 1.5m in some areas.

There are two major overland flow paths through the site which will need to be managed; the drainage spine along the southern side the Mitchell Highway, and the external catchment flows that travel along the northern side of Dairy Creek Rd.

The flood mapping representing the depths experienced in a 1% AEP flood event in existing conditions can be seen below in Figure 19.

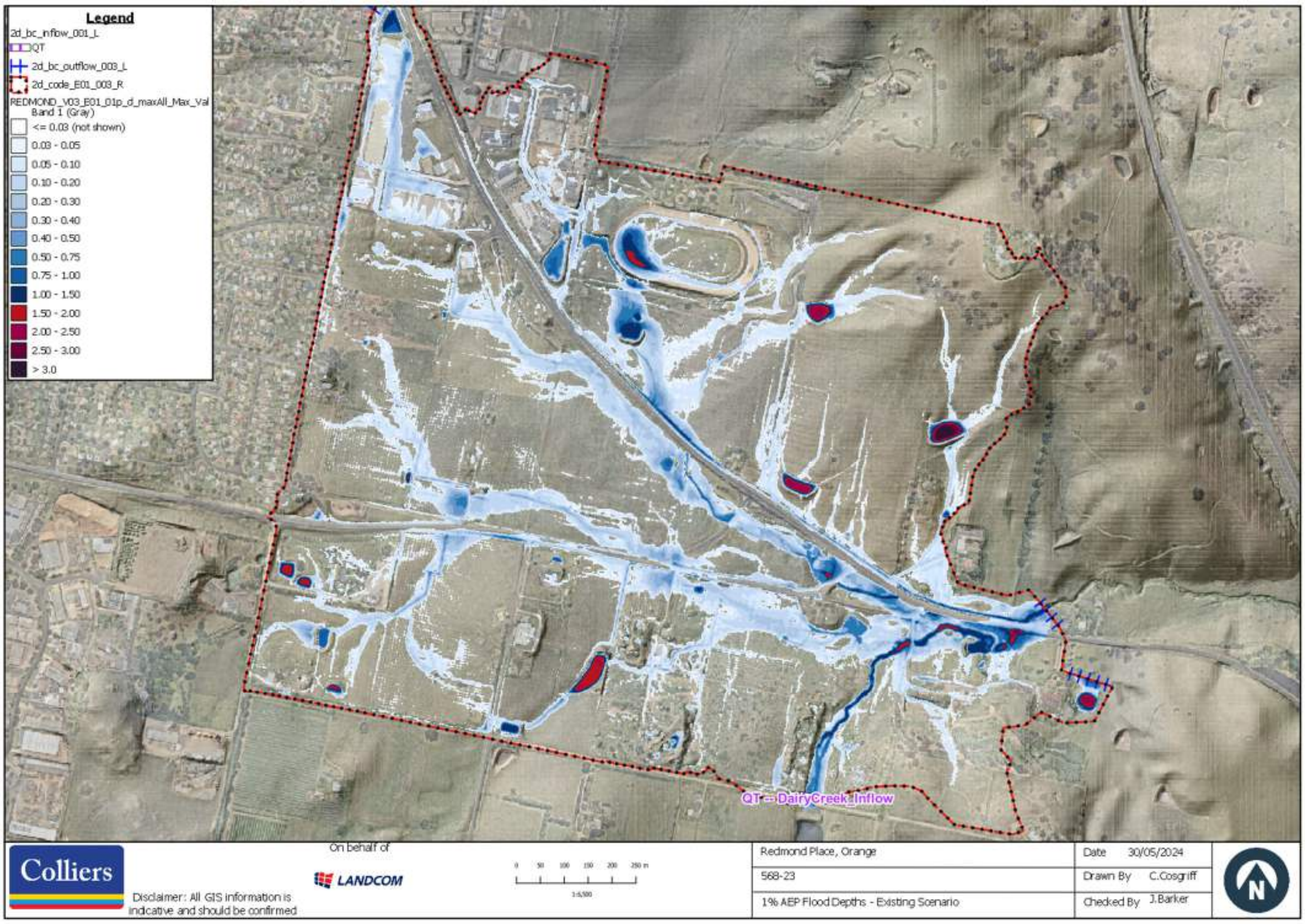


Figure 19 1% AEP Flood Depths – Pre-Development Scenario

7.5.2 Post-development Flood Results

The post development flood results can be seen below and demonstrate the flooding within the development is managed within the roads, and the external catchments can be catered for with further refinement of the infrastructure and development earthworks at the DA stage. The flood behaviour is summarised below.

- The peak flood level experienced in the detention basin is 892.10mAHD. The adjacent roads provide significant freeboard to this level (893.5mAHD)
- The green spine watercourse proposed along the north-east boundary has a flood level of 899.25mAHD at the upstream section and feeds into the detention basin at 892.10mAHD and the downstream end.
- There are several trapped low points within the subdivisional road design, with the results showing pooling water at these locations. These will be removed when the subdivisional drainage is designed and Q100 underground pipes will be required where flow cannot escape overland.
- Pooling of water where the external catchments to the west was expected, and further design and surface refinement is required to accept the flows efficiently in the interim scenario.
    - Ultimately the development to the west will design infrastructure to connect to the subdivisional drainage and the water pooling will not be experienced.

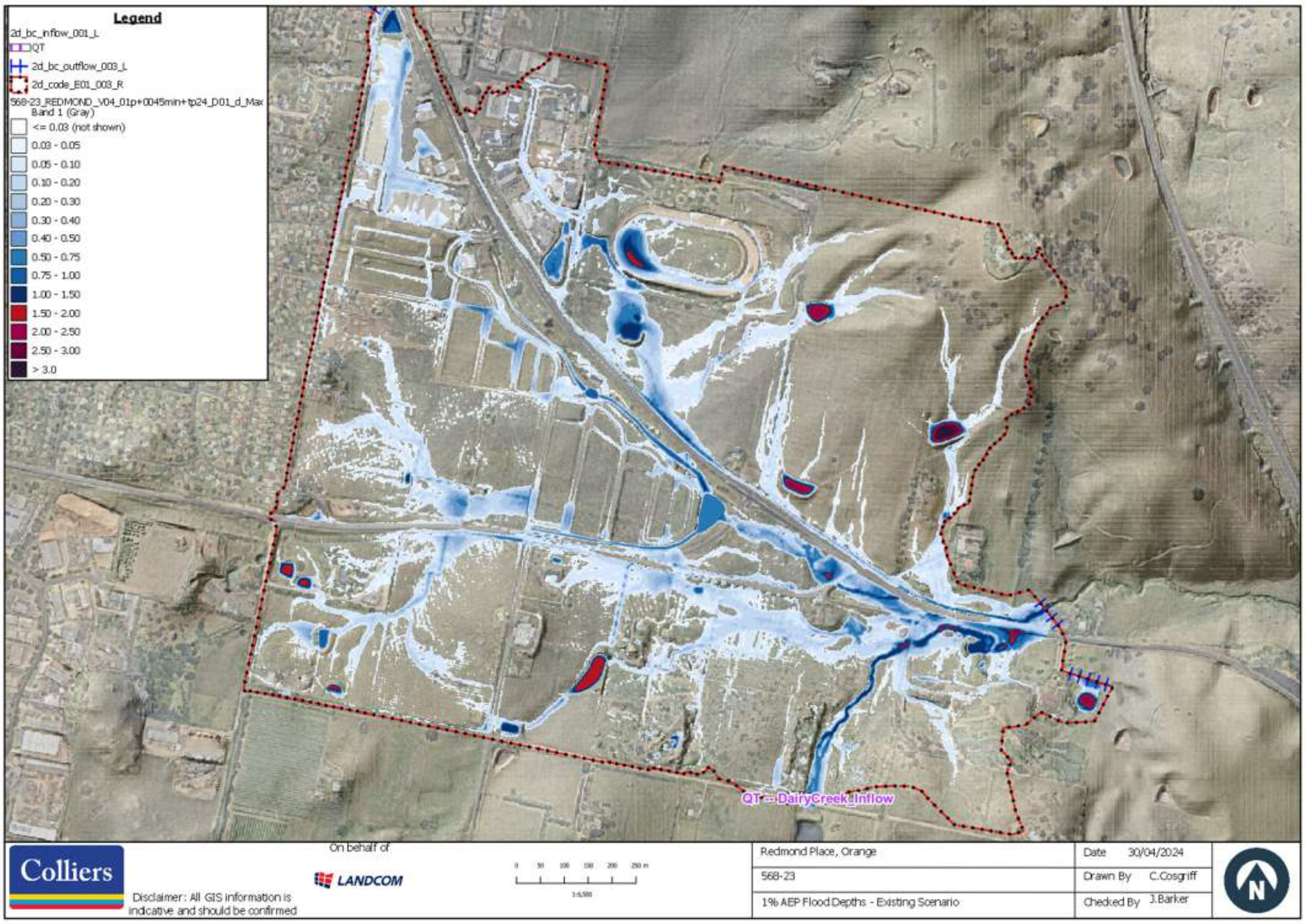


Figure 20 1% AEP Flood Depths – Post-Development Scenario

7.5.3 Flood Impact Assessment

Afflux is the difference between water surface elevation levels from the developed case to the existing case. The flood impacts identified due to the development of Redmond Place Rezoning are as follows.

- Generally, there are no regions or isolated locations of increased flood levels outside of the development parcels.
- There is an increased depth at the location where the external catchment enters the site at the western boundary. The drainage design is yet to be undertaken, and preliminary modelling provides confidence these flows can be accepted through the site without impacting upstream flood conditions.
- There are reduced flood depths downstream of the site, demonstrating the mitigation measures within the development are having a positive affect on flood conditions downstream.
- The wet/dry analysis identifies all areas that were dry and are now wet due to the development (pink) and all areas that are now dry that were previously wet (cyan).
    - The analysis shows that all newly wet terrain is within the development boundary due to newly defined flow paths.
    - There are large areas of dried areas within the parcels demonstrating the flood resilience of the lots.

The afflux mapping is illustrated below in Figure 21.

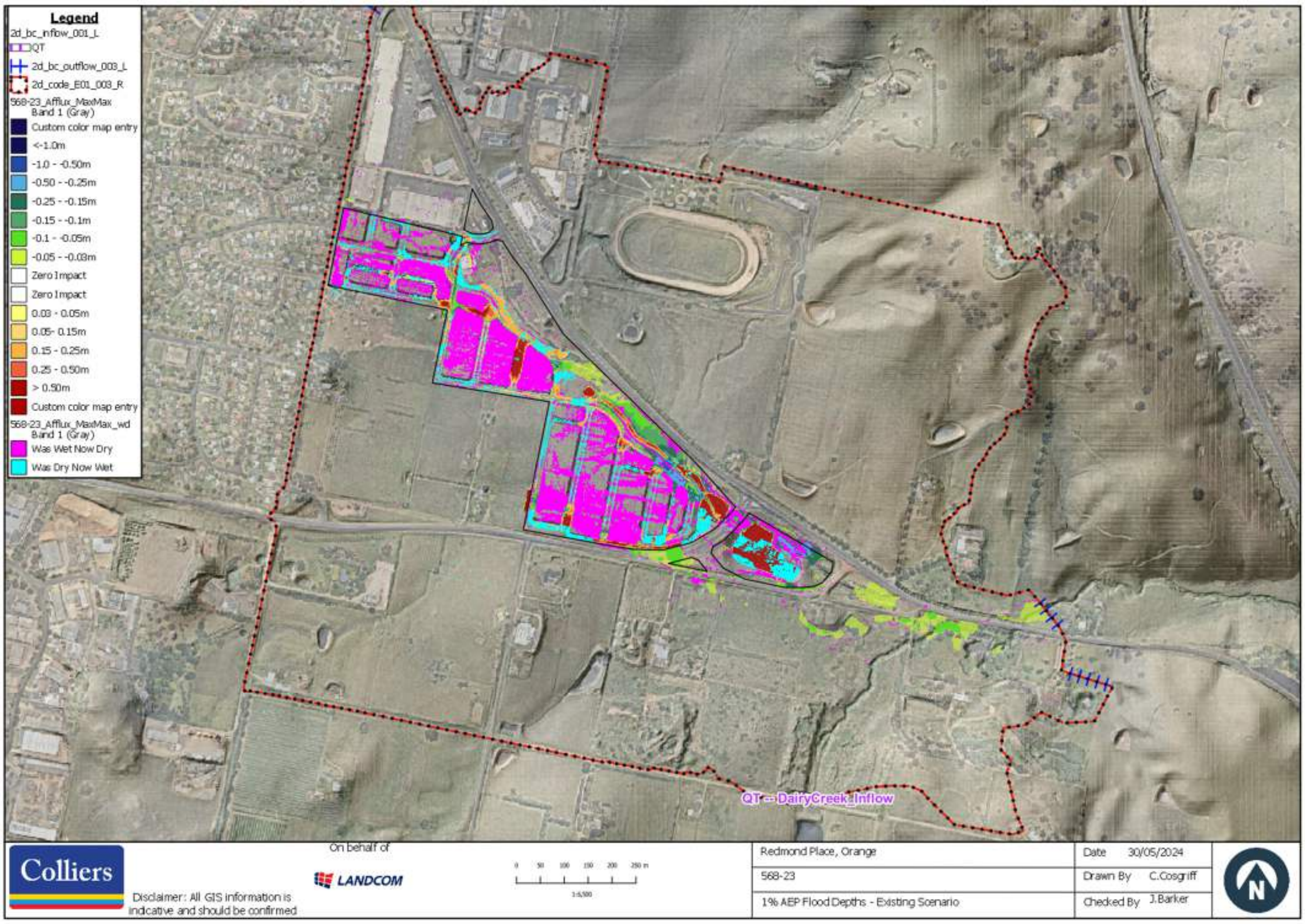


Figure 21 Afflux Map

7.5.4 Discussion

Preliminary 1% AEP flood modelling for the Redmond Place Precinct demonstrates that there are minimal offsite impacts due to the development of the site. Changes in flood behaviour within the site are due to the changed terrain which was designed to contain flooding within designated riparian corridors. The flood impacts have been managed through appropriate interventions such as infrastructure upgrades and detention systems.

With further refinement of the basin sizing and the additional detail of the road drainage network and riparian corridor design during the DA stage, these minor impacts can easily be mitigated. Thus, the Planning Proposal is considered acceptable from a flooding perspective.

8 Water Quality Management

8.1 Introduction

The Stormwater Management Plan for the City of Orange was prepared in April 2008 in conjunction with The University of Sydney in consultation with the community to investigate stormwater issues for the Orange Urban Catchment. The following are key points that should be noted as relevant to the subject site from the Stormwater Management Plan:

- The primary objective for stormwater management is to *improve water quality and health of waterways within the urban catchment of Orange.*
- The main stormwater objectives for new development are to ensure appropriate erosion and sediment control plans are implemented to prevent environmentally harmful impacts of downstream sedimentation. This can be achieved by:
  - Minimising disturbance of vegetation cover;
  - Regulating surface water flow paths and volumes across development sites;
  - Trapping the mobilised sediment; and
  - Stabilising disturbed lands.
- While there are no specific goals for the amount of reductions in pollutant loads the general criteria from the Council is that pollutants generating from a site should be no higher than the pre-development state

In addition to the Stormwater Management Plan for the City of Orange, the following key principles have been adopted as they are the most relevant to the subject site:

- Protect and enhance natural watercourses and their associated ecosystems and ecological processes.
- Maintain, protect and/or rehabilitate modified watercourses and their associated ecosystems and ecological processes towards a natural state.
- Minimise potable water demand and wastewater generation.
- Match the post development runoff to the predevelopment or natural water runoff regime as closely as possible.
- Mitigate the impacts of development on water quality and quantity.
- Integrate water cycle management measures into the landscape and urban design to maximise amenity.
- Minimise the potential impacts of development and other associated activities on the aesthetic, recreational and ecological values of receiving waters.
- Minimise soil erosion and sedimentation resulting from site disturbing activities.
- Ensure the principles of ecologically sustainable development are applied in consideration of economic, social and environmental values in water cycle management.

8.1 Pollutant Reduction Targets

The targets for pollutant reduction and associated modelling methodology is consistent with the Orange City Council (OCC) Subdivision and Development Code (April 2024). The main objectives of the subdivision and development code of Orange City Council is listed below:

1. Targeting pre-development water quality for surface and ground waters.
2. Reducing demand on reticulated water supply by having alternative water sources.
3. Integration of water into the landscape for visual, ecological and cultural amenity.

To achieve a zero impact and satisfy the requirements of the OCC Subdivision Code, the development will prepare a Water Cycle Management Plan in accordance with Neutral or Beneficial Effect (NorBE) guidelines. The NorBE guidelines are satisfied if the development:

- Has no identifiable potential impact on water quality, or;
- Will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on site.
- Will transfer any water quality impact outside the site where it is treated and disposed of to the standards approved by the consent authority.

The strategy for this site will target the first approach and demonstrate a neutral or beneficial impact on target pollutants leaving the site from predevelopment conditions under Module 3 of the NorBE guidelines. Two scenarios will be assessed to understand the impact of targets requested by Orange City Council.

- Scenario 1: No net increase in pollutant loads for total suspended solids, total phosphorus and total nitrogen from predevelopment loads.
- Scenario 2: At least a 10% improvement in pollutant loads for total suspended solids, total phosphorus and total nitrogen from predevelopment loads.

Post development cumulative probability pollutant concentration curves will be assessed to ensure they are equal to or less than the predevelopment curves for total phosphorus and total nitrogen between the 50th and 98th percentile for both scenarios.

8.2 Water Quality Treatment Approach

The adopted stormwater quality management strategy includes provision of a treatment train to treat surface runoff to the drainage network for the fully developed conditions. The treatment system includes the use of end of line and distributed management features that can be integrated within the landscape and open space areas and distributed throughout the catchment, such as rainwater tanks, or they can be concentrated in centralised locations as end-of-line treatments, such as bio-retention basins.

The following water quality control assets are proposed for implementation within the development:

- Distributed rainwater tanks – for collection of runoff from roofs and re-use of water for irrigation and household use and;
- End-of-line bioretention systems for capture of finer sediment and treatment of nutrients.

8.2.1 Methodology

The stormwater quality management modelling was prepared using the industry standard MUSIC Model (Model for Urban Stormwater Improvement Conceptualisation) Version 6.3. Blacktown City Council has a MUSIC template available for use and this template was adopted for modelling of the site, with the rainfall template being changed to reflect the conditions within Orange more closely.

8.2.1.1 Hydrologic Data Inputs

Blacktown City Council has recommendations for using rainfall data provided through MUSIC-Link however, this data doesn't accurately portray what is happening within the development. Therefore, monthly Potential Evapotranspiration (PET) and rainfall data has been found from Rainfall Station No. 63253 – ORANGE Station. The data was based on a the time series 20/06/1963 12:00 AM to 30/06/1973 12:00 AM, with a mean annual rainfall value of 943mm/year.

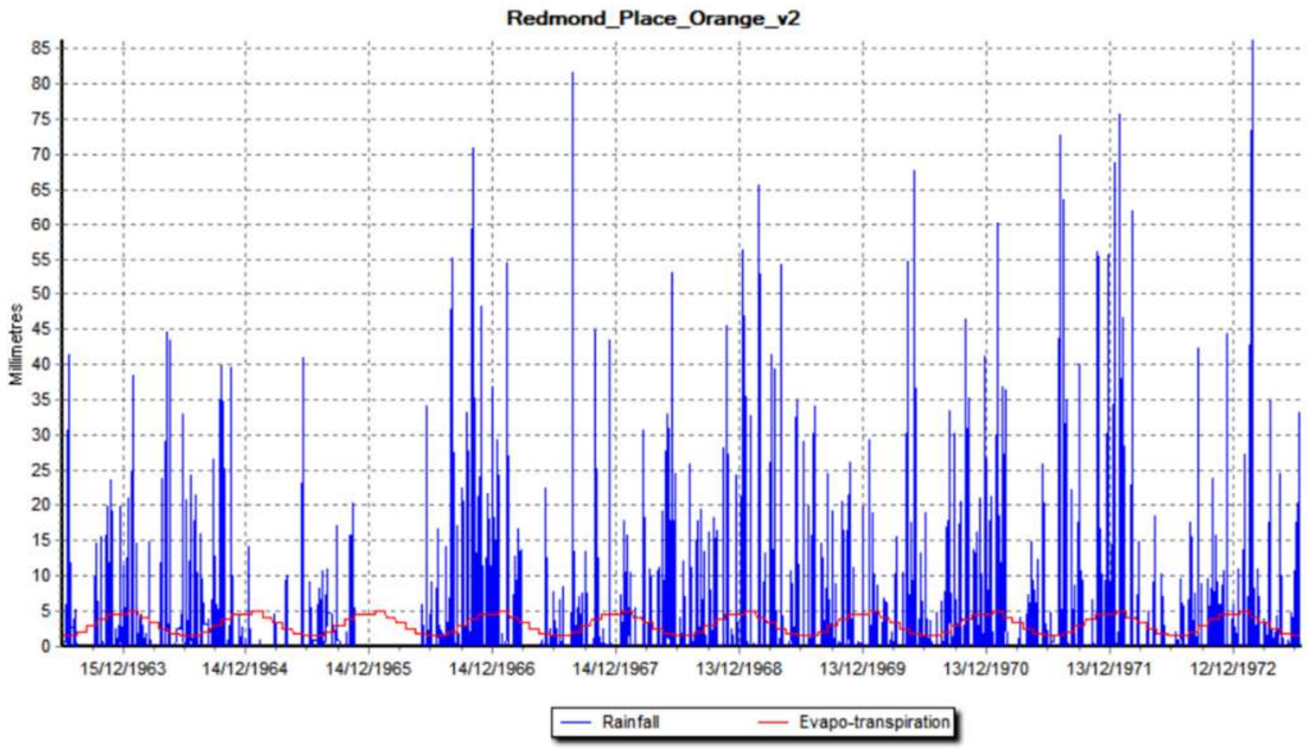


Figure 22 Rainfall and PET graph from Orange Rainfall Station

8.2.1.2 Source Node Data Inputs

Source Node parameters were adopted by Blacktown City MUSIC template. The following table summarises the source node inputs used within the MUSIC model.

Land-use category		Log10 TSS (mg/L)		Log10 TP (mm/L)		Log10 TN (mg/L)	
		Storm flow	Base flow*	Storm flow	Base flow*	Storm flow	Base flow*
BCC Roof areas (Roof)	Mean	1.30	1.20	-0.89	-0.85	0.30	0.11
	Std Dev	0.32	0.17	0.25	0.19	0.19	0.12
BCC Road Areas (Sealedroad)	Mean	2.43	1.20	-0.30	-0.85	0.34	0.11
	Std Dev	0.32	0.17	0.25	0.19	0.19	0.12
BCC Other Impervious areas (Unsealedroad)	Mean	2.15	1.20	-0.60	-0.85	0.30	0.11
	Std Dev	0.32	0.17	0.25	0.19	0.19	0.12
BCC Pervious Areas (Revegetatedland)	Mean	2.15	1.20	-0.60	-0.85	0.30	0.11
	Std Dev	0.32	0.17	0.25	0.19	0.19	0.12

Figure 23 Stormwater Quality Parameters - Source Nodes

8.2.1.3 Soil Parameters

MUSIC rainfall-runoff parameters were adopted from Blacktown City Council's MUSIC Template Data for all urban source nodes. See below table for rainfall-runoff parameters.

Parameter	Recommended values
Rainfall threshold (mm)	1.4
Soil capacity (mm)	170
Initial storage (percentage)	30
Field capacity (mm)	70
Infiltration capacity coefficient a	210
Infiltration capacity coefficient b	4.7
Initial depth (mm)	10
Daily recharge rate (percentage)	50
Daily baseflow rate (percentage)	4
Deep seepage (percentage)	0

Figure 24 Soil Parameters adopted in MUSIC

8.2.1.4 Catchment Details

The proposed development has been broken into two main sub-catchments primarily based on the lot layout and 1m LiDAR, see Figure 25 for catchment breakdown.

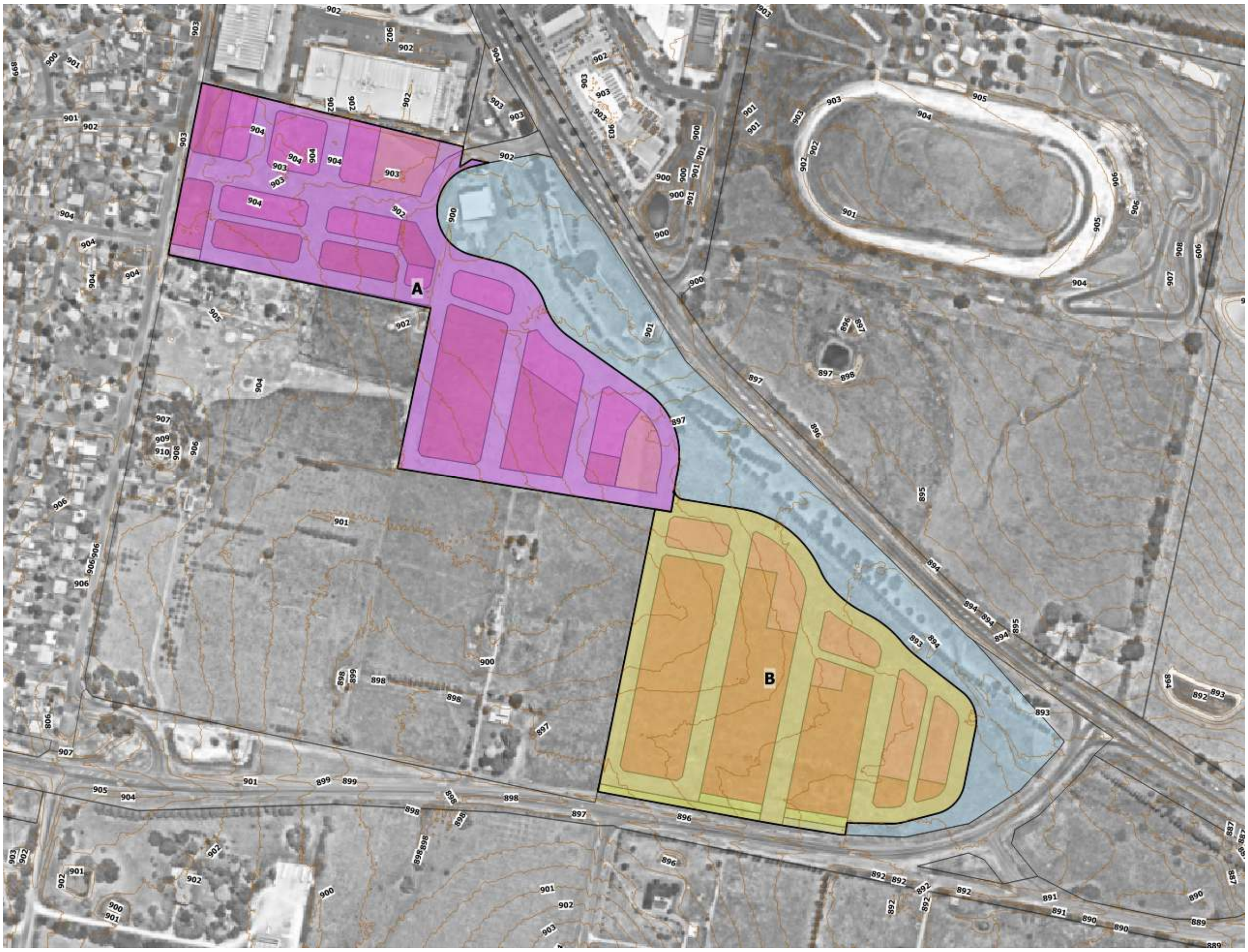


Figure 25 MUSIC Catchment Overview

The land use within these catchments have been broken down into 6 main categories for modelling purposes, the specific fraction imperviousness for these categories have then been used to find a general fraction imperviousness for the entire catchment. These specific fraction impervious categories are listed in the table below, with relevant fraction imperviousness.

Table 21 Catchment A Fraction Impervious Summary

Land Use	Fraction Impervious (%)	Total Area (Ha)	Area Impervious (Ha)	Area Pervious (Ha)
Apartments	90	0.392	0.333	0.059
Road Reserve	60	3.524	2.115	1.410
Open Space	10	0.218	0.022	0.196
Low	70	2.456	1.597	0.860
Medium	80	1.725	1.294	0.431
Total Catchment A	64	8.316	5.360	2.956

Table 22 Catchment B Fraction Impervious Summary

Land Use	Fraction Impervious (%)	Total Area (Ha)	Area Impervious (Ha)	Area Pervious (Ha)
Drainage Reserve	10	0.131	0.000	0.118
Road Reserve	60	3.119	0.013	1.248
Open Space	10	0.357	1.872	0.321
Low	70	3.546	0.036	1.241
Medium	80	0.837	2.305	0.209
Total Catchment B	61	7.99	4.853	3.137

The site has been modelled using a general site imperviousness of 64% for Catchment A and a general site imperviousness of 61% for Catchment B.

8.2.2 Treatment Train

The stormwater design for the development will use a combination of at-source conveyance controls, such as rainwater tanks and end-of-line features such as bio-retention basins to treat the stormwater runoff from the site. The treatment trains proposed for this development are detailed in the below sections.

8.2.2.1 Rainwater Tanks

Rainwater tanks are proposed for each dwelling greater than 300m² is size, and have been modelled within MUSIC for preliminary understanding the benefits and feasibility of Rainwater Tanks within the development.

A preliminary assumption that all lots will be fitted with an approximate 2KL rainwater tank informed the preliminary modelling, with the size and number of rainwater tanks to be further refined at DA stage.

The Blacktown City Council WSUD Developer Handbook (2020) Section 11.14.3 Non-potable reuse rates for modelling reuse tanks in MUSIC have outlined the demand rates that will need to be provided to MUSIC for modelling purposes to ensure that demand can be met. See Figure 26.

Lots	Allowance
lots > 730 m^2	allow 0.1 kL/day internal use & 55.0 kL/year as PET- Rain
lots > 520 & < 730 m^2	allow 0.1 kL/day internal use & 45.0 kL/year as PET- Rain
lots > 320 & < 520 m^2	allow 0.1 kL/day internal use & 32.0 kL/year as PET- Rain
lots < 320 m^2	allow 0.1 kL/day internal use & 25.0 kL/year as PET- Rain
row houses, villas and townhouses	allow 0.1 kL/day internal use & 20.0 kL/year as PET- Rain
apartments or home units	allow 0.0 kL/day internal use (that is, zero daily demand) & 0.4 kL/year/m^2 of watered landscape areas (excluding turf) as PET- Rain (where used)

Figure 26 Water Demand allowance per lot size

8.2.2.2 Bio-Retention Basins

It is proposed to incorporate bioretention systems as end-of-line treatment. End-of-line bioretention systems are incorporated for all impervious catchments. The basins will have a high flow bypass to convey the 1% AEP flows and low flows will be treated before they are discharged downstream. Figure 27 shows a typical section of the bioretention basin adopted for this study.

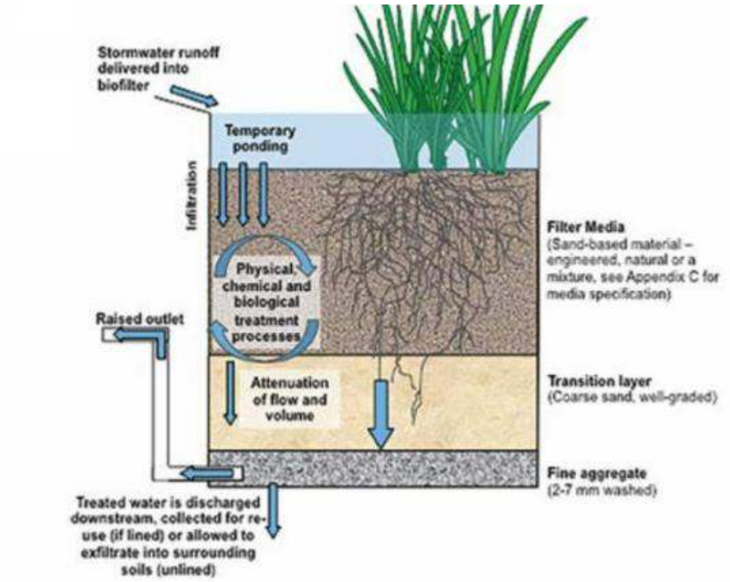


Figure 27 Bioretention System Schematic

The design parameters adopted for the bioretention systems are shown below in Table 23. Within the MUSIC model, the basin surface area (the surface area at the extended detention depth) was set equal to the filter media area (basin invert area). This is a conservative approach as in reality; all basins are likely to have side slopes of at least 1V:4H meaning the surface area will be greater than the filter media area. However, this simplified approach is appropriate at this stage as it allows for optimisation of bioretention design in later detailed design stages.

Table 23 Bio Retention Basin Parameters Adopted in MUSIC

Parameter	Catchment A Value	Catchment B Value
Pre-treatment / Inlet Protection	N/A	N/A
Extended Detention Depth	0.3m	0.3m
Filter Media Depths	0.5m	0.5m
Filter Media	Loamy Sand	Loamy Sand
Filter Media Area	80m	80m
Filter Media Permeability Saturated Hydraulic Conductivity) (mm/hr)	100mm/Hr	100mm/Hr
TN Content (mg/kg)	800mg/kg	800mg/kg
Orthophosphate Content (mg/kg)	40mg/kg	40mg/kg
Exfiltration Rate (mm/hr)	0mm/hr	0mm/hr
Impervious Base Liner	Yes	Yes
Overflow Pit	Yes	Yes
Submerged Zone	No- With Carbon present	No- With Carbon present

8.3 MUSIC Model

The MUSIC model was built to assess the current masterplan allocation of treatment area is adequate to satisfy the NorBE guidelines. The footprints of 600m² and 500m² were used to provide Gross Pollutant Traps (GPT's), sediment forebays and Bio-Basins, the configuration of which is shown in Figure 28 below.

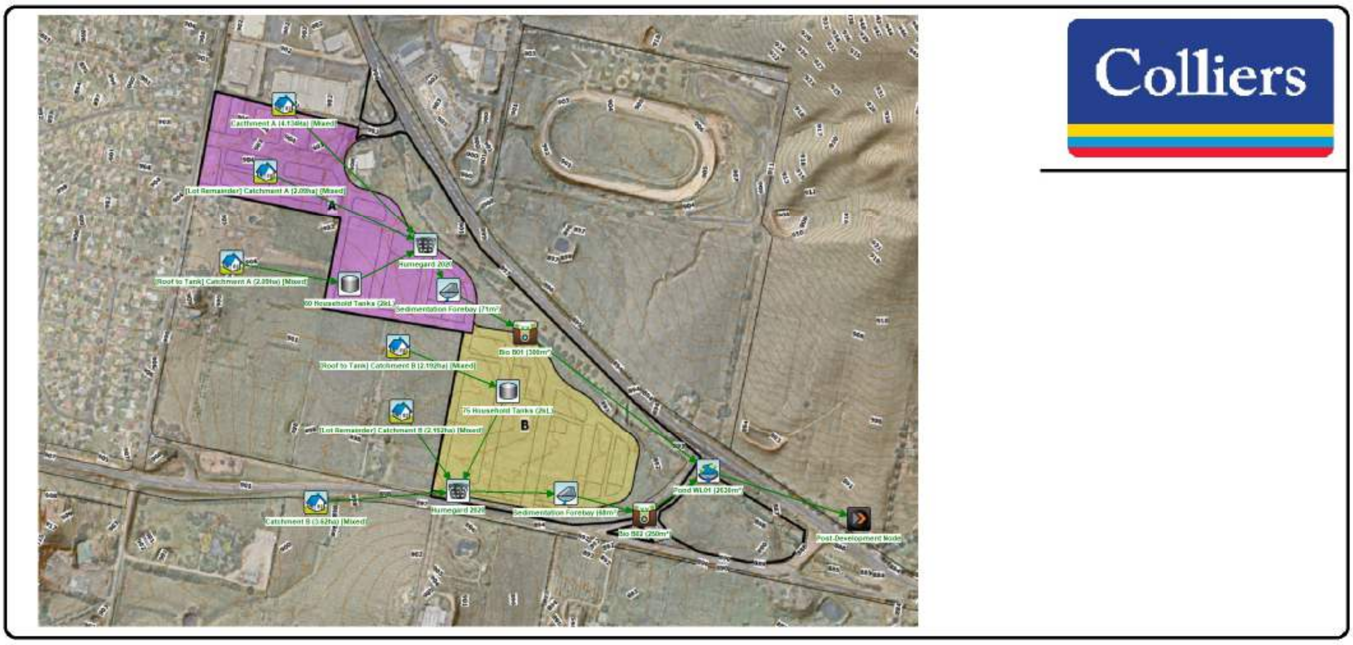


Figure 28 Post Development MUSIC Model

The assets, to be owned and maintained by Council, are listed below. It should be noted that the below assets satisfy the NorBE + 10% criteria as discussed below.

- A 2630m² Open Water Body Pond (WL01)
- 300m² Bio-retention basin at BR01 with incorporated 71m² Sediment Forebay (approximate 600m² footprint)
- 250m² Bio-retention basin at BR02 with incorporated 68m² Sediment Forebay (approximate 500m² footprint)
- 2xHumeguard Gross Pollutant Traps

The water quality benefits of 2kL tanks on all lots over 300m² have also been included in the modelling.

8.3.1 Water Quality Results

To determine if the treatment performance of the above treatment train is adequate, the proposed development pollutant loads are compared to those of the existing conditions of an agricultural node of the same size. The results demonstrate the mean annual loads have been reduced to satisfy the required targets, exceeding the requirements of the NorBE and even NorBE +10% considerably. The analysis of the water quality results is outlined below in Table 24.

Table 24 MUSIC model results analysis – (NorBE)

Pollutant	Predevelopment (kg/yr)	Post Development (kg/yr)	NorBE Met?	NorBE +10% Met?	% reduction from predevelopment levels
Total Suspended Solids	6000	1710	Yes	Yes	72%
Total Phosphorus	18.3	9.26	Yes	Yes	50%
Total Nitrogen	129	99.4	Yes	Yes	33%
Gross Pollutants	586	0	Yes	Yes	100%

Pollutant concentrations for Total Phosphorus (TP) and Total Nitrogen (TN) were compared in accordance with the assessment requirements. As can be seen from both TP and TN, the pollutant concentration (mg/L) for post development is reduced in comparison to the predevelopment concentration. Therefore, the results below show that the reductions have been achieved for the proposed Redmond Place development.

The cumulative frequency graphs for TP and TN are shown in Figure 29 and Figure 30 below, relating to Scenario 1 – reducing in pollutant loads from predevelopment levels.

Figure 29 Cumulative frequency analysis of TP concentrations

Figure 30 Cumulative frequency analysis of TN concentrations

8.3.2 Existing Source Node Sensitivity Check

A sensitivity analysis was undertaken to understand the implications on water quality treatment performance if a revegetated land use node was used to evaluate existing conditions pollutant loads. The land-use node for existing conditions should best represent the current land use of the Site, in this case agricultural, which was determined by an assessment of the land zoning and physical site visit. The nodes can be seen below in Figure 31.

Figure 31 Predevelopment Nodes

The pollutant production comparison between source nodes can be seen below in Table 25.

Table 25 Existing Pollutant Loads – Revegetated Vs Agricultural Source Nodes

Pollutant	Revegetated (kg/yr)	Agricultural (kg/yr)
Total Suspended Solids	2790	6000
Total Phosphorus	6.76	18.3
Total Nitrogen	63.4	129
Gross Pollutants	633	586

The implications of replacing the agricultural node with a revegetated node, whilst satisfying the NorBE guidelines designated within the OCC subdivision code, would result in the following asset sizes. These assets would be owned and maintained by Council.

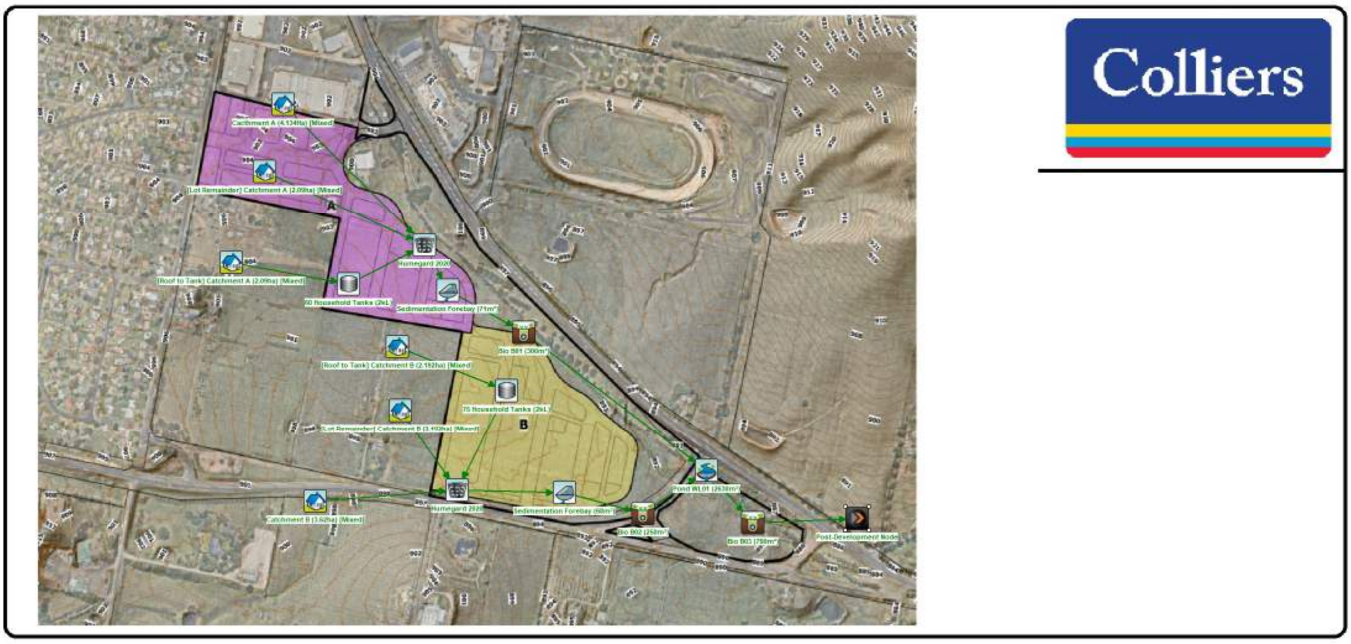


Figure 32 Sensitivity MUSIC Model – Revegetated Nodes

- A 2630m² Open Water Body Pond (WL01)
- 300m² Bio-retention basin at BR01 (approximate 600m² footprint)
- 250m² Bio-retention basin at BR02 (approximate 500m² footprint)

- 790m² Bio-retention basin at BR03 (approximate 1500m² footprint – incorporated into detention asset)
- 2xHumeguard Gross Pollutant Traps

The water quality benefits of 2kL tanks on all lots over 300m² have also been included in the modelling.

It should be noted that the bypass arrangement for utilising BR03 for treatment would likely require separation of its inflows from that of the external catchments (to the north and west) and therefore would require additional culverts underneath Dairy Creek Road. Alternatively, the external catchments could be received by the asset which would have implications on loading and ultimately the maintenance burden of the filters.

8.3.3 NorBE Guideline Targets + 10% reduction from predevelopment pollutant loads.

The above exercise was then repeated to understand the required assets if the NorBE guidelines designated within the OCC Subdivision Code were to be exceeded by 10%. The assets that would be owned and maintained by Council are shown below.

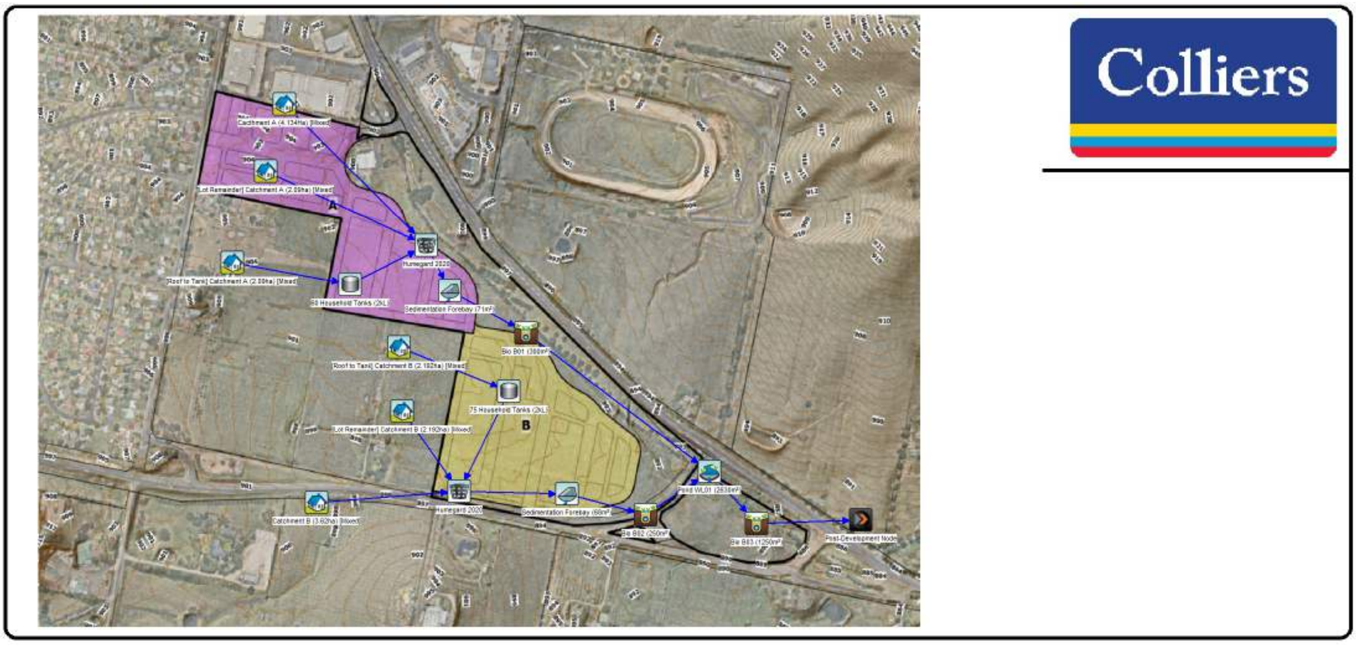


Figure 33 Post Development MUSIC Model – NorBE + 10% reduction

The assets to be owned and maintained by Council, that are required to satisfy the NorBE + 10% reduction requirements are listed below.

- A 2630m² Open Water Body Pond (WL01)
- 300m² Bio-retention basin at BR01 (approximate 600m² footprint)
- 250m² Bio-retention basin at BR02 (approximate 500m² footprint)
- 1250m² Bio-retention basin at BR03 (approximate 2000m² footprint – incorporated into detention asset)
- 2xHumeguard Gross Pollutant Traps

The water quality benefits of 2kL tanks on all lots over 300m² have also been included in the modelling.

8.3.4 Passive Treatment Option.

Analysis was undertaken to assess the required footprints if passive treatments, in the form of large waterbodies such as a constructed wetland, were used instead of Bio-filters. The findings of the analysis are summarised below.

Table 26 Passive Treatment Indicative Sizes

Pre-developed Assumption	Re-vegetated Site	Re-vegetated Site	Agricultural Site	Agricultural Site
(BR03) Eastern Lobe	500m² sediment basin 19,000m² wetland	500m² sediment basin 25,000m² wetland	500m² sediment basin 1,200m² wetland	500m² sediment basin 2,500m² wetland
NorBE Outcome	NorBE	NorBE+10%	NorBE	NorBE+10%

Commentary relating to the above analysis is listed below.

- The feeding catchment is not fit for purpose for a wetland when broken into sub-catchments. A singular end of line asset would have to be proposed.
- A wetland of close to 2ha in area is not feasible for a feeding catchment of 8.31ha. The wetland would be subject to drying and plants would not survive.
  - Re-vegetated nodes are not producing reasonable results for water quality within the scenario.
  - These assets would not fit within the detention footprint and/or the 'eastern lobe' (BR03).
- With agricultural nodes, the site's treatment requirements can be serviced within the 'eastern lobe' location (BR03) with an appropriate and feasible wetland.

8.3.5 Treatment Option Summary

The above optioning can be summarised by the following.

- The current masterplan, allocating 600m² at BR01 and 500m² at BR02 is more than adequate to satisfy the NorBE, if agricultural nodes are used for predevelopment.
  - The above exceeds NorBE requirements by a minimum of 33% for all pollutants.
- If Council chooses to designate re-vegetated nodes for predevelopment conditions, the masterplan has adequate room within the location BR03 to satisfy the NorBE and NorBE +10%.
  - Connecting the developed catchment to BR03 would require separate infrastructure underneath Dairy Creek Road to separate loading from external catchments.
  - It should be noted that the assessment of land-use, which included assessing the zoning and physically walking the site indicated the land-use was strictly agricultural.
- There is adequate room within the detention basin to satisfy the NorBE and NorBE +10% if passive treatments are required, if agricultural nodes are used to assess predevelopment conditions.
- A wetland becomes counterproductive / unfeasible if re-vegetated nodes are required to assess predeveloped conditions.

Council should be confident the current masterplan can service the water quality requirements of the site.

9 Conclusion and Recommendations

This Water Cycle Management Strategy Report details the high-level assessments that were undertaken for Water Quality, Water Quantity and Flooding for the Redmond Place Rezoning application.

The analysis provided preliminary sizing and locations of proposed water quality treatment train features. The water quality management strategy was developed and modelled in MUSIC, which confirmed that dual bioretention basins were adequate to meet water quality targets. The Orange City Council Subdivision Code (2024) was used to set the treatment targets for the site. The treatment asset sizes are listed below.

- A 2630m² Open Water Body Pond (WL01)
- 300m² Bio-retention basin at BR01 with incorporated 71m² Sediment Forebay (approximate 600m² footprint)
- 250m² Bio-retention basin at BR02 with incorporated 68m² Sediment Forebay (approximate 500m² footprint)
- 2xHumeguard Gross Pollutant Traps

Detailed optioning was undertaken to ensure the masterplan had adequate space allocation for treatment assets under different scenarios. The above optioning can be summarised by the following.

- The current masterplan, allocating 600m² at BR01 and 500m² at BR02 is more than adequate to satisfy the NorBE, if agricultural nodes are used for predevelopment.
  - The above exceeds NorBE requirements by a minimum of 33% for all pollutants.
- If Council chooses to designate re-vegetated nodes for predevelopment conditions, the masterplan has adequate room within the location BR03 to satisfy the NorBE and NorBE +10%.
  - Connecting the developed catchment to BR03 would require separate infrastructure underneath Dairy Creek Road to separate loading from external catchments.
  - It should be noted that the assessment of land-use, which included assessing the zoning and physically walking the site indicated the land-use was strictly agricultural.
- There is adequate room within the detention basin to satisfy the NorBE and NorBE +10% if passive treatments are required, if agricultural nodes are used to assess predevelopment conditions.
- A wetland becomes counterproductive / unfeasible if re-vegetated nodes are required to assess predeveloped conditions.

Council should be confident the current masterplan can service the water quality requirements of the site.

Flood modelling was undertaken utilising the industry standard software TUFLOW, flood behaviour is described, and flood maps are provided within the appendices. The results of the flooding analysis demonstrates that there are minimal offsite impacts due to the proposed Zoning Plan and changes in flood behaviour within the site that could easily be mitigated through the incorporation of underground drainage network at a later stage. All development lots will be located above the 1% AEP flood level. PMF flood modelling was not undertaken for the Planning Proposal and will be undertaken at DA stage to assess evacuation constraints and address Emergency Management Planning.

An on-site detention basin was sized based using a detailed hydrological model using RORB software. To restrict the site discharge to the predevelopment rate, a 14,900m³ detention basin is proposed, which was validated using the hydraulic model, providing confidence the impact of development is mitigated.

The findings of this report support the proposed rezoning application with further analysis and detail proposed at DA stage to confirm and refine these findings.

APPENDIX A

A.1. Water Cycle Management Concept

On behalf of

0 25 50 75 100 125 m

1:3,500

Project Title	Redmond Place, Orange	Date	18/06/2024
Project Number	568-23	Drawn By	C.Cosgriff
Drawing Title	Stormwater Management Plan Concept	Checked By	J.Barker

APPENDIX B

B.1. Development Masterplan and Staging Plan

5.1 Master Plan

Legend

1	Homemaker precinct
2	Northern Entry Street
3	Existing picnic shelter and toilet block
4	Hangar building
5	Northern park
6	Central park
7	Stormwater basins
8	Southern entry street
9	Drainage swale
10	Wetland
11	Pump station
●	Open Space
●	Low Density Lots
●	Medium Density Lots
●	Low Rise Apartments
– –	Site Boundary

5.5 Staging

Water Sensitive Urban Design

Legend

◯	Bioretention basins
●	Standing water (wetland)
◯	Storm water swale
◯	Detention basin
– –	Site Boundary

APPENDIX C

Appendix C. RORB Catchment Data

Colliers

Disclaimer: All GIS information is indicative and should be confirmed

On behalf of

LANDCOM

0 100 200 300 400 500 m

1:15,000

Project Title	Redmond Place, Orange	Date	18/06/2024
Project Number	568-23	Drawn By	C.Cosgriff
Drawing Title	RORB Model - Existing Conditions	Checked By	J.Barker

N

Colliers

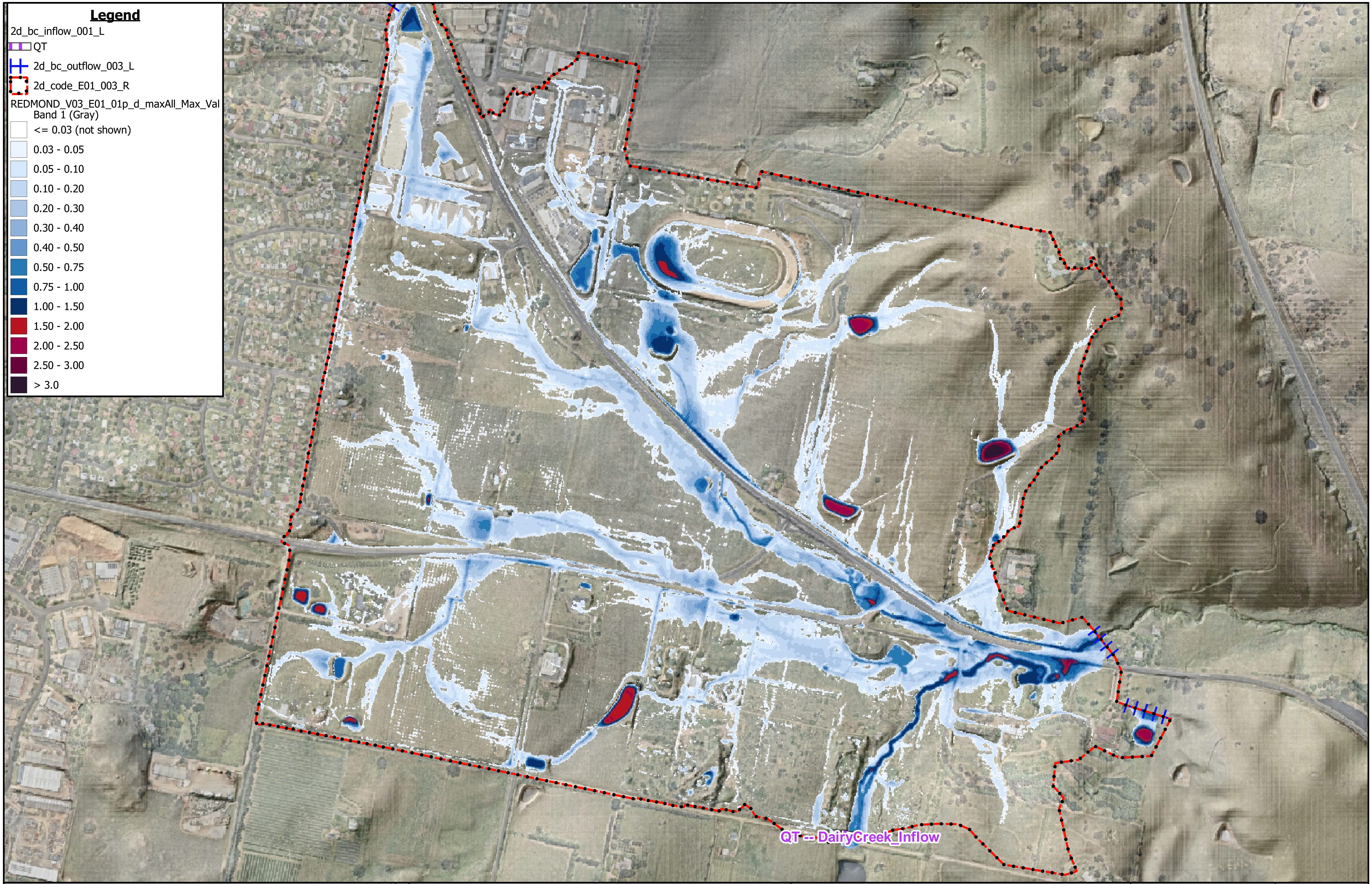
On behalf of

LANDCOM

Project Title	Redmond Place, Orange	Date	18/06/2024
Project Number	568-23	Drawn By	C.Cosgriff
Drawing Title	RORB Model - Developed Conditions	Checked By	J.Barker

APPENDIX D

Appendix D. Flood Mapping



Colliers

Disclaimer: All GIS information is indicative and should be confirmed

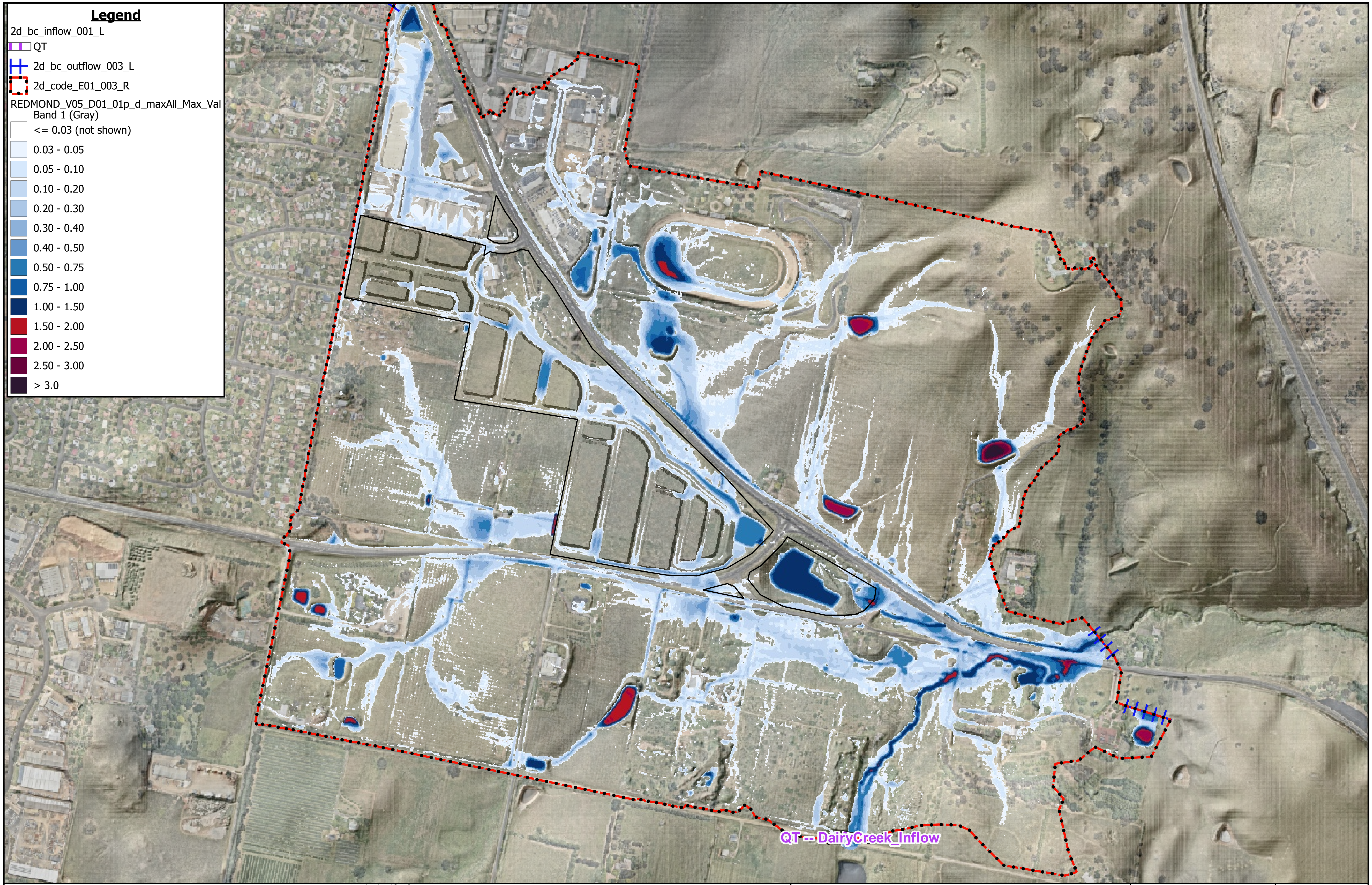
On behalf of

LANDCOM

0 50 100 150 200 250 m

1:6,500

Redmond Place, Orange	Date 30/05/2024
568-23	Drawn By C.Cosgriff
1% AEP Flood Depths - Existing Scenario	Checked By J.Barker



Colliers

Disclaimer: All GIS information is indicative and should be confirmed

On behalf of

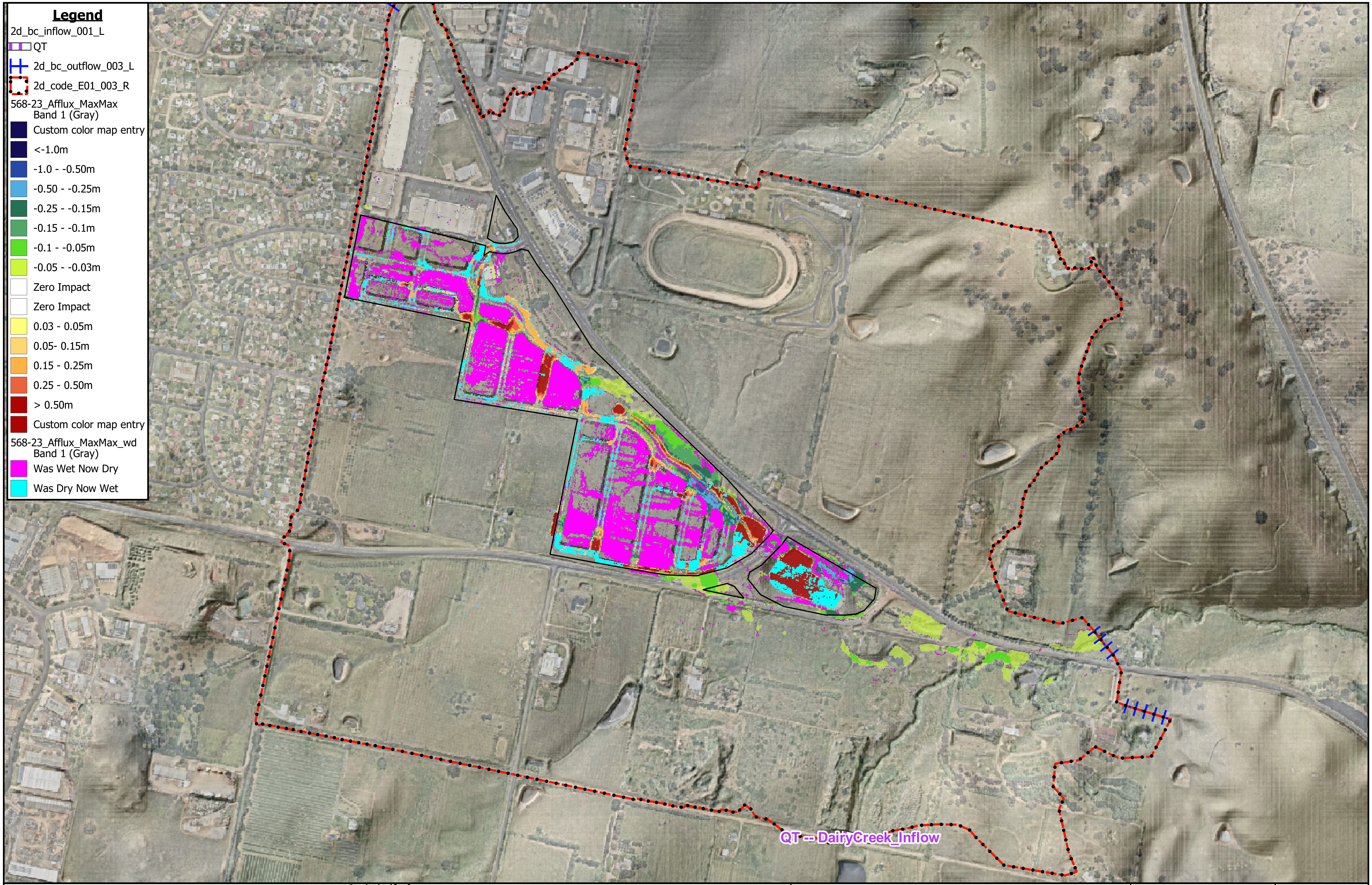
LANDCOM

0 50 100 150 200 250 m

1:6,500

Redmond Place, Orange	Date 30/05/2024
568-23	Drawn By C.Cosgriff
1% AEP Flood Depths - Existing Scenario	Checked By J.Barker

N



Colliers

Disclaimer: All GIS information is indicative and should be confirmed

On behalf of LANDCOM

Redmond Place, Orange	Date 30/05/2024
568-23	Drawn By C.Cosgriff
1% AEP Flood Depths - Existing Scenario	Checked By J.Barker