MOREE SPECIAL ACTIVATION PRECINCT

Flooding and Water Cycle Management Report

09 APRIL 2021

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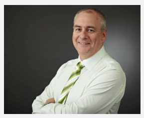

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NSW DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT (DPIE) MOREE SAP

Flooding and Water Cycle Management Report

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CONTENTS

APPENDICES

FIGURES

TABLES

1 INTRODUCTION

On 3 December 2019, the NSW Government declared Moree a Special Activation Precinct (SAP) investigation area to be delivered by the $4.2 billion Snowy Hydro Legacy Fund.

With a renowned, Australia-wide reputation and heritage of agriculture and farming, this SAP places the Moree region as the highest productive grain region in the country, capitalising on existing road and air freight, and the future Inland Rail.

The NSW Department of Planning, Industry and Environment (DPIE) is leading the master planning process of the SAP. Accordingly, DPIE has engaged Arcadis Australia Pacific (Arcadis) to prepare a series of flooding and water cycle management studies, including a Flooding and Water Cycle Management Report (this report) for the Moree SAP, which incorporates an assessment of flood behaviour and a strategy for water cycle management to help inform the Master Plan.

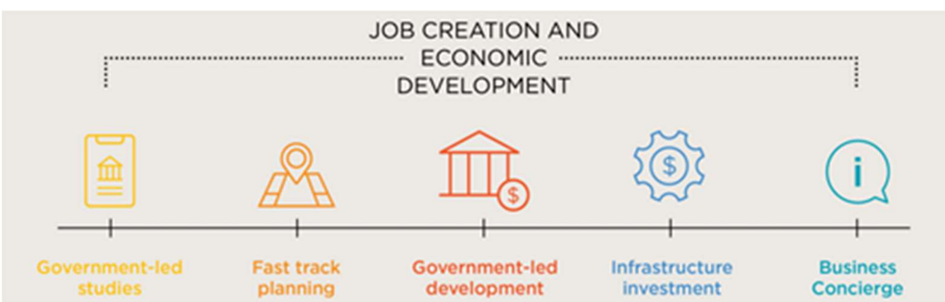
Two Enquiry by Design (EbD) workshops were organised as part of the SAP master planning process. A preliminary EbD was held on the 14 and 15 September 2020 to develop three initial land use scenarios. Following an interdisciplinary assessment of the three scenarios, a Final EbD workshop was held between 17 and 20 November 2020 to study the interdisciplinary constraints of the three scenarios, and identify and develop a final preferred land use structure plan.

This report assesses the flooding and water cycle management aspects associated with the land use Structure Plan developed from the final EbD workshop.

1.1 Moree Special Activation Precinct

The establishment of SAPs is a joint Government Agency initiative by the DPIE and the Regional Growth NSW Development Corporation (RGDC) as part of the *20-Year Economic Vision* for Regional NSW. SAPs are a new way of planning and delivering infrastructure projects in strategic regional locations in NSW to 'activate' State or regionally significant economic development and jobs creation. They will be delivered as part of the $4.2 billion Snowy Hydro Legacy Fund.

Job creation and economic development through SAPs are underpinned by five core components (Figure 1), which make up the SAP process (Table 1).



Source: NSW Government, 2019

Figure 1 SAP key elements

Table 1 SAP process

COMPONENT	DESCRIPTION
Government led studies	DPIE conducts technical studies to inform the development of the Master Plan and to ensure land uses and development occurs in the right locations for each precinct. This up-front planning takes the burden away from investors wanting to grow or start up a business in the precincts.
Fast track planning	Once the Master Plan and other supporting planning instruments are endorsed, this will provide investors with streamlined planning and environmental approvals. This may include providing for land uses that suit complying development or approval exemptions.
Government led development	The Regional Growth NSW Development Corporation will lead and coordinate the delivery, through Delivery Plans according to the Master Plan for each precinct, that supports orderly development, sensitive to market drivers, landowners and infrastructure delivery.
Infrastructure Development	Government will invest in new or upgrade roads, water, power, digital connectivity and social infrastructure for each precinct, removing barriers for investors to establish and grow.
Business Concierge	The Regional Growth NSW Development Corporation offers targeted business concierge services to attract investment and support businesses to establish growth in each precinct.

Source: NSW Government, 2019

Moree was chosen as it has a rich agricultural tradition dating back to the establishment of the initial pastoral land more than 150 years ago. There have been several step changes since, with the introduction of wheat and pecan nuts in the 1960s and cotton in the 1970s.

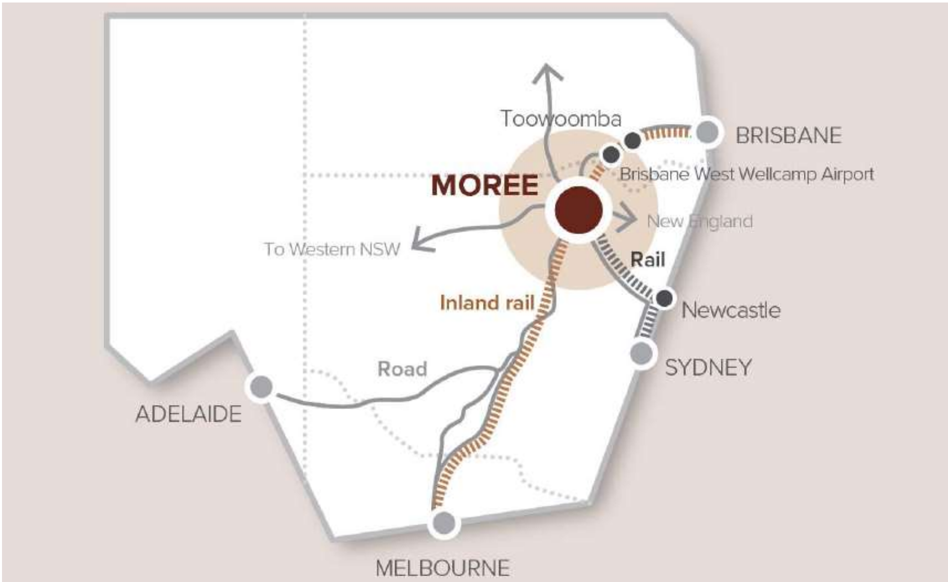
Moree is well placed in the freight network to be an intermodal freight hub as it is intersected by the Newell, Carnarvon and Gwydir Highways in addition to being located on the Inland Rail.

Moree SAP objectives include:

- Increasing the volume of freight mode shift to rail
- Enabling a broader cluster of freight and logistics-related activity
- Making Moree an attractive precinct for value-adding agribusiness
- Enabling businesses to establish on appropriate sites that would benefit from efficient access to freight and logistics networks
- Enabling businesses to establish that require access to a high quality and secure water supply
- Providing increased economic and enhanced social outcomes for the broader community with a focus on the local Indigenous population.

*The completion of Inland Rail, expected by 2025, has the potential to dramatically improve the efficiency of freight transport between Moree and key seaports, as well as large population centres (*Source: NSW Government 2019

Figure 2). Moree is located on the Narrabri and North Star (N2NS) section and would provide more immediate freight savings.



Source: NSW Government 2019

Figure 2 Moree transport connectivity

The presence of Inland Rail combined with the existing assets that Moree offers would enable for a more diverse range of industries to be established and for the Moree economy to be more productive and more resilient. Freight movements are primarily focused to the port of Newcastle with other movements to Port Botany and Port Kembla. Inland Rail would also enable access to Brisbane Port and other northern markets for bulk and containerised freight. The Moree SAP provides an innovative and effective program to capitalise on this potential.

1.1.1 Location of Moree SAP

Moree Plains Shire is located approximately 640km northwest of Sydney in the Gwydir River and McIntyre River valleys in north-western New South Wales. The Shire covers an area of approximately 17,930km^2 and according to 2016 Census data has a population of 13,429.

Moree itself is Moree Plains Shire's largest centre with a population of approximately 9,400, and an Indigenous resident population making up 21.6% of the total Moree population. Moree Plains has long been the ancestral home of the Gamilaroi people who, as traditional custodians, are members of the second largest Indigenous group in Australia.

The investigation area for the Moree SAP, is depicted by the red line boundary shown in Figure 3 encompassing an area of approximately 5,880ha. This investigation area has been used to scope all technical studies, including this Flooding and Water Cycle Management study for the Moree SAP.

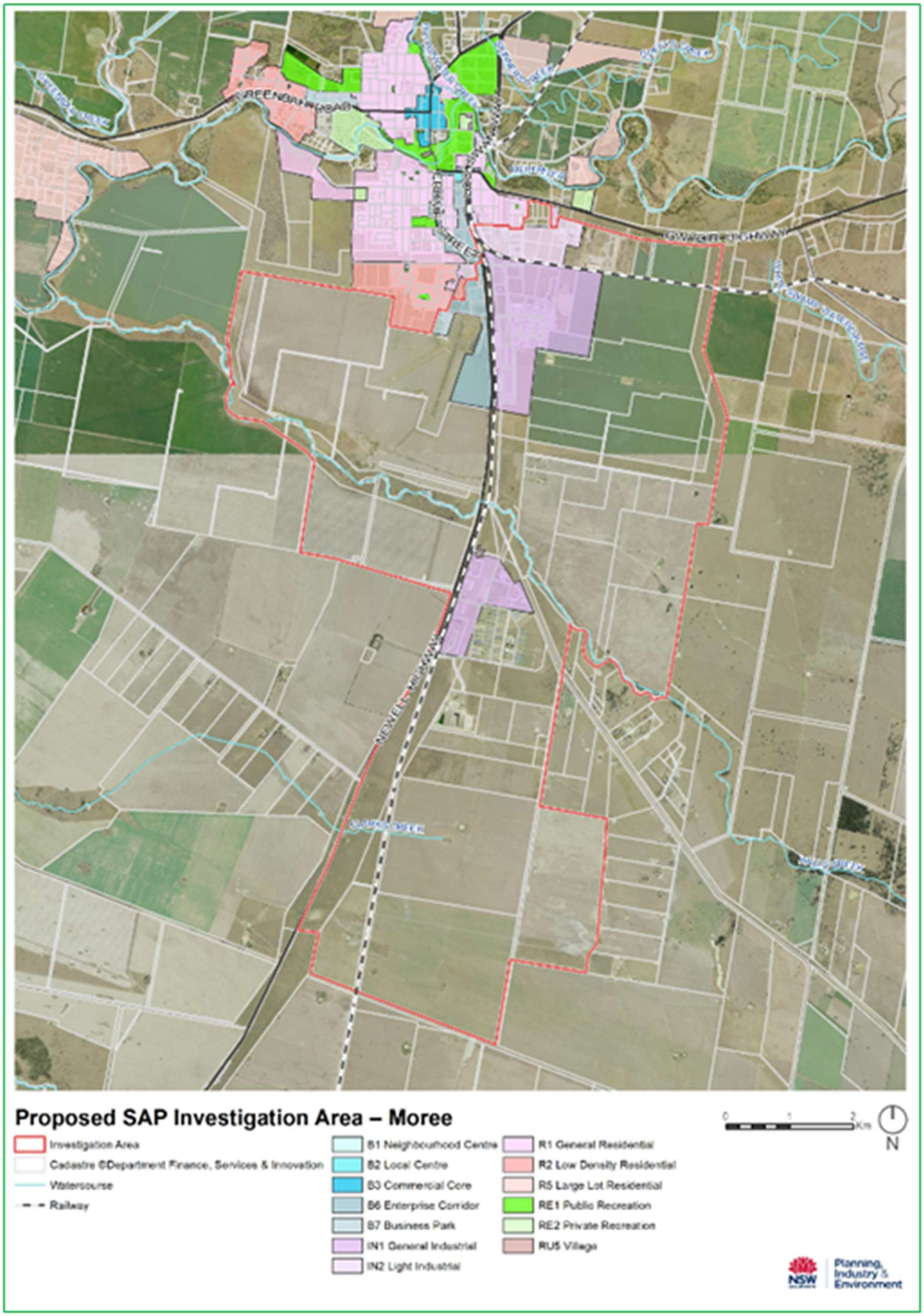
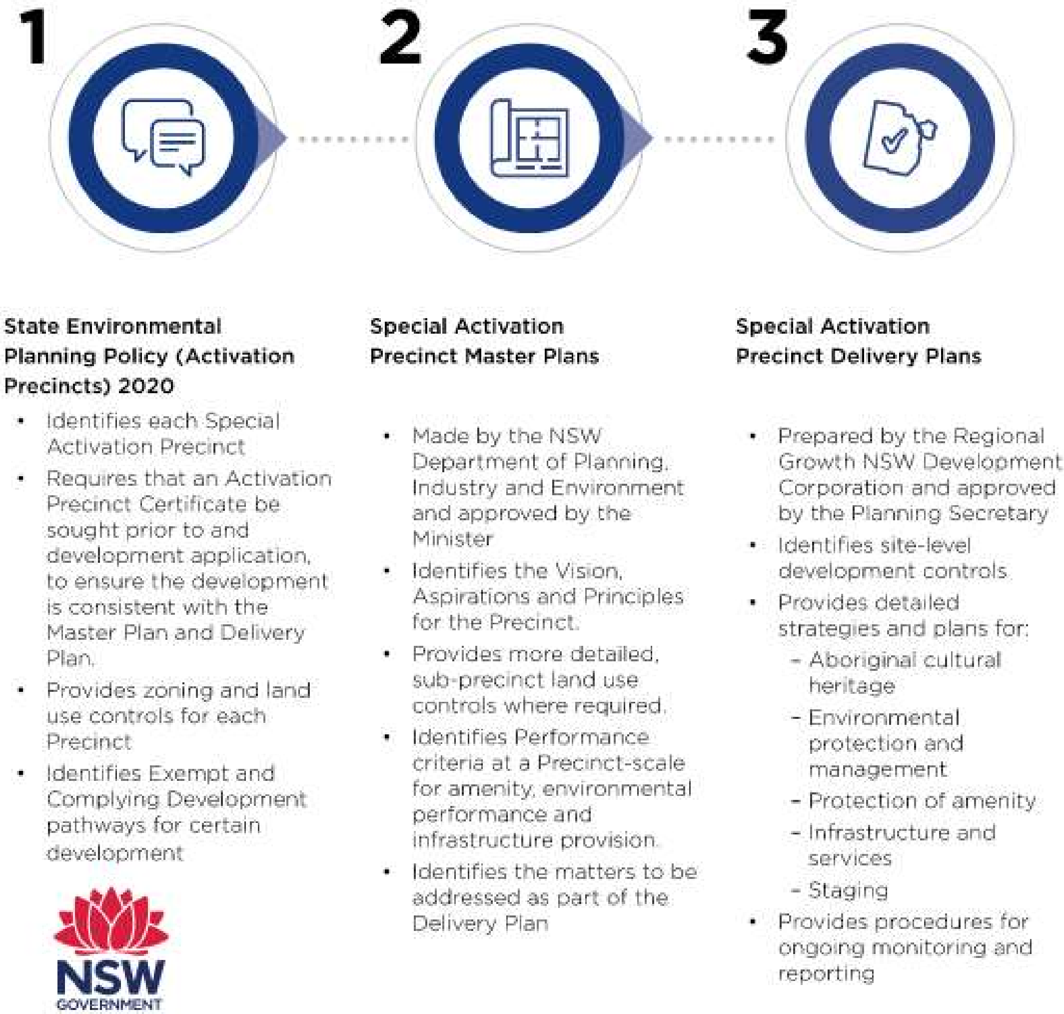


Figure 3 Moree Special Activation Precinct investigation area

1.2 Planning Framework

The new State Environmental Planning Policy (Activation Precincts) 2020 (SEPP) under *the Environmental Planning and Assessment Act 1979 (NSW)* sets the planning framework through which SAPs are being delivered. The statutory component of the policy framework contains a Master Plan and Delivery Plan for each SAP and these documents are given statutory weight by the SEPP (Figure 4).



Source: NSW Government, 2019

Figure 4 SEPP and SAP Plan inter-relationship

1.3 SAP master planning process

This Flooding and Water Cycle Management report is part of a wider strategic, statutory and regulatory process which has been outlined by DPIE in order to achieve the outcomes for the Moree SAP project as shown in Figure 5.

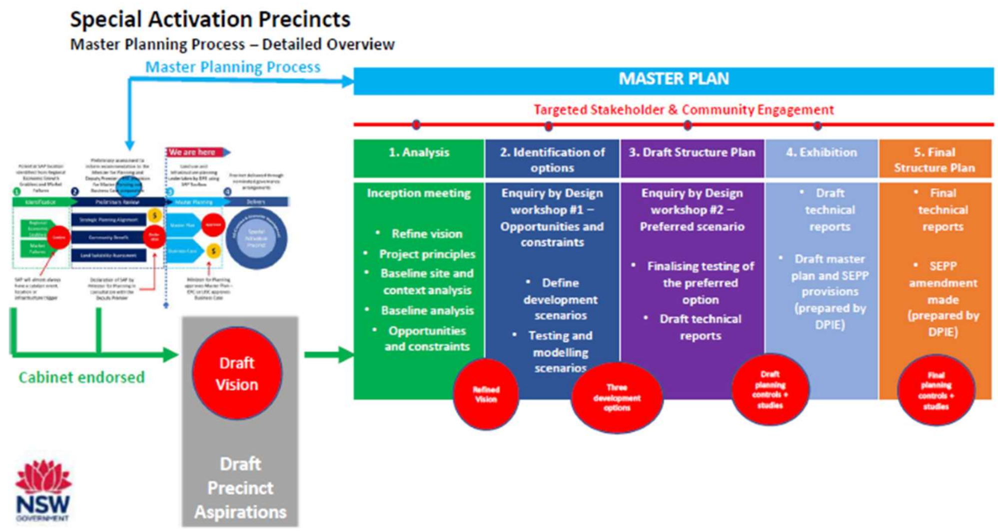


Figure 5 Special Activation Precinct Master Planning Process

1.4 Project methodology and timeline

The methodology adopted for the Structure Plan assessment included undertaking a series of flood and water cycle management studies for the Moree SAP investigation area and these have been documented in a Baseline Analysis Report and Scenario Testing Report. Along the way this process has been was guided and informed by the following two Enquiry by Design (EbD) workshops, a planning tool used to allow for key stakeholders to collaborate on the development of a vision for the Moree SAP:

- Preliminary EbD workshop – to develop three initial land use scenarios, which would then be further developed in an interdisciplinary assessment
- Final EbD workshop – to study the interdisciplinary constraints and opportunities of each scenario and develop a final land use Structure Plan based on the assessment.
- The main participants in the workshops were:
- DPIE
- Regional Growth NSW Development Corporation (RGDC)
- Moree Shire Plains Council (MPSC)
- Technical consultants
- State agencies, including Transport for NSW (TfNSW)
- Australian Rail Track Operation (ARTC) - Final EbD only.

The use of the EbD workshop process has enabled the development of the Master Plan scenarios; established the interdisciplinary understanding of their constraints and opportunities; and progressed the agreement on the Final Structure Plan.

This report assesses the land use Structure Plan from the Final EbD workshop from a flooding and water cycle management perspective and would be used as input to the Draft Master Plan.

shows the timeline of the Moree SAP project from commencement to completion of the Final Master Plan.

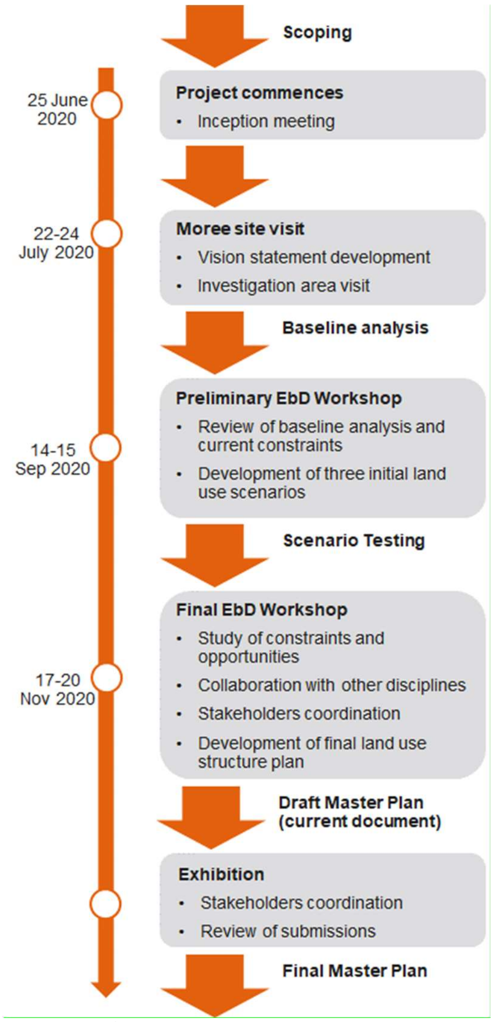


Figure 6 - SAP methodology and timeline

1.5 Report purpose

This Flooding and Water Cycle Management Report provides a summary of strategic context pertaining to the flooding and water cycle management situation in relation to the Moree SAP. It also provides a basis to help inform a streamlined planning process for fast-tracking future development of the SAP by identifying associated opportunities and constraints for the Moree SAP.

This report:

- Analyses the current state of Flooding and Water Cycle Management in the Moree SAP
- Provides details of existing flood behaviour in and around the Moree SAP site area
- Assesses the potential water quality issues associated with development of the Moree SAP
- Identifies potential flood constraints and/or building controls influencing the future development of the Moree SAP
- Broadly identifies various opportunities for stormwater re-use.

In addition to summarising the existing flood information already available for Moree and surrounding areas, further flood modelling has also been initiated specifically for the SAP. It should be noted that this overall assessment is considered to be sufficient for the purposes of informing the strategic Master Plan but further refinement of the modelling and results may be required as implementation of development progresses.

2 STRATEGIC CONTEXT

2.1 NSW State Government

2.1.1 Water Management Act 2000

The main piece of legislation for the management of water within NSW is the *Water Management Act 2000*. The provisions of this Act are being progressively implemented to replace the requirements of the previous *Water Act 1912*. The purpose of these Acts is to control the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in NSW.

Development on floodplains is managed under part 8 of the *Water Act 1912* which provisions for "controlled works" defined as works that affect, or are likely to affect, flooding and/or floodplain functions.

Following the introduction of the *Water Management Act 2000*, water sharing plans have been developed to preserve water resources in river and groundwater systems for the future. These plans establish rules for sharing water between the environmental needs of the river or aquifer and water users (for town and rural domestic water supply, industry, irrigation and stock watering). Water sharing plans specific to the Gwydir include:

- Gwydir Regulated River Water Sources
- Gwydir Unregulated and Alluvial Water Sources
- Lower Gwydir Groundwater Sources.

2.1.2 NSW Government Flood Prone Land Policy

The NSW Government's Flood Prone Land Policy provides a framework for managing development on the floodplain. The primary objective of the policy is to develop sustainable strategies for managing human occupation and use of the floodplain using risk management principles. Under the Policy, the management of flood liable land remains the responsibility of local Government but the State Government provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The NSW Government's Floodplain Development Manual (2005) (the Manual) has been prepared to support the NSW Government's Flood Prone Land Policy and provides councils with a framework for implementing the policy to achieve the required objectives. An outline of the policy framework is shown in Figure 7.

Moree Plains Shire Council (MPSC) has recently completed and adopted the background flood investigations and preparation of a Floodplain Risk Management Plan (refer Section 2.2.1). As part of the ongoing floodplain risk management process and following on from these studies, the Moree Plains Shire Floodplain Management Committee was formed in May 2018. The role of the Committee is to assist MPSC in the final phase of development and implementation of proposed works and measures to manage the flood prone lands of Moree and surrounds.

2.1.3 Gwydir Valley Floodplain Management Plan

The Gwydir Valley Floodplain Management Plan was prepared by the DPIE and commenced on 12 August 2016. The Plan includes management zones, rules and assessment criteria for granting or amending approvals for flood works within the plan area. Parts of the Moree SAP fall within the domains of Gwydir Valley Management Zones A, B and C as indicated in Figure 8.

The rules applicable within each zone vary and are provided to prevent a flood work approval from being granted where works or development on the floodplain may result in ecologic, cultural or hydraulic impacts greater than pre-defined assessment criteria.

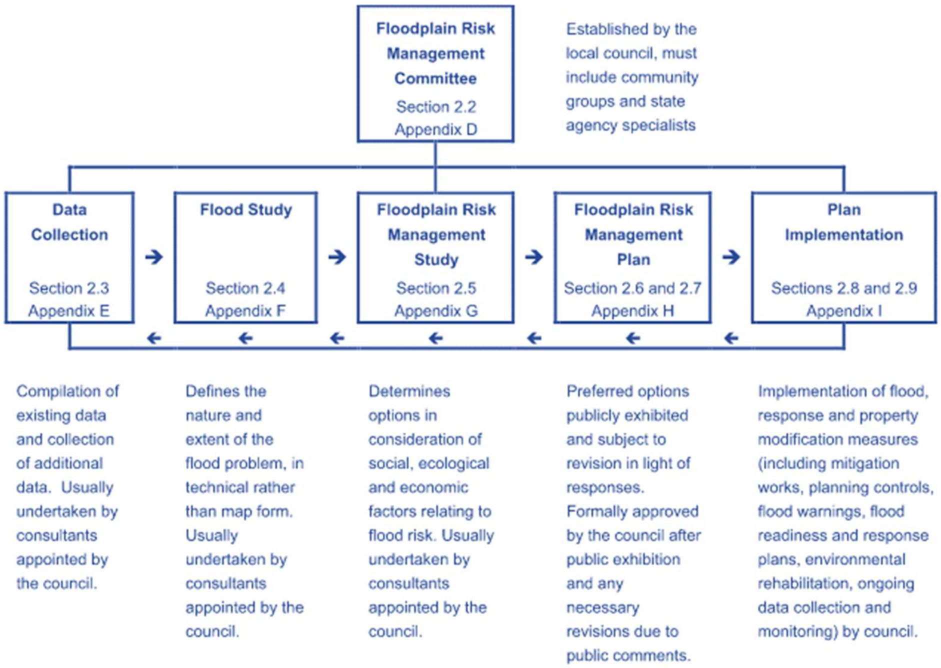


Figure 7 NSW government floodplain risk management process

Source: NSW DPIE website

Figure 8 Gwydir FMP Management Zones

2.2 Moree Plains Shire Council

2.2.1 Floodplain Management

Over the years, a number of flood and floodplain management studies have been undertaken for the Moree area. A brief timeline history for these studies is outlined below:

- 1983 – Moree/Pallamallawa Floodplain Management Studies, Cameron McNamara Consultants
- 1993 - Moree Flood Study, Patterson Consultants
- 1995 – Moree and Environs Floodplain Management Study: Final Report, Patterson Consultants
- 2003 – Gwydir River – Biniguy to Moree Hydraulic Modelling Study: Final Report, Patterson Consultants
- 2008 - Moree and Environs Floodplain Risk Management Plan, Parsons Brinkerhoff
- 2015 – Background document to the floodplain management plan for the Gwydir Valley Floodplain, DPI Water
- 2016 – Floodplain Management Plan for the Gwydir Valley Floodplain, DPI Water
- 2017 - Inland Rail - Narrabri to North Star - Hydrology and Flooding Assessment, GHD/ARTC
- 2017 – Review of Moree and Environs Flood Study/Floodplain Risk Management Study and Plan (3 Volumes), WRM Water & Environment.

The flood and floodplain risk management studies and plan undertaken by WRM in 2017 present the most recent and up to date flood related information for Moree and immediate surrounds. The studies, which have been adopted by MPSC (Plan endorsed May 2019), include calibrated hydrologic and hydraulic models providing detailed information and mapping of flood levels and extents, flows, velocities and hazard categories for the main Gwydir-Mehi floodplain areas.

2.2.2 Local Environmental Plan

The *Moree Plains Local Environmental Plan2011* (LEP) guides planning decisions for the Moree Plains Local Government Area through zoning and development controls, providing the framework for the way in which land in different areas can be used. The LEP also contains additional local provisions with respect to flood planning and development of flood prone lands (Clause 7.6). The applicable building and development controls are defined separately within the associated Moree Plains Development Control Plan 2013.

2.2.3 Development Control Plan

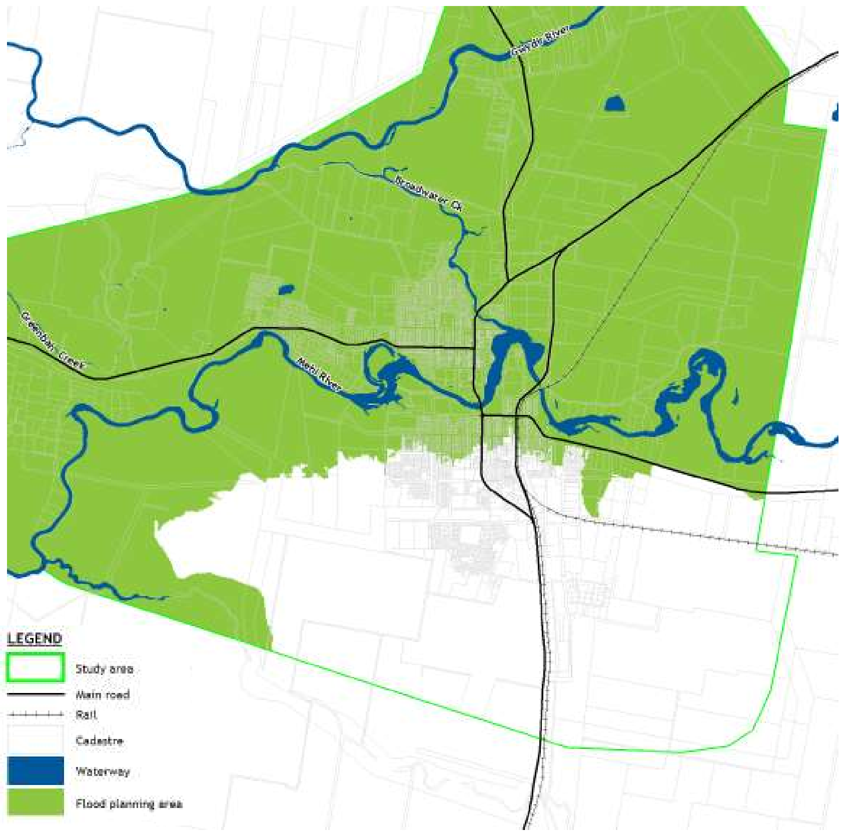
The Development Control Plan (DCP) is the primary instrument used by councils in managing development on the floodplain to ensure it is compatible with the local flood conditions and situation. Flood related building and development controls for flood prone lands in the Moree Plains area have been identified and developed in accordance with the ongoing floodplain management process (refer Section 2.2.1) and are defined in the Moree Plains DCP.

The current Moree Plains DCP 2013 came into effect in April 2013. This DCP was developed based on the flood related information and outcomes available from the earlier Moree and Environs Flood Risk Management Plan (2008).

A recommendation from the more recent Floodplain Risk Management Plan (2017) is to update the development controls for flood prone land and also update the associated DCP and LEP policies utilising the latest flood modelling results. Council has recently engaged Dryside Engineering supported by Water Modelling Solutions to undertake the “Moree Feasibility Study of Flood Risk Management Plan Recommended Options” which is a 12-month project that includes updating the DCP and LEP and related policies.

2.2.4 Flood Planning Levels

Consistent with recommendations of the Manual (NSW Government 2005), MPSC has adopted the 1% AEP flood event plus 0.5m freeboard for Flood Planning Levels (FPL) applicable to the Moree area. The extent of the flood planning area based on the FPLs derived by the most recent flood modelling (WRM 2017) is shown in Figure 9. Pending further updated modelling, as outlined in the Floodplain Risk Management Plan, the flood planning area defined by these levels is then recommended to be incorporated into the Moree Plains DCP.



Source: WRM, 2017

Figure 9 Moree flood planning area

3 EXISTING CONDITIONS

3.1 Available studies and data

3.1.1 Previous studies

As outlined in Section 2.2.1, there have been numerous flood and floodplain management studies undertaken over the years. Generally speaking, nearly all of these studies have involved some form of flood modelling or assessment to help define flood behaviour for the Gwydir-Mehi floodplain. Typically, each study has reviewed and considered the information contained in the previous studies with the aim of improving on the overall understanding and definition of flood levels and extent.

Therefore, the models recently established and used for the Moree and Environs studies (WRM, 2017) and also the Inland Rail Narrabri to North Star EIS are of most relevance to the current study. In the absence of more detailed information or flood models covering the Moree SAP itself (currently under development), the majority of results and information referred to in this report are based on the Moree and Environs studies undertaken for MPSC. A brief mention of the Inland Rail investigations is included in Section 3.1.2.

3.1.2 Inland Rail - Narrabri to North Star, ARTC/GHD 2017

As part of the overall programme to provide an upgraded inland rail connection between Melbourne and Brisbane, this particular proposal relates to the 188km section from Narrabri to North Star via Moree. From a flooding perspective, one of the target performance objectives of the Inland Rail upgrade project is to achieve a flood immunity for the 1% AEP event by providing waterway structures with 1% AEP conveyance capacity in conjunction with raising of the rail line where necessary and appropriate. Once the upgrade works are complete, this should help to maintain the regional rail links to the north and south of Moree. However, the report notes that the line could well be overtopped by up to 0.37m adjacent to Burrington Road south of Moree within the SAP.

3.2 Catchments and flood characteristics

The town of Moree is situated on the Mehi River, an effluent stream of the Gwydir River. The Gwydir-Mehi floodplain at Moree extends some 15km north from the Mehi River to Marshall Ponds. There are numerous interconnected river channels and overland flow paths extending from the Biniguy breakout, approximately 50km upstream of Moree, to Moree and beyond.

The Gwydir-Mehi River system draining through Moree has a catchment area of 13,320 km^2 and a long flood history with reports dating back to the mid-1800s and official records commencing around 1890. Numerous floods have occurred over the years with February 1955 the highest event on record and similar major flood events experienced in 1976 and more recently in 2011 and 2012.

Flooding in Moree is largely dependent on the peak flow (discharge) in the Gwydir River, the occurrence and duration of breakouts overtopping the Gwydir River banks and runoff from tributary creeks and local catchments draining to the Mehi River. Only a small portion of north Moree is considered to be flood free in the 1% AEP event but most of south Moree, including the SAP site area, is above the estimated mainstream flood levels (refer Figure 9).

While the SAP area is largely unaffected by flooding from the Gwydir-Mehi Rivers, the non-perennial Halls Creek traverses through the middle of the site draining east to west from around Burrington Road. Halls Creek, to just upstream of the Newell Highway, was modelled as part of the recent Moree and Environs Flood Study (Vol I WRM, 2017). However, the majority of the creek beyond approximately 3km upstream of the Mehi River junction, was outside the nominated study area and consequently a notable section of the creek which includes the Moree SAP was excluded from the mapped flood planning area. There is also another small non-perennial tributary watercourse, known as Clarks Creek, that originates near the southern boundary of the SAP. Both of these smaller watercourses generally contribute to local catchment flooding but could also potentially convey floodwaters originating from upstream catchments that breakout from Tycannah Creek during large flood events (refer Section 3.3.2.1 and 3.3.2.4 for further discussion).

3.3 Flood assessment

3.3.1 Background

A review of the existing flood information available for the SAP site was undertaken as part of the initial Baseline Analysis stage of these SAP investigations. While it was found that recent investigations for the main Gwydir-Mehi River catchments and associated floodplain around the Moree township had been undertaken, the level of detailed flood information and model representation of potential flood conditions for the SAP site were found to be limited. Additional flood models were therefore established to better represent flood behaviour applicable to the SAP site itself. The overall flood assessment and reporting is therefore covered in two components:

- Gwydir-Mehi – regional flood behaviour associated with the broader Gwydir-Mehi catchments
- SAP – local flood behaviour associated with the smaller local contributing catchments including Halls Creek and Clarks Creek.

3.3.2 Information and data used

3.3.2.1 Models and data overview

Flood models have been specifically created for the Moree SAP to supplement previous studies and to fill in data gaps. Previous studies for Moree focussed mainly on the major Gwydir-Mehi river systems north of the township, but with the proposed SAP area generally south of this area, the flood models established for the Moree SAP have focussed on the local creek systems either side of its boundary as well as the flow paths within it. These local creeks and watercourses are indicated in Figure 10 with the SAP boundary shown in yellow.

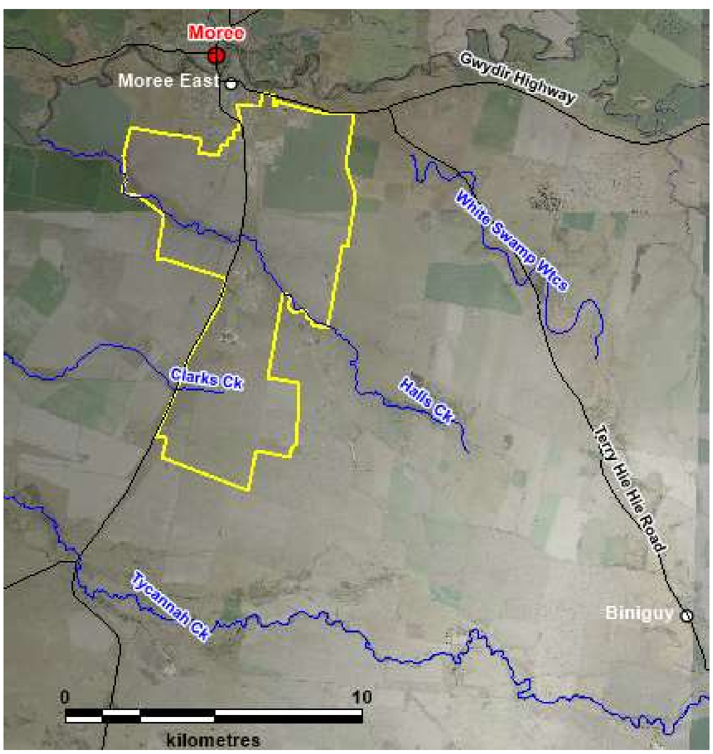


Figure 10 Local creeks affecting the Moree SAP

A specific focus of the Moree SAP flood models was to investigate the potential for large floods to breakout of the creek banks and deliver floodwater directly into the SAP. Inspection of the available ground survey data showed remnants of creek anabranches with this type of flood behaviour. Figure 11 shows examples of these historical flood breakout areas. The terrain data is based on 5m LiDAR available from the ELVIS portal as of July 2020. The catchment terrain is comprised of several LiDAR projects circa 2008 to 2012.

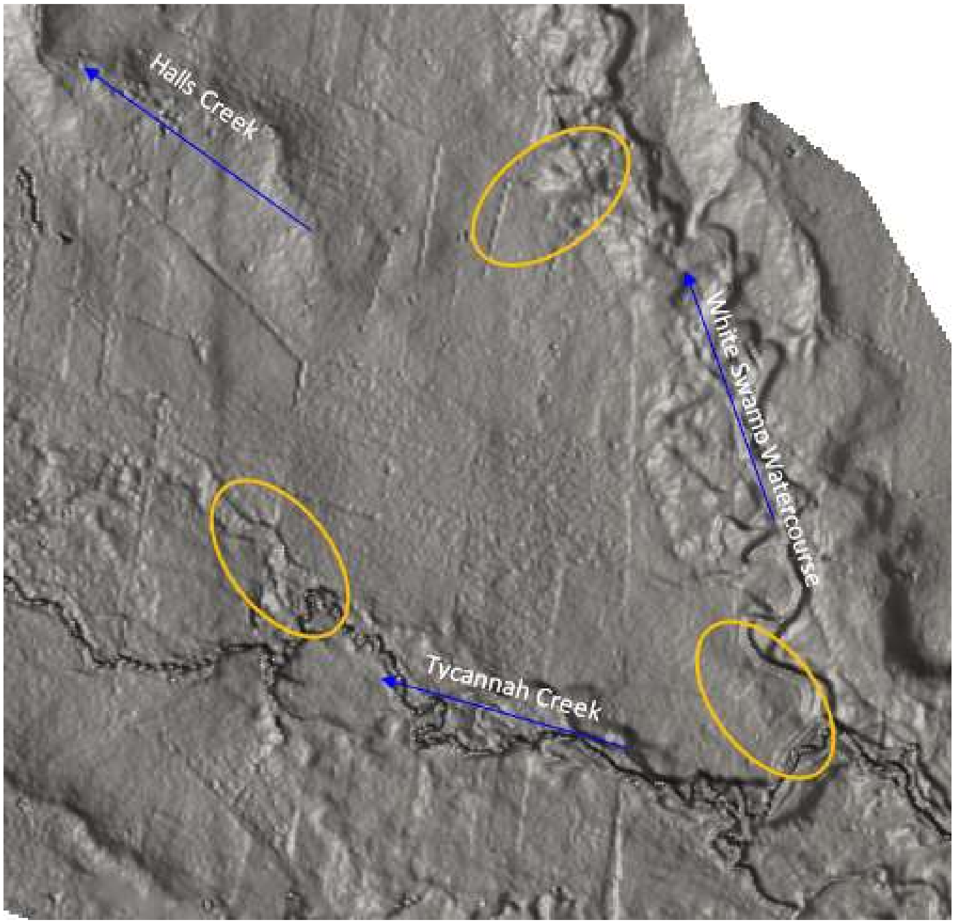


Figure 11 Terrain upstream of Moree SAP showing historical floodwater breakout locations

The terrain of the Moree SAP catchment area ranges from steep mountainous country, where erosion has scoured the landscape into many gullies, to flat terrain where eroded material has been deposited as floodwater slows and spreads widely across the floodplain. Regular flood events have carved low flow channels through this deposited material and it is within the overbank areas that the anabranches can be seen.

The Moree SAP flood models were configured to guide decisions on land use planning within the SAP and to explore the flood behaviour, particularly the potential for localised flooding to be increased by overbank inundation in the creeks upstream and surrounding the site. The focus for these investigations was not to produce a calibrated flood model but rather to explore the general flood behaviour surrounding and through the site in large flood events.

The modelled flood events were assessed using Australian Rainfall and Runoff 1987 (ARR 1987) data and methods to be consistent with the recently completed regional flood studies for the Gwydir-Mehi catchments. An envelope of 20 storm durations were combined to give an estimate of maximum flood levels at all locations in the vicinity of the site. Application of the updated ARR 2019 data and methodologies was not adopted for this study in the interests of satisfying the constrained project timeframes for delivery. The models established for the SAP involved reasonably long run times and the ARR2019 approach would have required an order of magnitude increase in the number of computer run simulations for each event frequency and duration. The overall increase in model run times would likely have taken many more weeks to run and process results making it impossible to complete the assessment and deliver to the tight project timeframes that were involved, particularly for the initial stages of the investigations. Overall, it is considered that the approach adopted has enabled the flood assessment to progress in accordance with the study timeframes and objectives whilst producing results that may be slightly conservative but consistent with existing studies and results for the area. A review of the model results produced suggests that the extent of flooding and general conclusions with respect to the area of development and potential for impacts would not be significantly different and possibly less.

The catchment area of the local creeks surrounding the site is relatively large. It is approximately 75km long and ranges in width from about 7km to 20km. The upper catchment is steep with many creek lines but moving downstream the catchment narrows with all flow paths joining. From this location the terrain flattens and the main Tycannah Creek splits into two. The southern flows form the downstream end of Tycannah Creek and the northern flows are the headwaters of White Swamp Watercourse. Figure 12 shows the terrain for the catchment with the boundary in red. The location of the watercourse convergence is indicated with a thick black line.

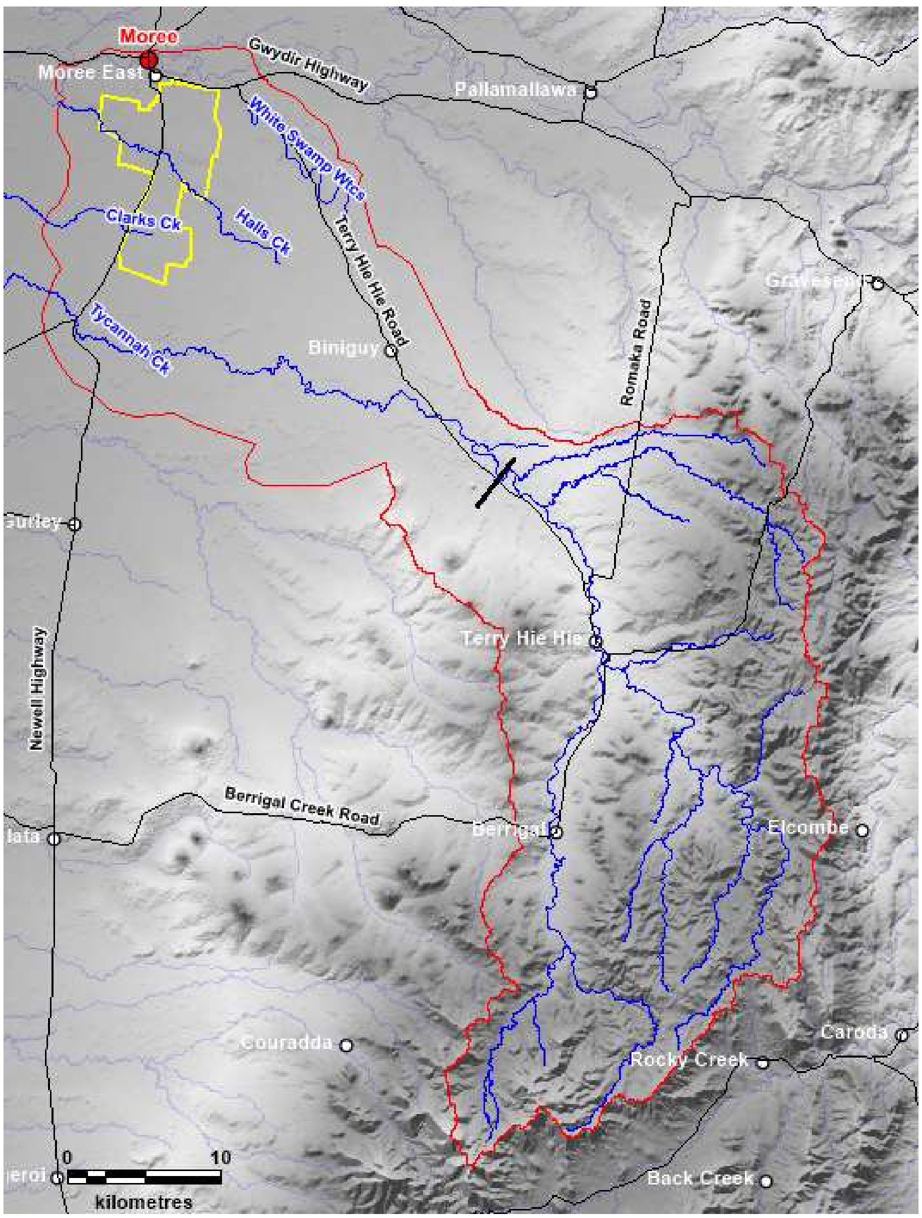


Figure 12 Terrain and creek lines of the Moree SAP local catchment

3.3.2.2 Moree SAP flood model setup and parameters

Due to the large size of the Moree SAP catchment, the flood modelling was split into two models; a total catchment hydrology model, and a lower catchment hydraulic model. Both models were created using the latest version (2020-01-AB) of the TUFLOW software package and applying rainfall-on-grid methods. The lower catchment model was of higher resolution (10m cell size compared to 50m for the total catchment model) and used an inflow hydrograph from the total catchment model taken at the location of the thick black line in Figure 12. Figure 13 presents an example output from the total catchment TUFLOW model for the 1% AEP. Note how the upper catchment flow paths converge mid-catchment and then diverge almost around the SAP. Also note that the flat terrain in the lower catchment creates opportunity for floodwater to breakout over the creek banks with some floodwater from Tycannah Creek passing through the SAP at its southern end. This type of flood behaviour with the potential for flows to diverge and/or breakout overland to exacerbate local catchment flood conditions really requires a two-dimensional flood modelling package that can account for upstream inflows as well as local catchment runoff. TUFLOW rainfall on grid approach is particularly suited to this purpose.

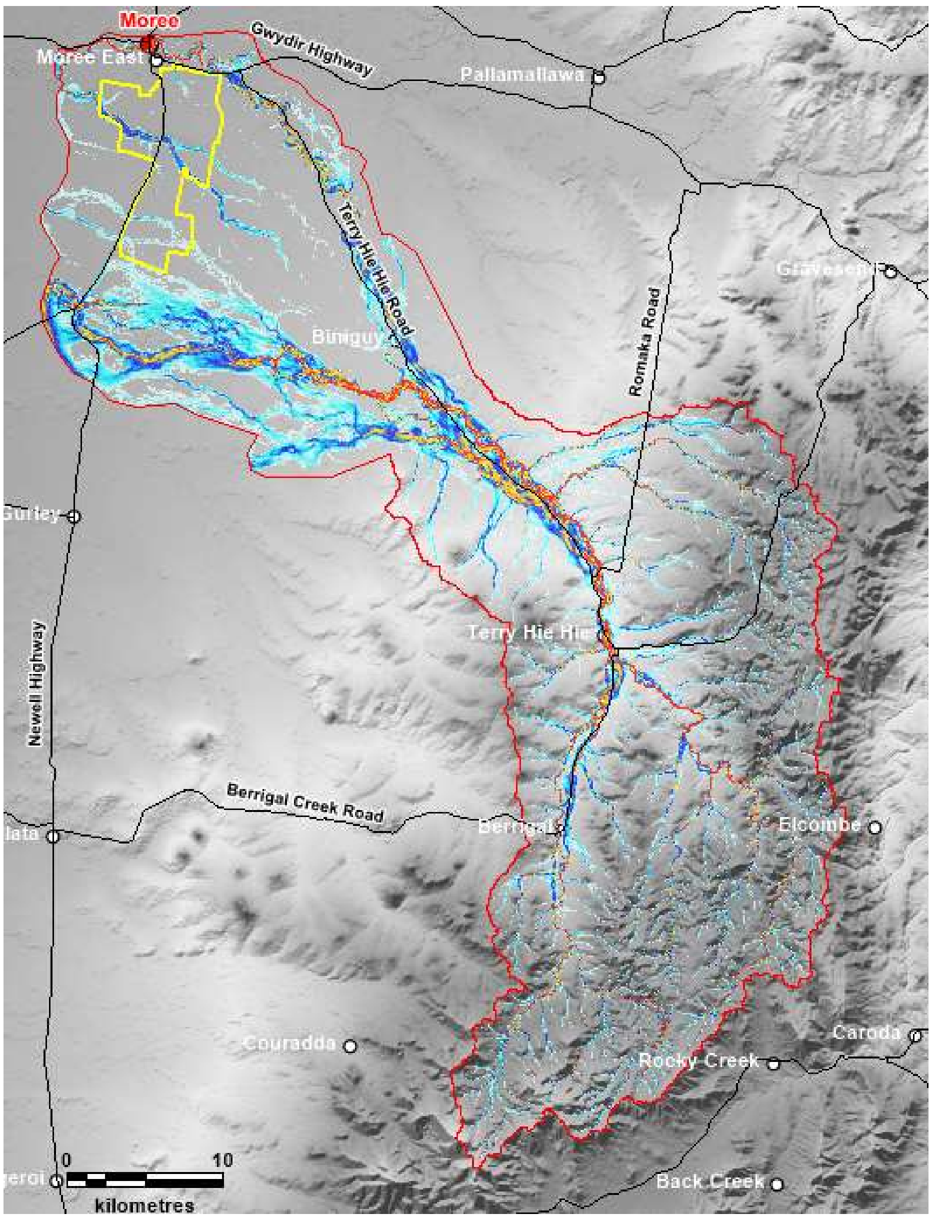


Figure 13 Total catchment flow paths from the TUFLOW model output – 1% AEP

The TUFLOW models established used standard inputs of terrain, surface roughness, rainfall, and outflow. The rainfall data used in the modelling was spatially varied according to the Bureau of Meteorology gridded Intensity-Frequency-Duration data at 2.5km intervals. IFD grids were created for each of the 20 storm durations modelled as the spatial distribution of rainfall intensity is unique to each storm duration. The grid data was contoured into regions of similar rainfall intensity and used to feed rainfall into the TUFLOW models via the time varying temporal patterns provided in Australian Rainfall and Runoff 1987. An example of the rainfall intensity contours for one storm is presented as Figure 14.

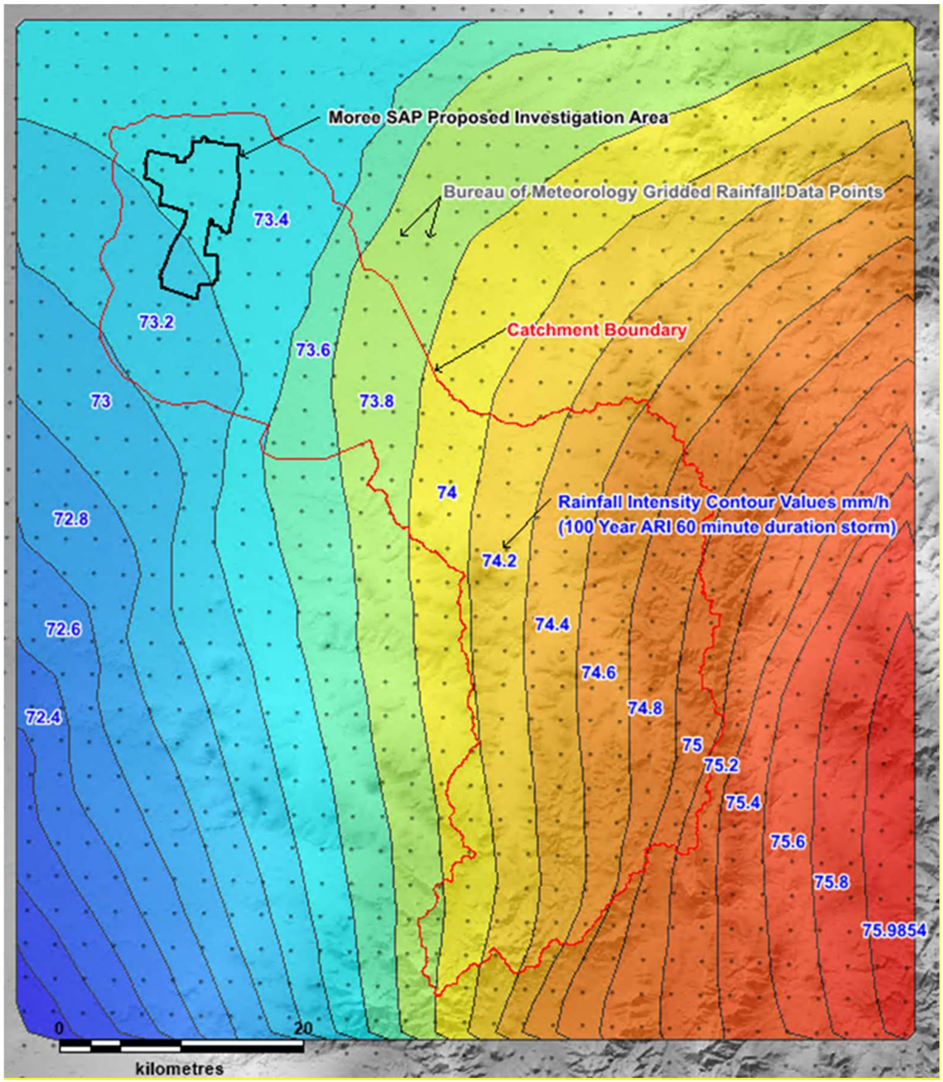


Figure 14 Example spatial distribution of rainfall intensity - 1% AEP 1hour storm

Rainfall losses were applied equally across the catchment as most if not all of the catchment is typically vegetated. An initial loss of 10mm was applied with a continuing loss of 2.5mm/h. Surface roughness for the catchment was categorised into two types:

- rough country heavily forested with a Manning's 'n' value of 0.12, and
- rural pasture land with a value of 0.035.

The differentiation between these categories was defined by polygons derived from currently available aerial photography of the catchment.

Given the complex nature of the upstream floodplain breakouts and the lack of any observed flood data for the local SAP area at the time of this study, it was therefore not possible to verify the above model establishment using typical alternative methods such as runoff-routing modelling or RFFE.

3.3.2.3 Halls Creek tailwater assumption

The downstream boundary conditions have been assumed to be free draining via hydraulically 'normal' flow conditions rather than using a combined local catchment flood coinciding with a main river flood. Within the overall Moree floodplain, the SAP site comprises relatively high ground and recent flood studies for the Gwydir-Mehi Rivers indicate the SAP is largely above or outside the regional 1% AEP flood extent apart from Halls Creek and the backwater influence from the Mehi River downstream.

A review of the mapping available from the Gwydir-Mehi flood investigations (WRM, 2017) suggests that any potential tailwater/backwater influence from the Gwydir-Mehi River on the local Halls Creek flood levels is unlikely to extend into the SAP area. The flood contours presented in Figure 16 and Figure 17 for the Gwydir-Mehi 10% and 1% AEP events respectively, indicate a relatively flat flood gradient (tailwater) extending some 3km from the junction of Halls Creek with the Mehi River up to the SAP boundary. The gradient and flood levels then begin to steadily rise in a more consistent fashion.

When comparing the estimated peak flows and flood levels in the regional 1% AEP event with those for the local SAP flood modelling, it is also noted that the peak flow for Halls Creek is considerably greater for the local SAP modelling (307m^3/s on Figure 24 compared to 71m^3/s in Table 2) and the local flood level at the downstream SAP boundary is up to a metre higher (refer Figure 25).

It is possible for the flood peak of a local creek system such as Halls Creek to coincide with that of the main Mehi River but due to the vastly different catchment sizes of these two systems the likelihood of flood peaks coinciding is much rarer than each individual flood peak. The critical storm duration modelled for the overall Gwydir-Mehi catchment is 48 hours compared to around 6 hours for the local Halls Creek catchment. For this reason, the Moree SAP flood model has considered the local catchment flood to be occurring independently of a major flood in the Gwydir-Mehi River system.

Adopting a smaller Mehi River flood level as the downstream tailwater condition, such as say the 10% AEP, is also unlikely to significantly influence the estimated local catchment flood levels through the SAP site. The 10% AEP Mehi level at the downstream SAP boundary is around RL 203m AHD (refer Figure 16) which is up to 2m lower than the estimated local 1% AEP flood level and also noting the typical steeper increase in flood gradient that seems to occur upstream from the SAP boundary as mentioned above.

3.3.2.4 Upper catchment flow breakouts

As mentioned in discussions above, the potential for floodwaters upstream of the SAP area to escape Tycannah Creek and then flow into the SAP is especially of interest as it could change the overall flood behaviour and risks for any future development within the SAP.

Figure 15 indicates the intensity of flow conveyance for an [1]Extreme flood event *(note this event was found to be similar in magnitude to the PMF event. It is also consistent with the approach adopted in Council's regional flood study for such large events and has been included to indicate the flow break outs and for comparison)*. The redder areas of flow indicate a higher concentration of floodwater, running both fast and deep. The black arrows on the image indicate locations where the creek banks are overtopped and sending floodwater into the SAP. The two breakouts at the southern end of the SAP are the most significant but the other two breakouts to the north do not show a large amount of floodwater heading towards the SAP.

Large floods can alter the profile of a creek bed. This is a natural process which is to be expected. The Moree SAP flood models have somewhat tested the potential for this process to affect the SAP by looking at the flow intensity of a large flood as shown in Figure 15. It appears that the flood breakouts are relatively minor with low flow intensity. Creek morphology of the upstream creeks should be monitored at intervals throughout the life of the SAP but initial results indicate that the potential for a new major flow path to emerge at the SAP due to a large flood event has relatively low potential.

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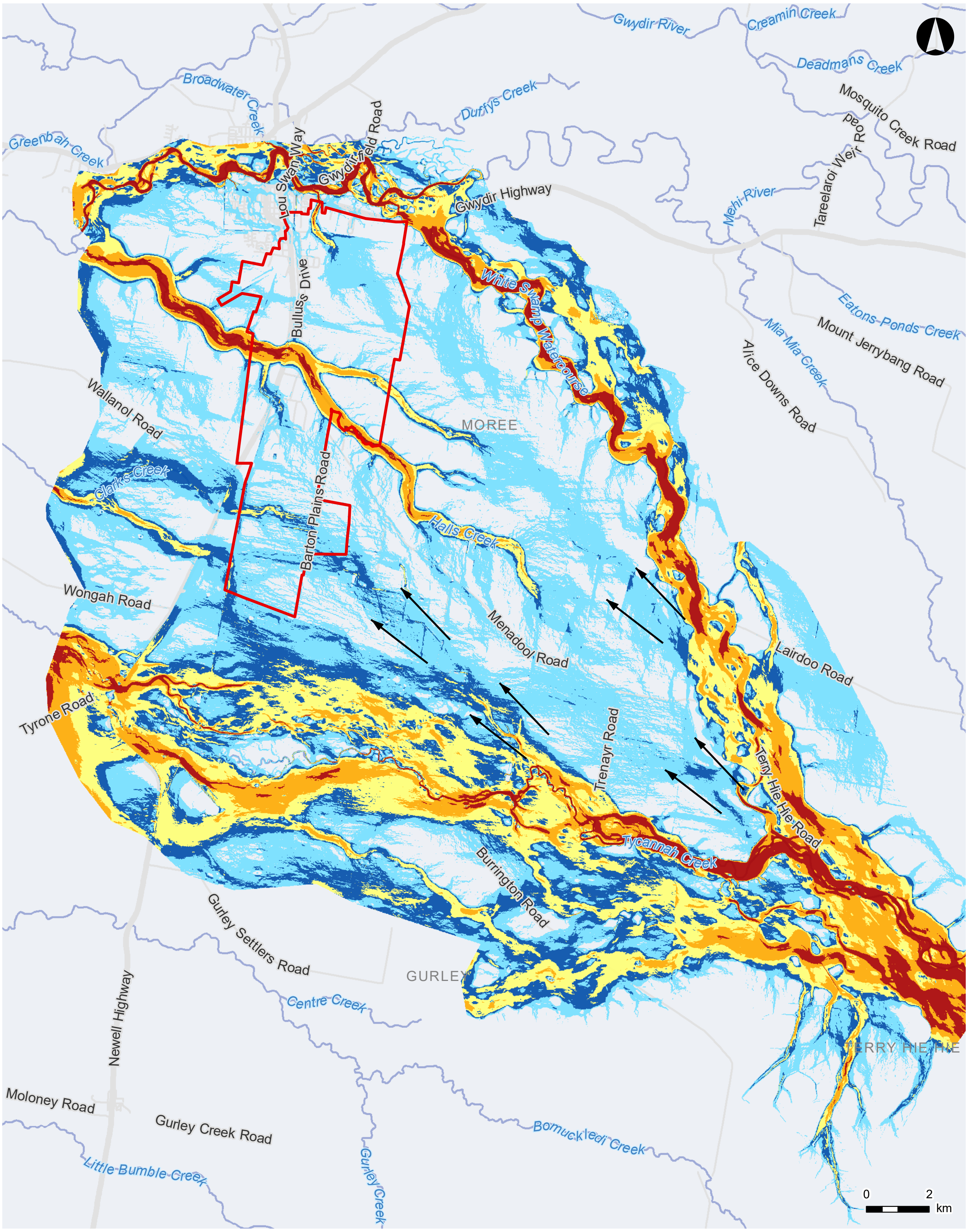
[1] Estimates for the Extreme event are based on three (3) times the 1% AEP flow as per the approach adopted for the Moree and Environs Flood Study (WRM 2017)



LEGEND

Proposed SAP boundary

Watercourse

Velocity x Depth (m²/s)

< 0.05

0.05 - 0.25

0.25 - 0.5

0.5 - 1.0

1.0 - 2

> 2

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1:180,000 at A4

Figure 15 Flow paths showing overbank breakouts – Extreme flood

3.3.3 Results from previous studies

3.3.3.1 Regional flood levels and extent (Gwydir-Mehi flood model)

Detailed flood modelling of the Moree area was recently undertaken as part of the review of Moree and Environs flood behaviour and floodplain risk management (WRM 2017). The modelling was primarily focused on the broader Gwydir-Mehi floodplain and river systems that mostly pass to the north but also through parts of Moree. Flood behaviour was modelled and mapped for a range of design flood events spanning from 20% AEP to 0.5% AEP (5 to 200 year ARI) as well as an estimate of an extreme event.

Results from a selection of the events modelled are provided below to provide general context of flood conditions associated with the main Gwydir-Mehi river systems. Figure 16 shows the estimated flood extent, depths and flood contours in the vicinity of Moree for the 10% AEP event. The following is of note:

- The 10% AEP event is largely in-bank along the Mehi River through Moree. The only Mehi River overflow of consequence for the town occurs around the golf course, while an overflow through Bendygleet impacts a number of properties.
- Much of the floodplain between the Mehi River and the Gwydir River is inundated during the event.
- The low level Albert Street bridge is overtopped in the 10% AEP event.
- Both the Carnarvon and Newell Highways heading north from Moree would be overtopped. The depth of overtopping is generally shallow though some isolated sections may be untrafficable. The Gwydir Highway to the east of Moree between Biniguy and the Mehi Washpool is also inundated with some sections of highway likely to be untrafficable.

The estimated 1% AEP flood extent, depths and flood contours in the vicinity of Moree is shown Figure 17 and the following is noted:

- The 1% AEP peak flood levels along the Mehi River are approximately 0.3m higher than the 1955 peak flood level and 0.5 m higher than those that were experienced in the recent 2012 flood.
- The Gwydir River and Mehi River drain as one water body past the town of Moree during the peak of the event with all areas between the two rivers inundated.
- Inundation is widespread with all major roads and highways inundated for varying lengths of time.

An indication of the estimated flood extent, depths and flood contours in the vicinity of Moree for an extreme event is shown in Figure 18. The overall extent of flooding for this event is generally used to indicate the extent of flood prone land.

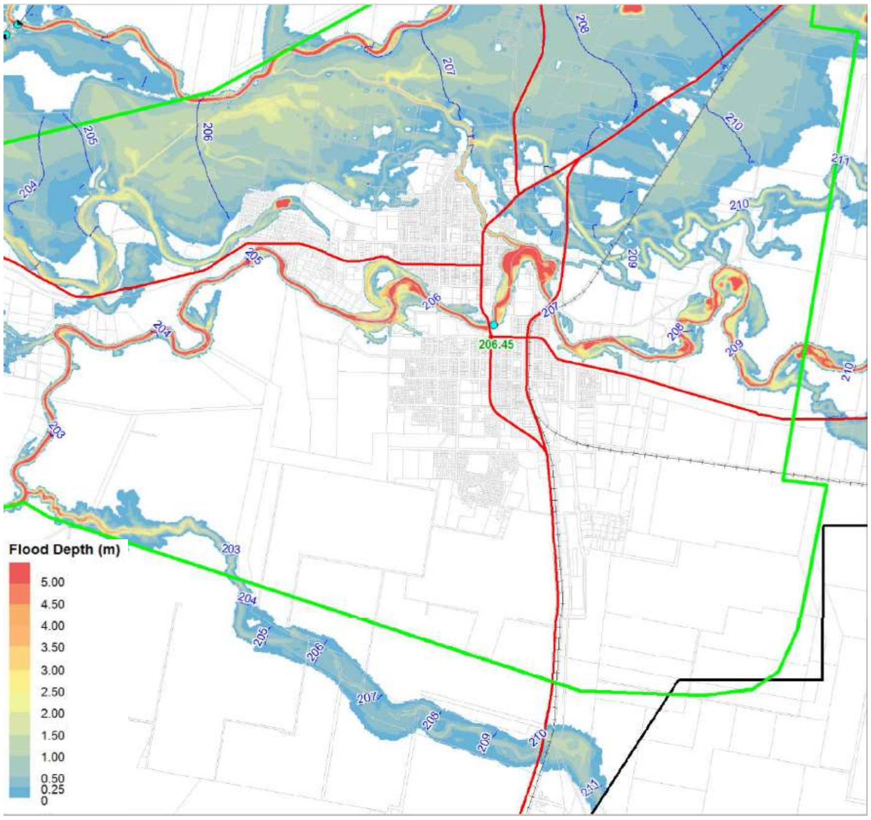

Figure 16 Estimated flood depth, level and extent - 10% AEP regional event (source: WRM 2017)

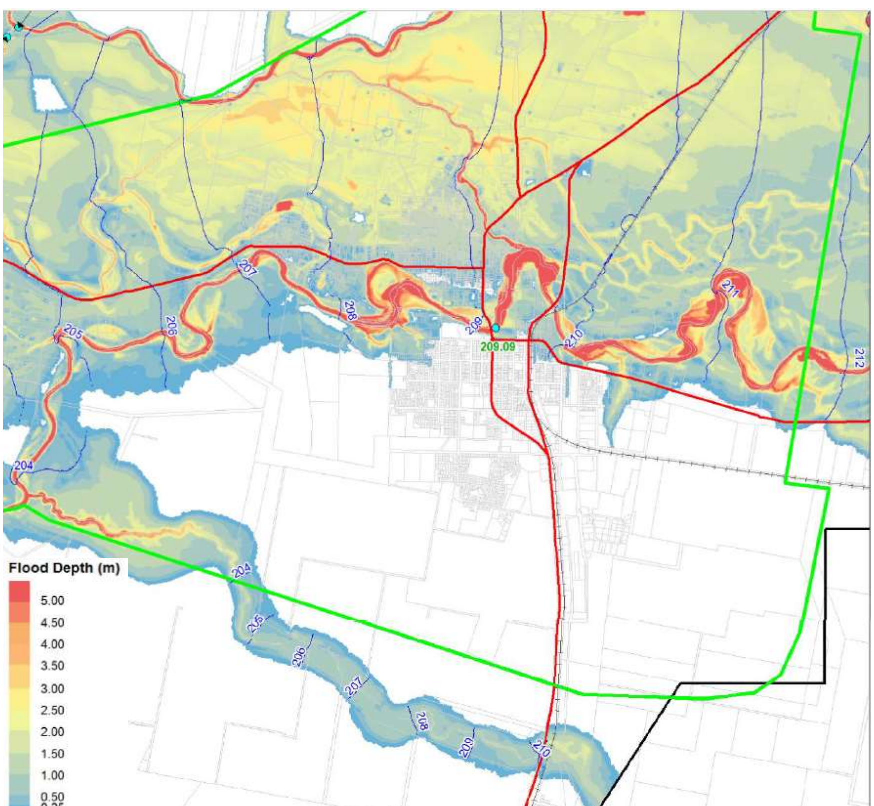

Figure 17 Estimated flood depth, level and extent - 1% AEP regional event (source: WRM 2017)

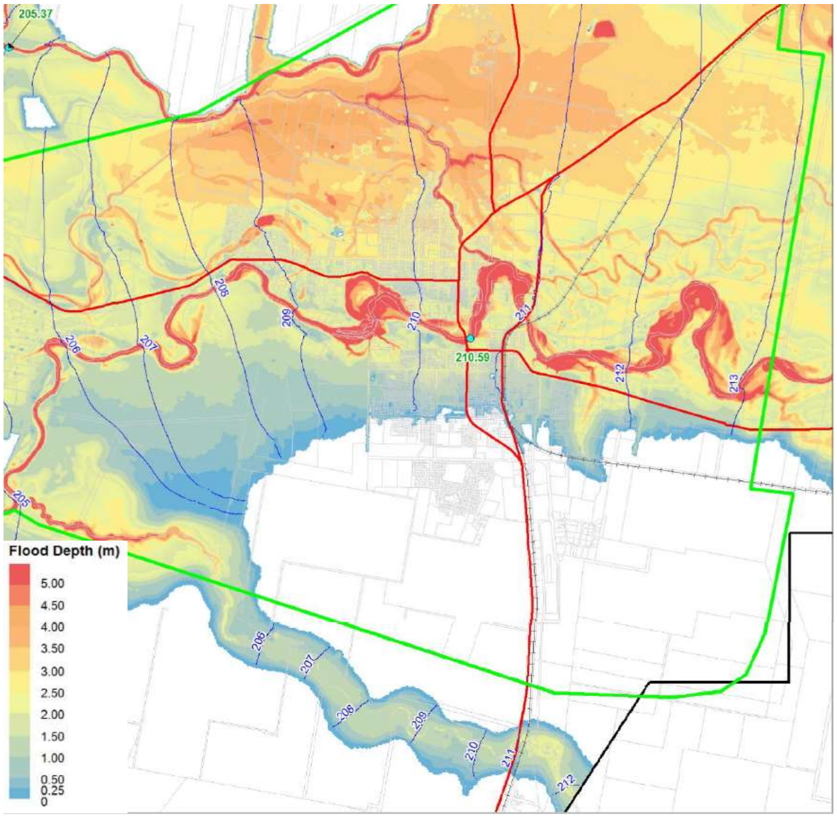

Figure 18 Estimated flood depth, level and extent - Extreme regional event (source: WRM 2017)

Based on the above mapping much of the Moree SAP, with the exception of Halls Creek, would appear to be flood free and unaffected but it should be noted that this previous modelling did not consider flooding from the local tributary catchments or the potential for overflow breakouts in large events to occur much further upstream of Moree. This potential breakout issue was only recently identified as part of the ongoing Inland Rail investigations and becomes more apparent from a broader review of the LiDAR information as discussed in Section 3.3.2.1 and indicated in Figure 11.

Additional modelling, specifically for the Moree SAP, has therefore been undertaken to account for the local tributary catchments and also the possibility of upstream overflow breakouts. Further discussion is provided in Section 3.3.4 and results for the 1% AEP local flood event are indicated in Figure 24.

3.3.3.2 Peak flow estimates

Estimates of the peak design flows in the vicinity of the Moree SAP have been obtained from the available flood modelling for a range of flood events and are summarised in Table 2.

Maintaining the distribution of flood flows across the floodplain is a key objective of the Gwydir Valley FMP (DPIE 2016). Maintaining the flood function of the floodplain is also a key objective of best practice in flood risk management in Australia because it is essential to managing flood behaviour. The flood function of areas of the floodplain will vary with the flood magnitude. An area that may be dry in small floods may become an active flow conveyance area during larger events. It is therefore important that these flow path areas are not adversely affected or impinged upon by development.

Table 2 Peak flow estimates - 48 hour storm event

Location	Peak Flow (m^3/s)			
	10% AEP	1%AEP	0.5% AEP	Extreme[2]
Halls Creek	21	71	112	213
Tycannah Creek	330	890	1269	2670
White Swamp	19	62	98	186

Source: WRM 2017

3.3.3.3 Flood hazard and hydraulic categories

The Moree and Environs Flood Study (Vol I, WRM 2017) defined provisional hydraulic and hazard categories across its study area for a full range of design flood events. Further investigations undertaken as part of the floodplain risk management study (Vol II, WRM 2017) then assessed the other factors that influence hazard to define three hydraulic category areas that can be used to assess the potential suitability of future types of land use and areas for possible development. These hydraulic categories are consistent with the definitions outlined in the Manual (NSW Government, 2005).

Figure 19 shows the locations of the floodway, flood storage and flood fringe areas recommended for Moree. The floodway area is based on the extent of the high hazard area for the 5% AEP design flood with manual modifications to remove areas not in active flow zones (i.e. are high hazard based on depth only in backwater areas). It also includes areas that have formed isolated islands where access is difficult. The floodway areas have also attempted to match with the Gwydir Valley FMP floodways (Management Zone A - DPIE 2016) both upstream and downstream of the study area.

In addition to the hydraulic categories, provisional flood hazard categories were also defined for a range of design flood events across the Moree area. The hazard categories were assessed based on a combination of depth and velocity results obtained from the hydraulic model in accordance with Figure L2 of the Manual (NSW Government 2005). The hazard across the floodplain was further delineated and grouped into six categories in accordance with recommendations in the Australian Disaster Resilience Guideline 7-3 (2017). It should be noted however, that other factors can also influence flood hazard, such as warning time, readiness, evacuation access etc, but these were not necessarily considered in the provisional mapping. The resulting flood hazard mapping for the 1% AEP regional flood event is indicated in Figure 20.

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[2] Estimates for the Extreme event are based on three (3) times the 1% AEP flow as per the approach adopted for the Moree and Environs Flood Study (WRM 2017)

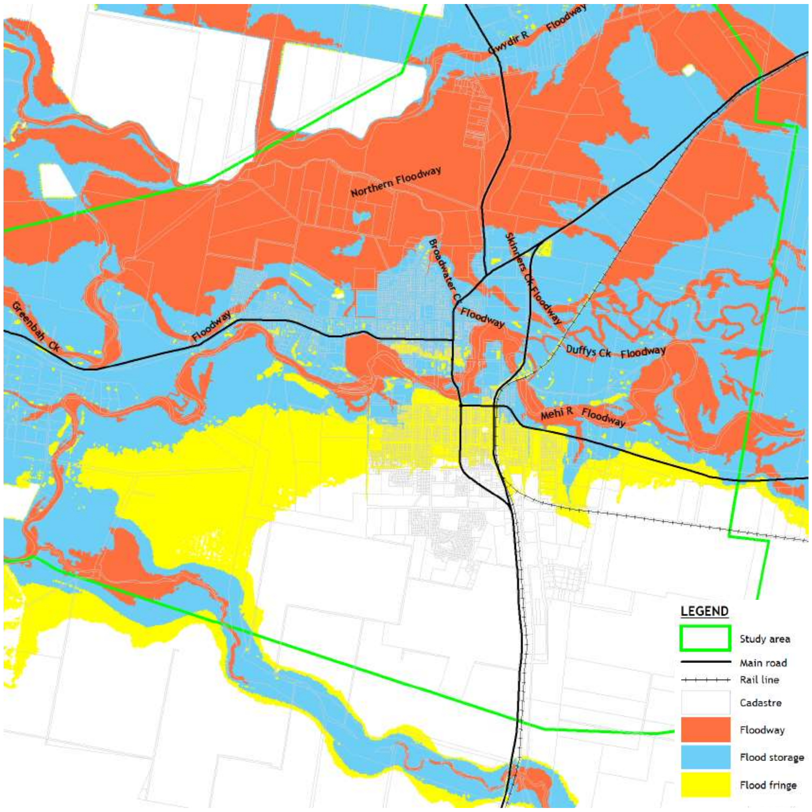


Figure 19 Hydraulic Categories (source WRM 2017)

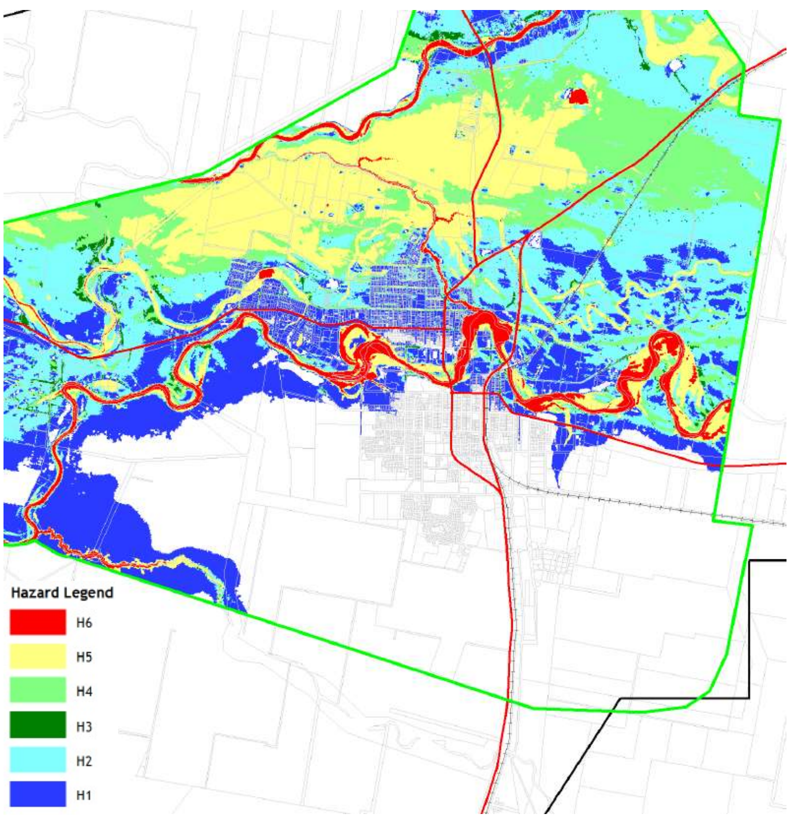


Figure 20 Flood hazard - 1% AEP regional event (source WRM 2017)

3.3.3.4 Flood immunity for local and regional transport links

A key consideration in the management of risks to floodplain occupiers and users is the need for appropriate transport access locally and regionally. At the local level it is primarily about evacuation needs, access for emergency services, flood recovery and minimising potential disruption to community movements. The regional considerations are more to do with maintaining transport links to surrounding areas to minimise disruption to essential supplies and allow freight movement to continue through the region. Aside from the depth and extent of inundation, the time or duration of inundation can also have a significant influence on route serviceability for affected users. Areas or routes that may experience prolonged periods of inundation may require special attention or consideration for the need to evacuate or to restock additional supplies.

An indication of how local and regional access roads in the vicinity of Moree may be affected during flood events is presented in Figure 21. The preliminary mapping shows roads estimated to be inundated by depths of more than 0.3m for periods greater than 24 hours in the 1% AEP design event. It should be noted that as each flood event is actually different (in magnitude, duration and rate of rise) this assessment and mapping should be considered as an indicative guide only. Additionally, this mapping is not necessarily complete or comprehensive for those areas to the south of Moree away from the main regional floodplain).

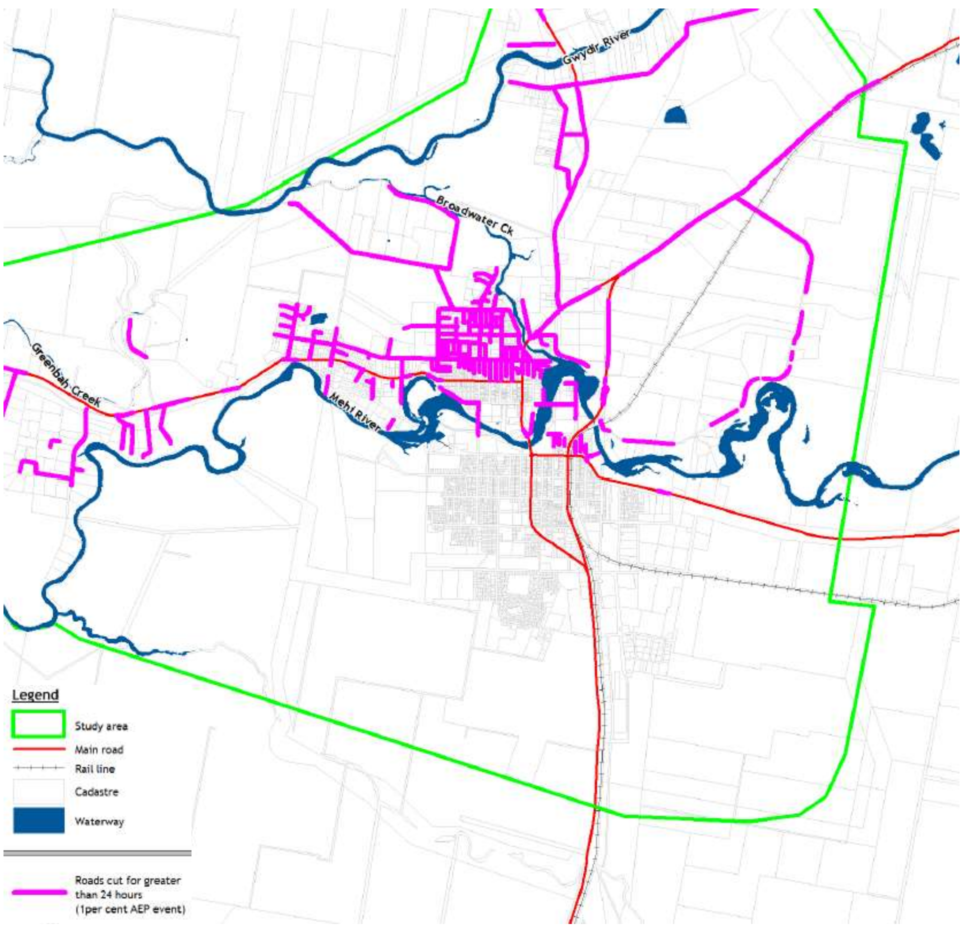


Figure 21 Access roads inundated by 0.3m for more than 24 hours - 1% AEP regional event (source: WRM 2017)

For the purposes of emergency response planning, the township of Moree has been divided into a number of communities to suit their differing emergency response requirements (flood warning, evacuation access, hazard categorisation etc). The extent of these communities and properties at risk are indicated on Figure 22, noting that the evacuation centres are located in Moree South.

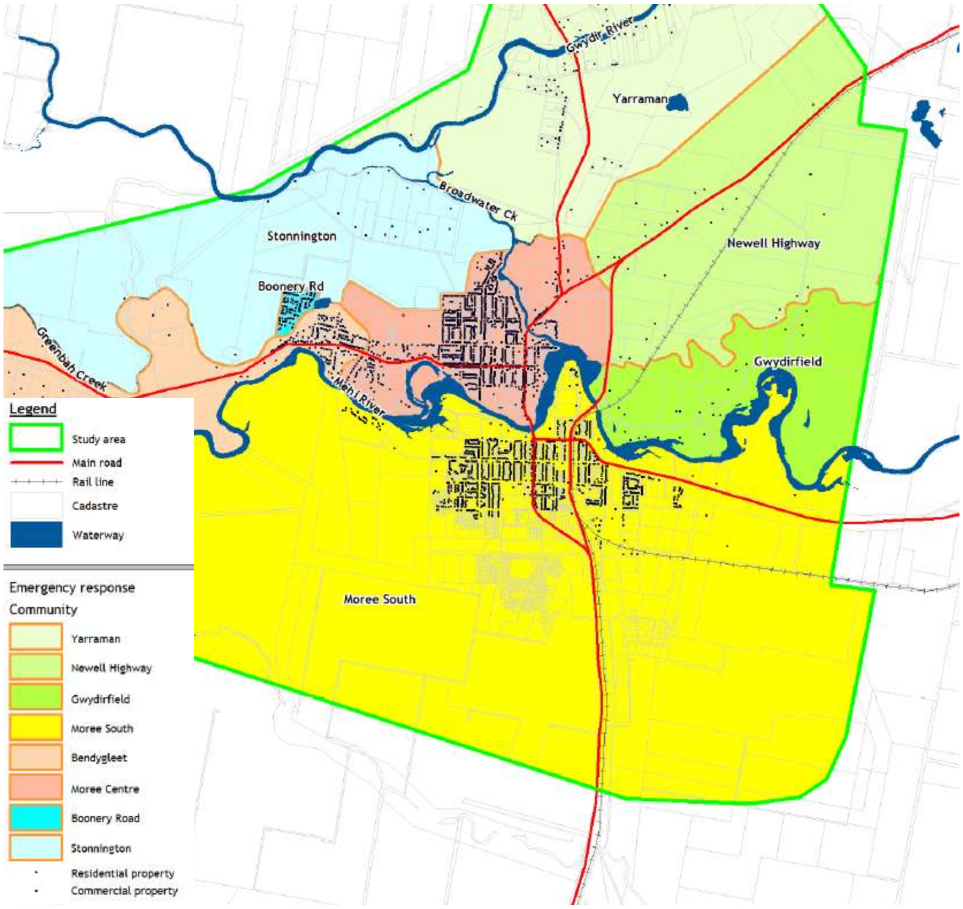


Figure 22 Flood emergency response planning communities (source: WRM 2017)

3.3.4 Moree SAP flood model results

3.3.4.1 10% AEP local flood event

Figure 23 shows the estimated flood levels, depths and extent for the 10% AEP local catchment flood event. The majority of the SAP area appears to be largely unaffected by significant flooding in the 10% AEP event.

The main flooding through the SAP area is attributable to Halls Creek where the depths are mostly shown to be in the range of 0.3m to 0.5m with some areas up to 1.0m deep. Depths greater than 1.0m are also evident and these mostly reflect the actual creek channel alignment. There is however a larger ponded area shown just upstream of the Newell Highway embankment but this is mostly contained to the Travelling Stock Route and riparian corridor areas and would not really impose on the developable lands.

The extent of inundation in the southern portion of the SAP around Clarks Creek is generally scattered and relatively shallow (0.3m to 0.5m). There appears to be a slight localised build up in depth along the main railway line and Newell Highway embankments, but this is may well be attributable to the model definition with limited details available for the smaller culverts or waterways in this area. The majority of this area is situated between the highway and rail embankments which is outside of the SAP boundary. The lesser ponding just upstream of the rail embankment may be reduced with the proposed Inland Rail Upgrade works but as this area is nominated for solar land use or large industry (with buffer zones) it would be a low flood risk. Should the potential for development of this area change or become more important than the model should be updated with more details at that time.

3.3.4.2 1% AEP local flood event

3.3.4.2.1 Peak flow estimates

The Moree SAP flood models were run with a full sweep of storm durations. This is because every location in a catchment has a particular critical storm duration that produces a peak flow and flood level. Some locations with a small upstream catchment will peak in a high intensity ‘thunderstorm’ that may not last long, whereas other locations will see peak flooding conditions from multi-day storms. Normally locations where peak flood levels occur from long duration storms are in the proximity of the main creek lines or their overbank areas. In the Moree SAP catchment some locations are susceptible to local creek overbank flooding where floodwater breaks out of one creek or watercourse and travels overland into another. The flood modelling results indicate that Halls Creek is susceptible to this type of flood behaviour.

Figure 24 shows the flow paths for the Moree SAP lower catchment flood model with peak flow values (cubic metres per second – m^3/s) and the storm duration (minutes) that produced the peak flow. Note that some relatively minor flow paths which would normally be triggered by short duration storms are triggered by relatively long storm durations such as the 1,080 minute storm (18 hour storm). This is because Tycannah Creek breaks its banks and sends floodwater into the SAP. The Mehi River flooding, shown as brown shading, in Figure 24 has been taken from the WRM 2017 study.

3.3.4.2.2 Flood levels and extent

Figure 25 shows the 1% AEP local flood levels and depths. The results show that Halls Creek is a major flow path that is well defined through the SAP. Land use planning around this creek should be uncomplicated, with simple no-build zones derived from the flood extent.

In

Figure 25 the Newell Highway and adjacent railway line can be seen to present a notable hydraulic feature in the vicinity of the main waterways traversing the SAP. If necessary and appropriate, land use planning for the SAP should consider possible future upgrades of waterway infrastructure at these locations which may lead to changes in flow path widths and flood levels downstream and/or upstream of the highway and railway. The segment of Halls Creek downstream of the SAP is about 3km from the Mehi River. This is a relatively short distance that may be able to sustain acceptable changes in flows and/or flood levels in conjunction with implementation of appropriate development controls and measures as part of the overall Master Plan strategy.

South of Halls Creek the overbank flows from Tycannah Creek can be seen to spread and follow ill-defined flow paths, probably influenced by vegetation more than terrain. The model’s terrain can be seen to include LiDAR vegetation artefacts from crops even though LiDAR terrain is supposed to represent ground levels. In low lying vegetation areas this is rarely the case and the flood model results reflect this input data deficiency. However, this also highlights that changes in vegetation over time which will occur, can potentially influence flood behaviour in flat terrain. The model results indicate that formalisation of a flow path may be a good option when planning the land use for the southern part of the SAP.

At the south western corner of Figure 25, near Clarks Creek, the results show floodwater ponding locally against the Newell Highway and adjacent railway embankments. In the absence of any suitably detailed information for the smaller culverts/waterways in this area, these have not been represented in the flood model. The current mapping results are therefore more indicative of the extent of ponding that may occur if the culverts exist and were fully blocked by debris. Should the potential for development of this local area change or become more important then the model should be updated with more details at that time.

3.3.4.2.3 Flood hazard

Figure 26 shows the 1% AEP 'provisional' flood hazard delineated and grouped into six categories in accordance with recommendations in the Australian Disaster Resilience Guideline 7-3 (2017). The categories are considered to be provisional because the results have not been adjusted for other flood risk factors such as warning time, readiness, evacuation access etc.

The results show that areas of high hydraulic hazard are well defined and are mainly within Halls Creek. Small areas of high hazard outside of Halls Creek are narrow and will not cause land use planning issues. Most of these areas are within obvious flow paths which should not be developed.

3.3.4.3 0.5% flood event

Figure 27 shows the estimated flood levels, depths and extent for the 0.5% AEP event. This event is often used to indicate any change or difference in flood behaviour and extent for flood events slightly larger than the 1% AEP. Alternatively, it is also considered to represent the potential implications for the lower bound climate change estimate of increase in rainfall intensities (+10%). Comparison of the 0.5% AEP flood extent with that of the 1% AEP (refer Figure 32 in Section 3.5) indicates that there is very little difference in flood behaviour or extent.

3.3.4.4 0.2% flood event

Figure 28 shows the estimated flood levels, depths and extent for the 0.2% AEP event. Similar to the 0.5% AEP mapping, this event is often used to assess potential implications for flood behaviour that may be associated with the upper end of climate change predictions for increases in rainfall intensities (+20%). Comparison of the 0.2% AEP flood extent with that of the 1% AEP indicates that there is only a relatively nominal difference in flood behaviour or extent.

3.3.4.5 PMF event

Figure 29 shows the estimated flood levels, depths and extent for the estimated PMF event.

The overall extent of inundation is more noticeable and widespread across the southern portion of the SAP with depths typically up to 0.5m but also more definable areas extending up to 1.0m. Between the Newell Highway and railway line there are two areas with depths of ponding greater than 1.0m.

The extent of inundation associated with the tributary in the north eastern corner of the SAP is shown to be relatively shallow (0.3m to 0.5m) and spread out in the flatter middle parts of this smaller catchment before flows accumulate and concentrate in the lower reaches then discharge into the Mehi River.

Flooding within Halls Creek is still relatively contained and well defined with depths mostly in the range of 1.0m to 2.5m.

3.3.4.6 Climate Change

The issue of climate change was not assessed in the recent flood related studies for Moree and Environs (WRM 2017) and there is little other tangible information readily available for quantifying the possible implications on the current regional flood behaviour and planning levels. In this regard, the key climate change factor around the Moree area in north western NSW (which is grouped within the Central Slopes cluster of the 54 natural resource management catchment and bio regions of Australia) that may impact on the flood modelling results is variation in rainfall.

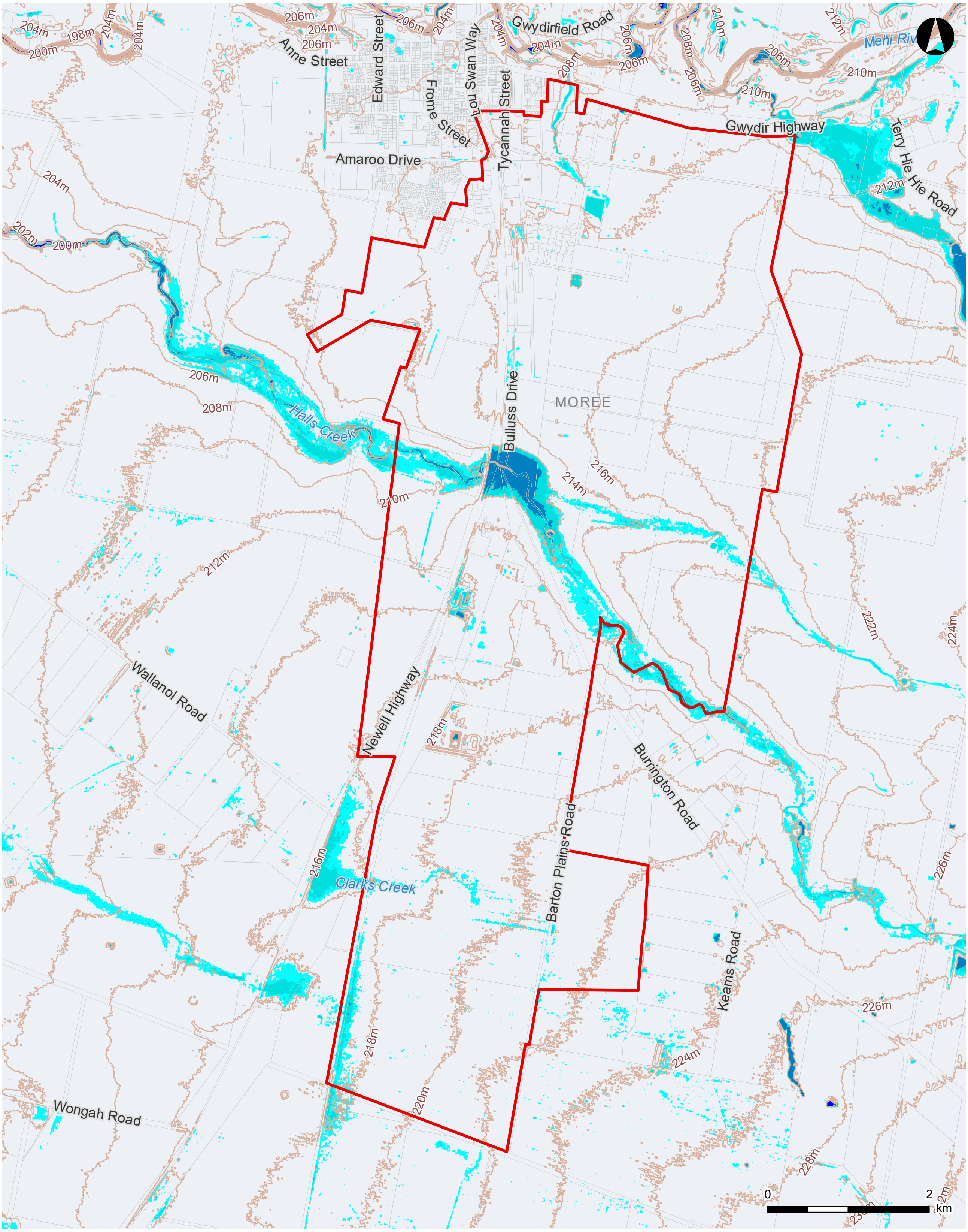
Regional projections for the Central Slopes cluster, based on outputs of global climate models, are summarised in *"Climate Change in Australia Projections Cluster Report – Central Slopes"* (CSIRO 2015). While the projections for mean annual rainfall are tending towards a decrease in the Central Slopes cluster, the heavy or extreme storm rainfalls are projected to increase (and more so for the rare extremes). The projected increases for the annual maximum 1-day rainfall are in the order of 10% to 15% for the RCP4.5 and RCP8.5 respectively and 20% to 25% for the 20 year return value (5% chance of occurrence within any given year) for the 1 day rainfall.

Climate changes associated with evapotranspiration and rainfalls combined have the potential to impact upon soil moisture and general runoff. The majority of the modelling undertaken to date suggests a decrease in overall runoff is likely. However, there is a low confidence in the modelled projections for impacts to runoff. This is because of low agreement on the direction of change by the models and the methods used are not able to properly consider the interrelated changes in rainfall intensity, seasonality and vegetation characteristics.

In summary, there is high confidence that the intensity of heavy or large rainfall events will increase in the Central Slopes region (possibly in the range of 10% to 25%). However, there is low confidence in the magnitude of such change and therefore the time when any change may become evident against natural fluctuations cannot be reliably projected (CSIRO 2015). The possible implications for existing flood behaviour due to increasing rainfalls in the larger or rarer storm events would involve model iterations as part of a sensitivity assessment. This analysis could be undertaken once the flood modelling has been refined at an appropriate future stage of the project development.

The assessment of climate change is often based on factoring the 1% AEP design rainfalls by an estimated percentage increase typically in the order of around 10% to 20% (CSIRO 2015, RCP 4.5).

The Floodplain Risk Management Guide (OEH 2019) allows for a larger flood event such as the 0.5% and/or 0.2% AEP to be used to simulate the higher flow conditions associated with climate change in lieu of generating a factored rainfall event. For the purposes of this study, the 0.5% and 0.2% AEP events have been adopted to represent the 10% and 20% climate change conditions respectively and the resulting flood levels and extent are shown in Figure 27 and Figure 28.



LEGEND

Proposed SAP boundary

Elevation contour (m)

Flood depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.5
- 2.5 - 5
- > 5.0

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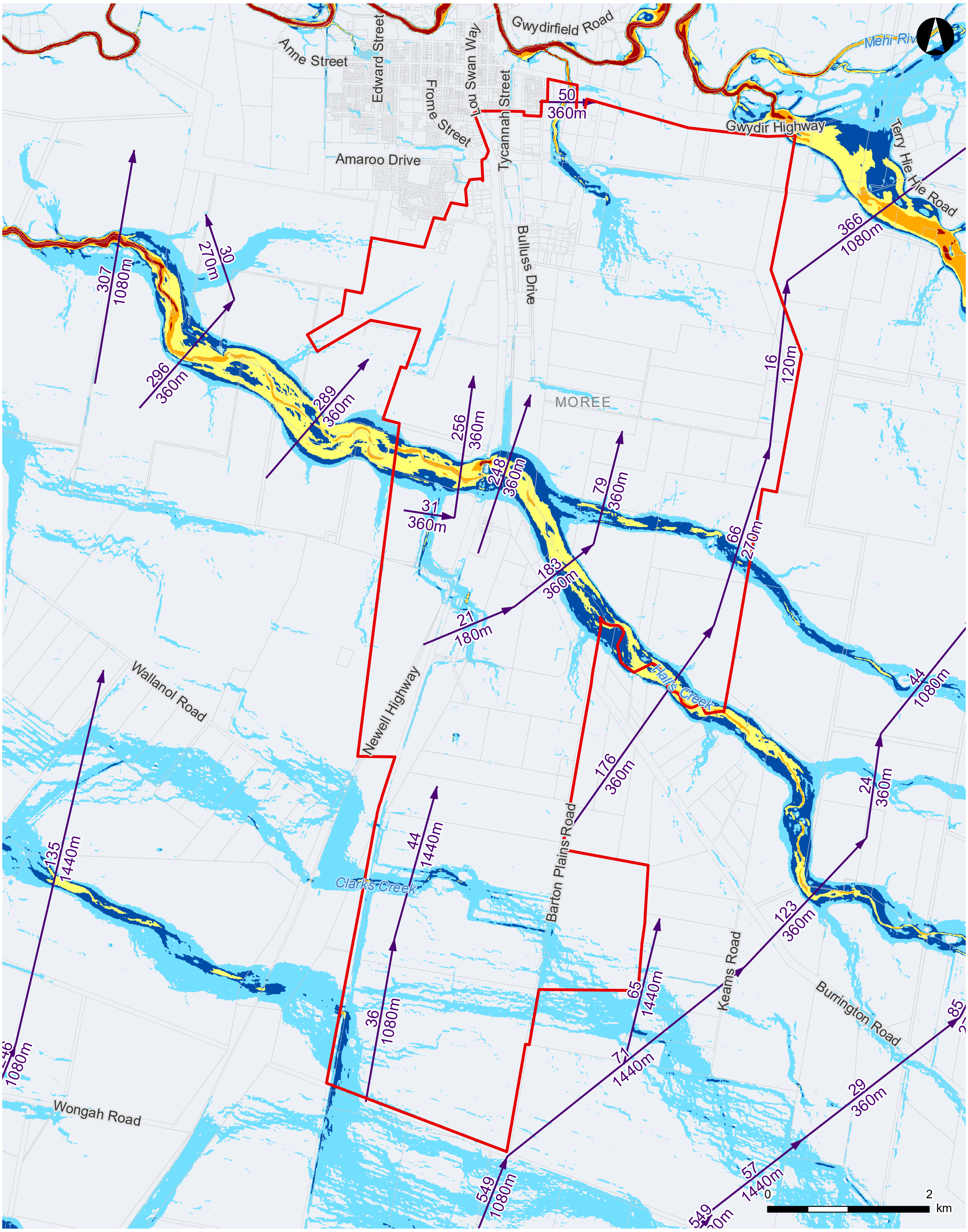
Figure 23 Peak flood levels and depths - 10% AEP local event



LEGEND

Proposed SAP boundary

Velocity x Depth (m²/s)

- < 0.05
- 0.05 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 2
- > 2

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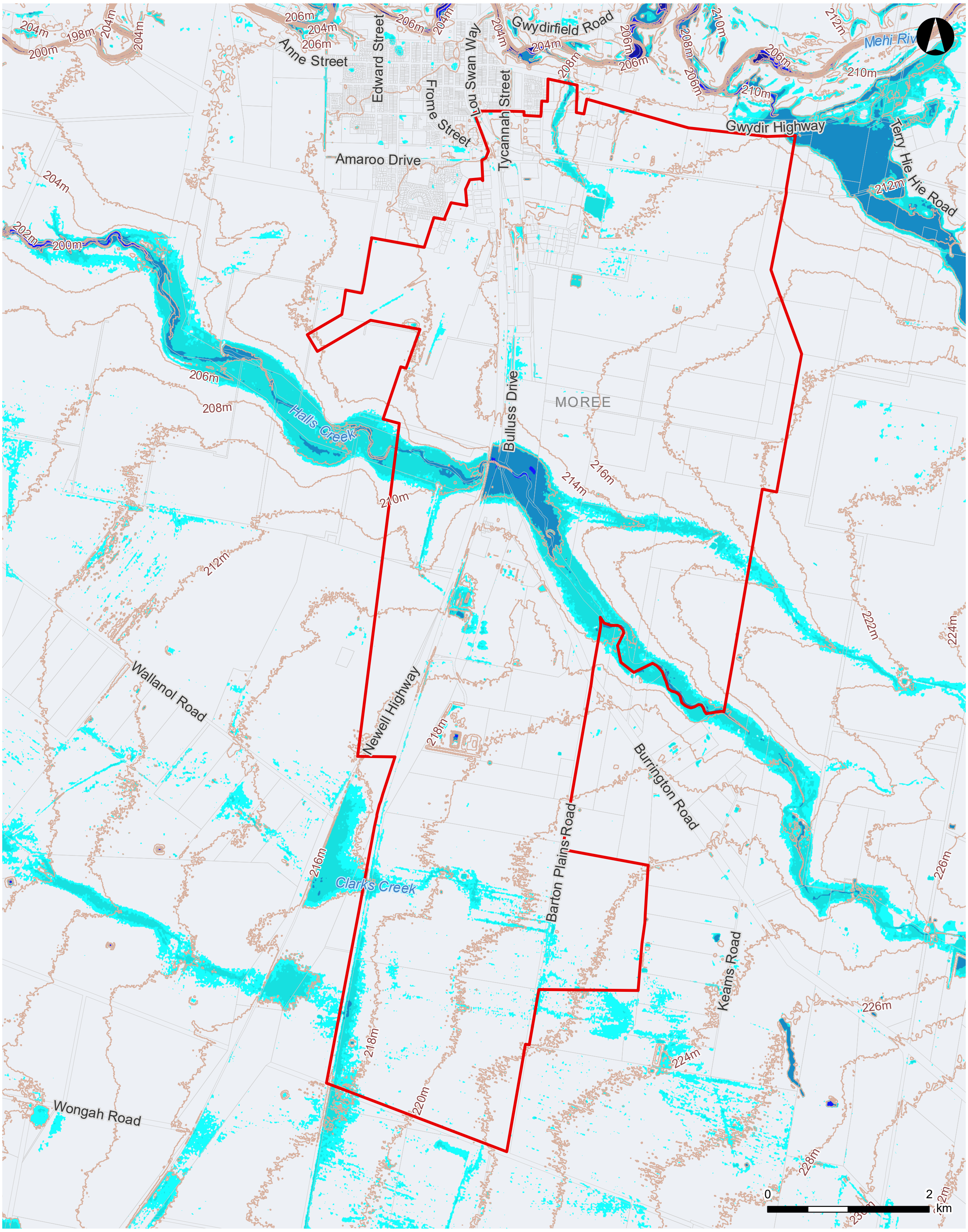
Figure 24 Peak flow values with corresponding storm duration - 1% AEP local event



LEGEND

Proposed SAP boundary

Elevation contour (m)

Flood depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.5
- 2.5 - 5
- > 5.0

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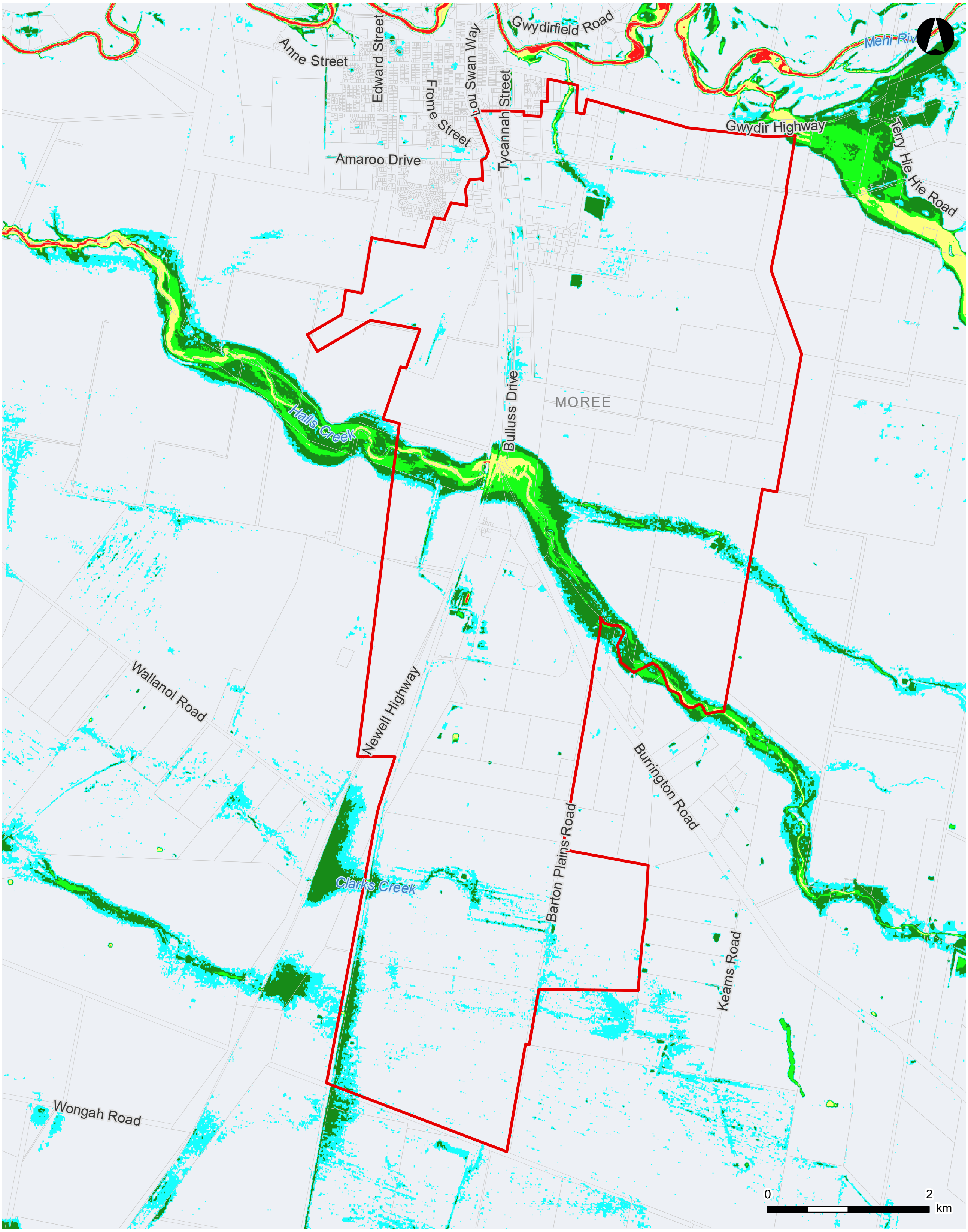
MOREE
WARIALDA

Figure 25 Peak flood levels and depths - 1% AEP local event



LEGEND

Proposed SAP boundary

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

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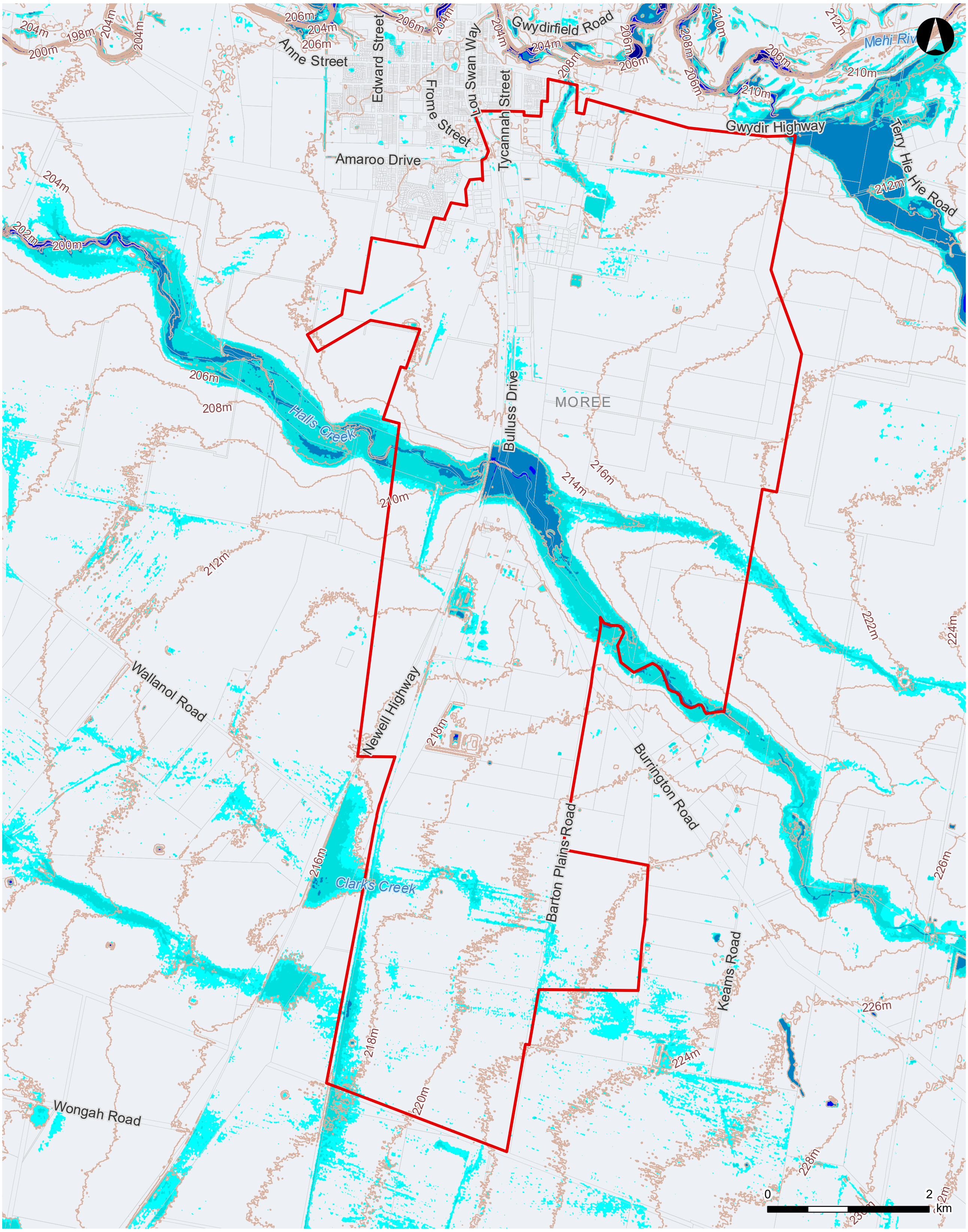
Figure 26 Provisional flood hazard for Moree SAP – 1% AEP local event



LEGEND

Proposed SAP boundary

Elevation contour (m)

Flood depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.5
- 2.5 - 5
- > 5.0

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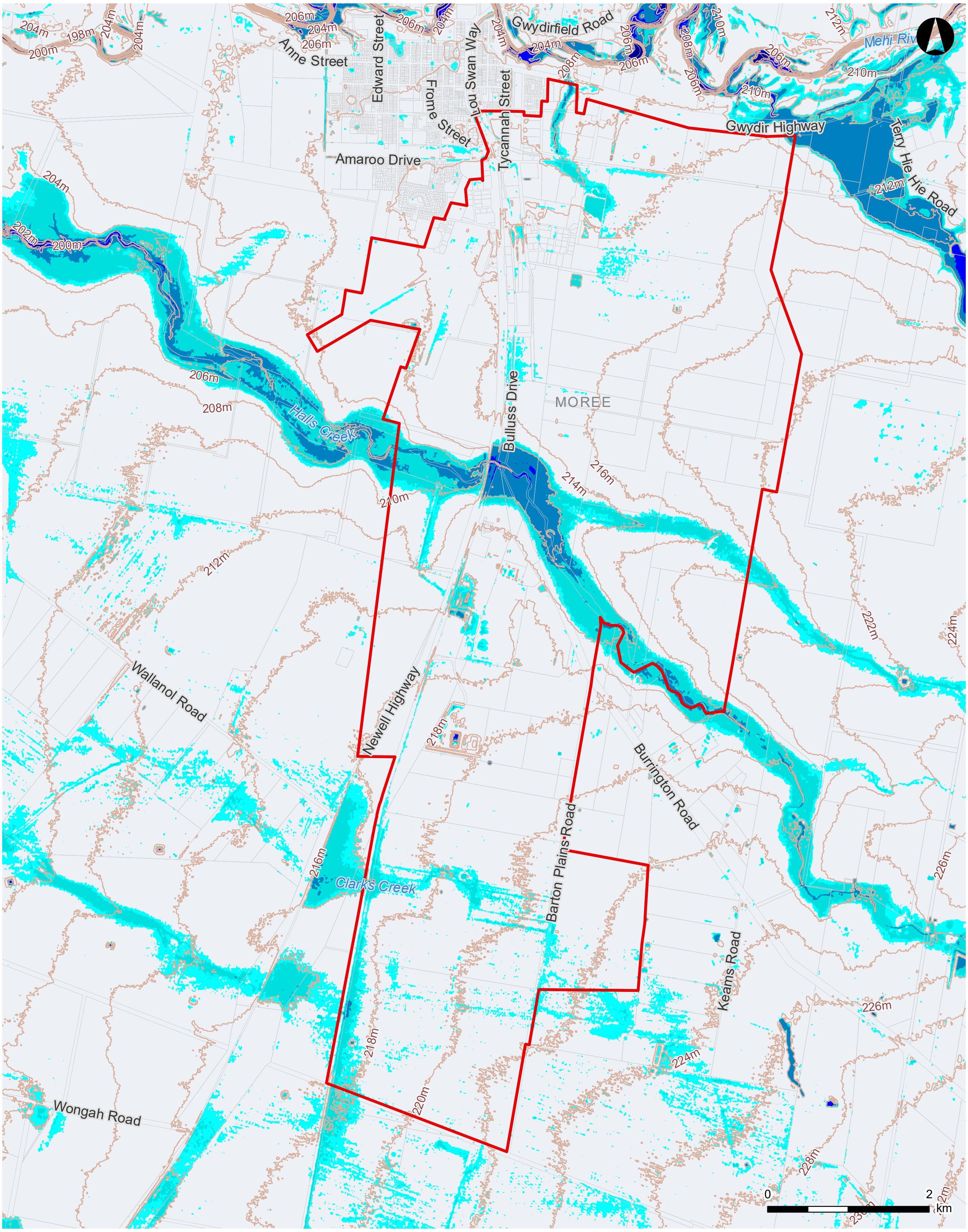
Figure 27 Peak flood levels and depths – 0.5% AEP and Climate Change (+10%)



LEGEND

Proposed SAP boundary

Elevation contour (m)

Flood depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 2.5
- 2.5 - 5
- > 5.0

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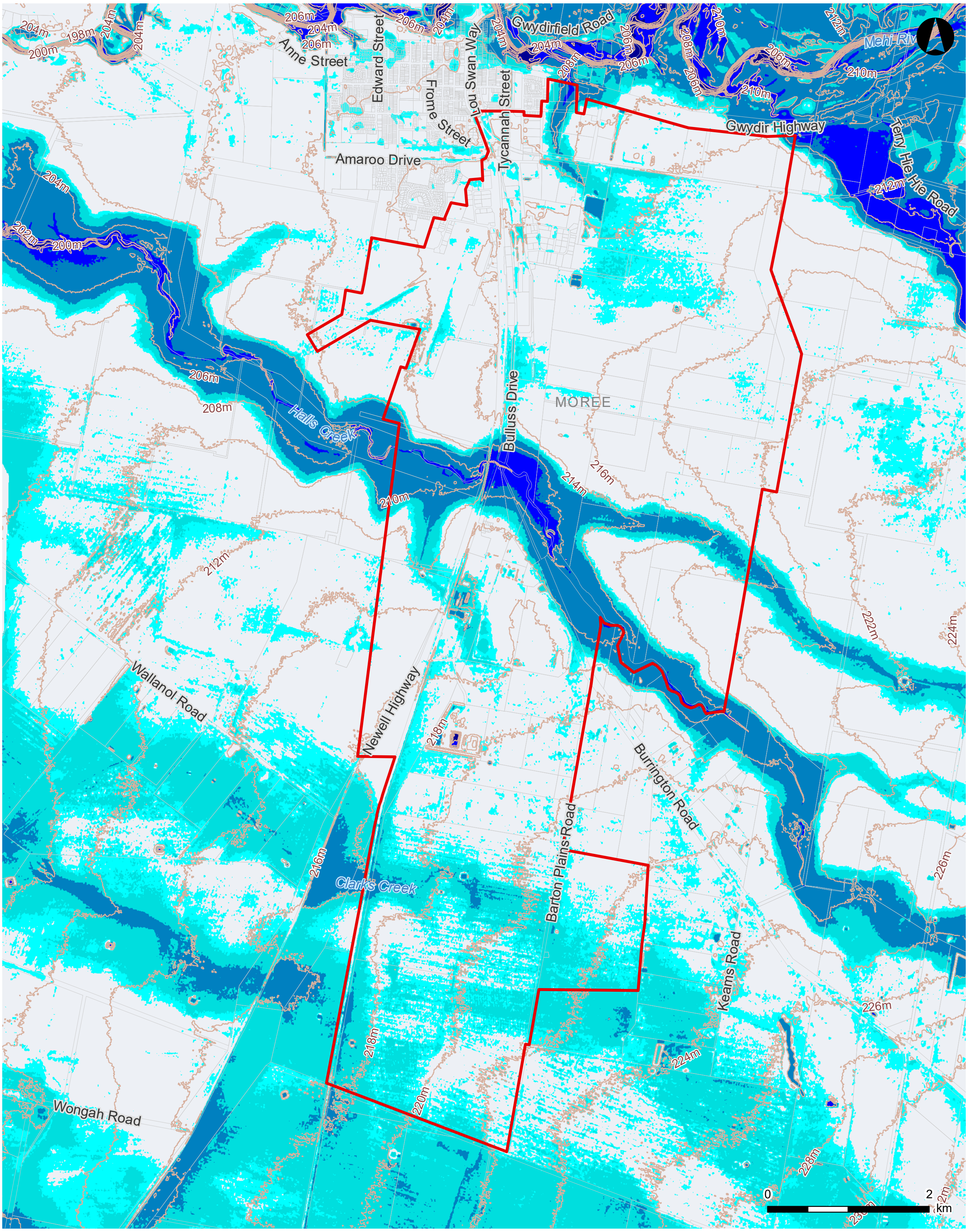
Figure 28 Peak flood levels and depths – 0.2% AEP and Climate Change (+20%)



LEGEND

	Proposed SAP boundary	Flood depth (m)			
	Elevation contour (m)		< 0.3		1.0 - 2.5
			0.3 - 0.5		2.5 - 5
			0.5 - 1.0		> 5.0

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Figure 29 Peak flood levels and depths – PMF event

3.4 Flood Planning Area

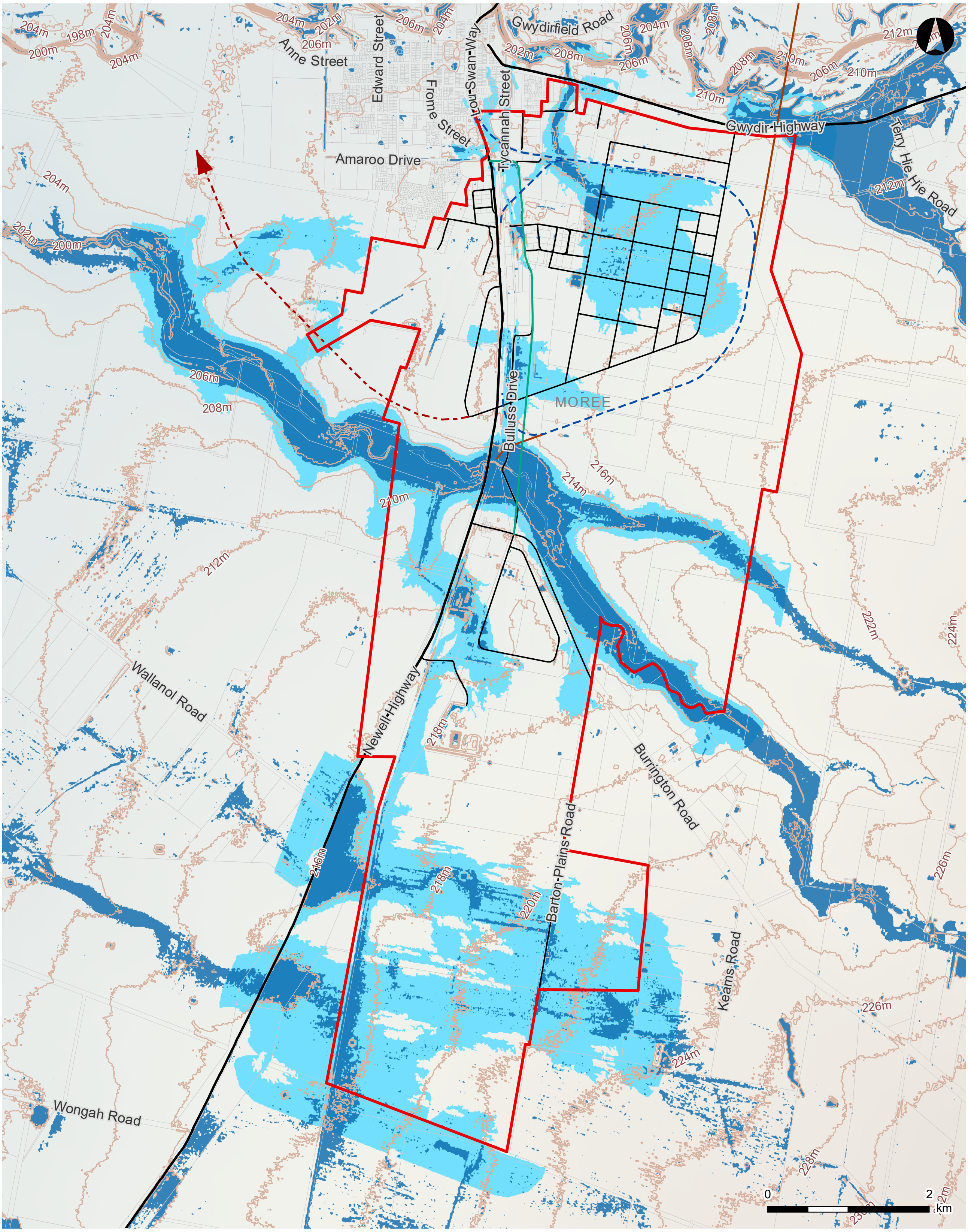
In order to minimise the risks of possible flood affectation for development within the precinct, or creating adverse flood impacts for surrounding properties (upstream and/or downstream), it is proposed to control development of all lands that would typically be defined to be at risk of flooding such as Council's Flood Planning Area (defined as the 1% AEP flood level plus 0.5m freeboard). Based on the flood modelling results for existing flood conditions, the extent of what would be the Flood Planning Area within the SAP site is indicated on Figure 30. As a means of identifying all potentially flood prone lands, the PMF flood extent is also indicated in Figure 33. It should be noted that it is not suggested to restrict development within either the Flood Planning Area or the PMF flood extent but rather any development in these areas should be considered on its merits (and risks) in accordance with the principles of the NSW Floodplain Development Manual (2005). This aspect should be considered in developing the Draft Master Plan for the SAP and identifying any mitigation measures or development controls that may need to be implemented.

3.5 Flood affectation

In order to better quantify the sensitivity of flood affectation in influencing the extent of development potential for the SAP, a range of flood conditions/extents have been mapped for relative comparison:

- Figure 31 - provides a comparison of 1% AEP flood extent for the local SAP catchment areas with that produced for the broader Gwydir-Mehi River system. Within the SAP area the local flood extent is generally greater than that shown for the Gwydir-Mehi flooding.
- Figure 32 – compares the local SAP 1% AEP flood extent with the slightly larger 0.5% AEP extent adopted to also represent possible Climate Change conditions. There is very little difference in overall flood extent evident due to the largely defined or incised nature of Halls Creek keeping the flows in bank.
- Figure 33 – compares the potential Flood Planning Area (represented by 1% AEP flood levels plus 0.5m freeboard) with the flood extent for the PMF event. Within the SAP area there are some flatter areas where the extent of the Flood Planning Area is still slightly greater than that shown for the PMF due to the freeboard provision being greater than the difference in flood levels. However, the overall extent is similar but slightly greater for the PMF through the main parts of Halls Creek where the topography is more defined.

It should be noted that the mapping is intended to help inform the planning process by providing some simple guidance on those areas that are not affected by flooding and the differences in flood extent for differing flood magnitudes. At the same time, it may also help to identify those land use types that might be more amenable to fringe areas of the floodplain with the potential to experience minor inundation (such as agricultural or solar). It is not envisaged that this mapping should predicate or limit the extent of development within the precinct as this should be assessed on its merits in accordance with standard floodplain risk management and planning processes. The actual limitations on development potential with associated building controls and/or mitigation measures are usually defined through the planning processes or by the local council and floodplain management committee. This aspect should be considered in developing the Draft Master Plan for the SAP.



LEGEND

- Elevation contour (m)
- Flood planning area (1% AEP flood level + 500mm)
- 1% AEP flood extent
- Proposed SAP boundary
- Future Regional Road Corridor - Moree Bypass
- North-East Intermodal Loop
- North-South Connector
- Rail Bypass
- Inland Rail
- Highway
- Road network (within SAP boundary)

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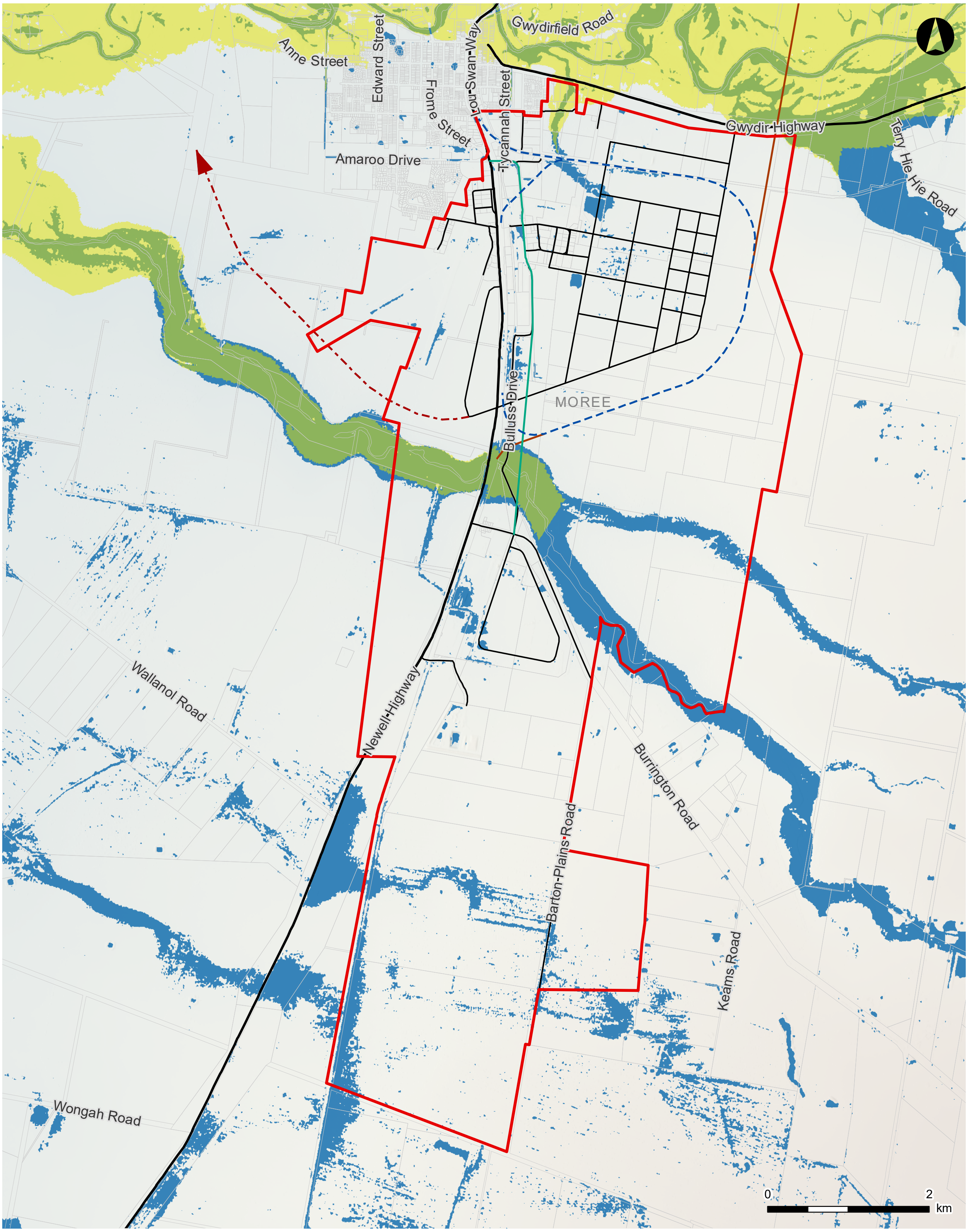
Figure 30 Moree SAP indicative flood planning area – 1% AEP + 0.5m



LEGEND

- 1% AEP flood extent
- 1% AEP flood extent (Gwydir-
- Proposed SAP boundary
- Future Regional Road Corridor - Moree Bypass
- North-East Intermodal Loop
- North-South Connector
- Rail Bypass
- Inland Rail
- Road network (within SAP boundary)
- Highway

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Figure 31 Comparison of flood extents for SAP and Gwydir-Mehi catchments – 1% AEP

LEGEND

- 1% AEP flood
- 0.5% AEP (Climate Change) flood extent
- Proposed SAP boundary
- Future Regional Road Corridor - Moree Bypass
- North-East Intermodal Loop
- North-South Connector
- Rail Bypass
- Inland Rail
- Road network (within SAP boundary)
- Highway

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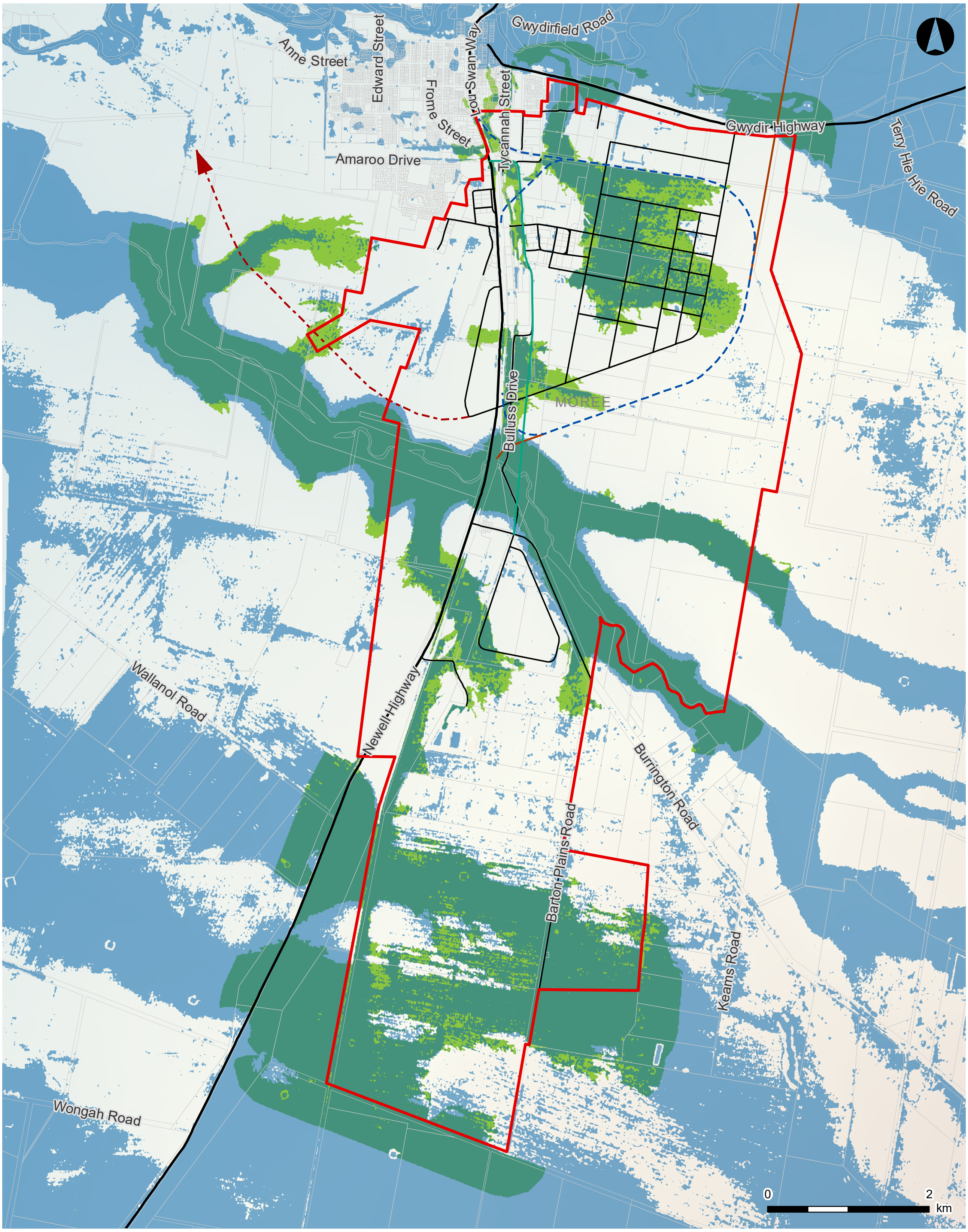
Figure 32 Comparison of flood extents - 1% AEP and 0.5% AEP (Climate Change)



LEGEND

- PMF flood extent
- Flood planning area (1% AEP flood level + 500mm)
- Proposed SAP boundary
- Future Regional Road Corridor - Moree Bypass
- North-East Intermodal Loop
- North-South Connector
- Rail Bypass
- Inland Rail
- Road network (within SAP boundary)
- Highway

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Figure 33 Comparison of flood extents – Flood planning area and PMF

3.6 Water Cycle Management

3.6.1 Information and data

3.6.1.1 Models and data

No models have been assessed as part of the water cycle management assessment for the Moree SAP. A desktop investigation of existing information has been undertaken based on a number of reports and guidelines.

3.6.1.2 State of Environment Reports

The State of Environment Report for the Moree and Narrabri Local Government Areas 2015-216 (Molino Stewart) was reviewed as part of this project. The key points from this report relating to water cycle management as it applies to the future development of the Moree SAP are summarised below:

- In order to treat the stormwater runoff from the area, a number (5) of Gross Pollutant Traps (GPTs) are present within the Moree Plains LGA covering a total catchment area of 171 hectares. This indicates that GPTs may be a preferred treatment method for gross pollutants within the LGA.
- The right to extract irrigation water from surface water sources is regulated under the *NSW Water Management Act 2000*. NSW policy has been to cap the volume of water available for extraction from surface water sources by not increasing the total volume issued under Access Licences. Therefore, future increases of total volume would not be expected unless there is a change in government policy.
- Moree Plains Shire Council reported that it irrigated 89% of its 14.6 hectares of Council-managed parks, sportsgrounds and public open space. As such, open spaces within the SAP would be expected to be irrigated.
- Residential water consumption is quite high for the Moree Plains LGA with annual household potable water usage at over 500kL.

3.6.2 Water quality

Statewide water quality objectives were first outlined in the NSW EPA document ‘Managing Urban Stormwater’ (Nov 1997). The NSW EPA also regulates discharge to waterways and waterbodies via the ANZECC Guidelines for Fresh and Marine Water Quality trigger values. It is not apparent that Moree Plains Shire Council has adapted these guidelines for a local context, as such any developments within the SAP will need to meet the objectives for stormwater quality runoff outlined in Table 3, which are extracted from the ‘Managing Urban Stormwater: soils and construction’ series of documents.

Table 3 Water Quality Objectives for Development within the SAP

Pollutant	Goal / Vision	ESD Treatment Objective
Post Construction Phase:		
Suspended Solids (SS)	Suspended solids load equal to that which would have been exported from the equivalent forested catchment.	85% retention of average annual load
Total Phosphorus (TP)	The load of phosphorus from the catchment that results in the attainment of the ambient water quality concentration objectives.	65% retention of average annual load
Total Nitrogen (TN)	The load of nitrogen from the catchment that results in the attainment of the ambient water quality concentration objective.	45% retention of average annual load

Pollutant	Goal / Vision	ESD Treatment Objective
Litter	No anthropogenic litter in waterbodies. Input of organic litter equal to that which would have occurred from the equivalent forested catchment.	90% retention of average annual load for litter greater than 5mm
Coarse sediment	Course sediment loads equal to those which would have been exported from the equivalent forested catchment.	Retention of sediment coarser than 0.125 mm* for EY peak flow
Oil and grease (hydrocarbons)	No visible oil and grease (anthropogenic hydrocarbons) in water bodies.	In areas with concentrated hydrocarbon deposition, no visible oils for EY peak flow
Construction phase:		
Suspended solids	Suspended solids load equal to those which would have been exported from the equivalent forested catchment.	Maximum SS concentration of 50mg/L for all 5 day rainfalls up to the 75th percentile depth. All practical measures to reduce pollution are to be taken beyond this event.
Other pollutants	No export of toxicants (eg pesticides, petroleum products, construction chemicals) from the site.	Limit the application, generation and migration of toxic substances to the maximum extent practicable

* based on idealised settling characteristics.

Environmentally sensitive receiving environments are unlikely to be impacted by any development within the SAP if appropriate water quality measures are implemented during the design and construction phases. Implementation of water quality measures would also minimise impacts to surface water quality within the SAP area.

A range of mitigation measures are available to protect the water quality of surface waters and groundwater. With the implementation of these measures, the water quality of surface waters and groundwater would be protected in accordance with the water quality objectives.

3.6.3 Groundwater

There is a high reliance on groundwater within the SAP for irrigation purposes. Several water sharing plans have been implemented to reduce extraction volumes. However, current extractions are still running close to the capacities set by the licences (Molino Stewart Pty Ltd, 2016). Therefore, it is unlikely that additional developments within the SAP will be able to rely on groundwater extraction as a primary or supplementary water supply.

Groundwater extraction within the SAP comes from the Lower Gwydir Alluvium, an alluvial aquifer associated with the Gwydir River, which primarily recharges via losses from watercourses (Welsh et al., 2014). Therefore, care must be given to manage runoff draining into local rivers. Runoff draining into the rivers should be minimised where possible and treated sufficiently to minimise the risk of pollutants entering and contaminating the groundwater supply which local farmers rely on.

The infiltration process is generally effective in filtering polluting particles (ARTC 2017). Therefore, it would be beneficial to increase the proportion of runoff infiltrating into the ground and reduce the proportion of runoff draining towards local rivers and streams. However, mitigation steps to treat runoff may still be required for soluble pollutants such as pH altering solutes and hydrocarbons.

4 WATER QUALITY ASSESSEMT

4.1 Overview

The methodology adopted for the water quality assessment incorporated the following:

- A MUSIC model of the Moree SAP area was established with due consideration of the prevailing topography, available climate data, proposed development land use and layouts as well as standard industry accepted parameters as recommended in various guidelines and references.
- The MUSIC model was used to estimate runoff volumes and pollutant loads from the Moree SAP area under the current existing conditions.
- The established model was also modified to represent and assess potential impacts associated with alternative future SAP development scenarios comprising various land use types, areas and distributions. Results from these scenarios provided background information to assist development of the proposed Master Plan during the final Enquiry by Design workshop.
- The model was subsequently updated with details of the proposed Master Plan development for final assessment.
- Possible water quality treatment measures to suit implementation with the development have been identified and assessed within the model to confirm performance against the objectives and targets.
- Results from the MUSIC model have also been used to determine the increase in volumes of stormwater runoff that may possibly be harvested and re-used for different applications within the SAP.

4.2 Stormwater quality management design criteria

4.2.1 Objectives

From a stormwater management perspective, the primary objective of the SAP development is to ensure that conditions downstream of the development (both quantity and quality of runoff) should be no worse than the existing situation and where possible and practical may even be improved. Accordingly, the following criteria have been assumed for the purposes of assessing the potential mitigation measures required:

- Runoff volumes discharged to the downstream receiving environment to be maintained at or close to existing.
- Pollutant loads discharged to the downstream receiving environment to be maintained at or close to existing (ie. In accordance with the neutral or beneficial effect – NORBE principle).

4.2.2 Water quality targets

The Moree Plains Development Control Plan 2013 was reviewed for requirements for the management of stormwater runoff quality and in particular pollutant retention targets. The DCP 2013 does not provide any specific guidance on water quality pollution reduction targets. The only exception to this is for the development of feedlots where the development needs to demonstrate no negative water quality outcomes (similar to the NORBE principle).

For the purposes of assigning water quality treatment requirements for this Moree SAP project, the pollutant retention targets as per Table 3 have been adopted.

4.3 MUSIC modelling

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC model) has been used to estimate stormwater runoff volumes and pollutant loads (including TSS, TP, TN and gross pollutants) for the SAP catchments under existing and proposed development conditions. This model was chosen as it can estimate the quantity and quality of surface water generated at a site under a range of conditions and also assess the relative effectiveness of potential mitigation measures.

The adoption of MUSIC modelling for the purpose of this report represents an industry best practice approach to water quality management in design.

4.3.1 Adopted input data and parameters

The MUSIC model combines a rainfall-runoff and stochastic pollutant generation algorithm to estimate the quantity and quality of runoff generated from catchments based on the level of assumed development (imperviousness) and using the following inputs:

- a meteorological template which details rainfall and potential evapotranspiration inputs
- source nodes which define the catchment properties, including land use type, catchment area impervious percentage and rainfall storage properties
- treatment nodes which represent the proposed water quality treatment measures.

Again, Council's DCP and Engineering Guides were reviewed and no information for these parameters were found to be readily available. Therefore, the required rainfall and climate information was obtained from the Bureau of Meteorology (BoM) while other required input parameters were sourced from the WaterNSW Standard *Using MUSIC in Sydney Drinking Water Catchment* and used to help set up the MUSIC models.

4.3.2 Rainfall data

Rainfall gauge data is used to inform the MUSIC model of rainfall intensity and duration for storm events recorded over a period of time and applies this to the catchments represented in the model to simulate the rainfall-runoff process using actual rainfall data for the local area.

The nearest and most appropriate rainfall station is located at Moree Regional Airport, within the SAP boundary, and 25 years of data was sourced from the BoM as per the details presented in Table 4. A summary of the mean rainfall recorded on a monthly basis is shown in Figure 34.

Table 4 Rainfall station data used for MUSIC modelling

Parameter	Details
Name	Moree Aero AWS 053115
Proximity to site (km)	0
Time step	6 minutes
Data Period	1995 to 2010
Mean annual rainfall (mm)	531

4.3.3 Potential evapotranspiration (PET) data

Potential Evapotranspiration (PET) data informs the rate at which rainfall or moisture is removed from the model. Typically, higher PET rates will result in lower runoff rates and volumes. Data for the mean daily evaporation rates sourced from the BoM and input to the MUSIC model are summarised in Figure 35. The average daily evaporation is 6.4mm and the annual evaporation is 2335mm.

MOREE AERO

Mean rainfall (mm)

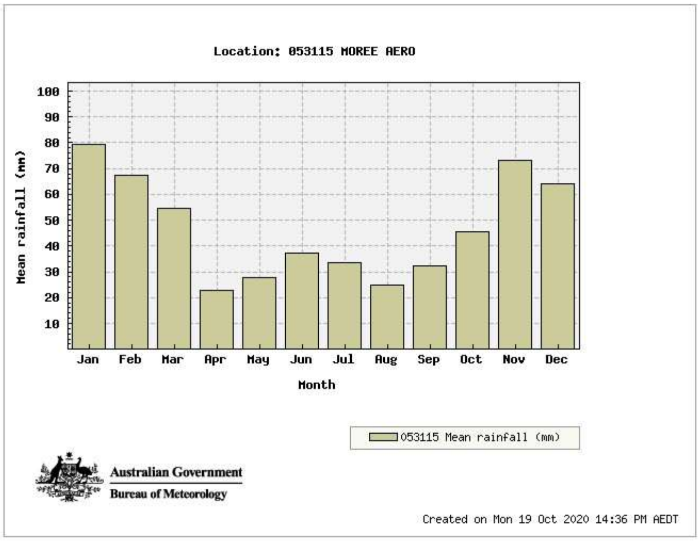
Site details

Site name: MOREE AERO **Site number:** 053115 **Commenced:** 1995
Latitude: 29.49 °S **Longitude:** 149.85 °E **Elevation:** 213 m **Operational status:** Still Open

Yearly data | 30 year statistics | Comparison site | First statistic | Second statistic

Note: Only one option can be redrawn at a time

Include data for the year: 2020 Redraw



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean rainfall (mm) for years 1995 to 2020	79.4	67.6	54.8	22.8	27.7	37.4	33.5	25.0	32.1	45.7	73.2	64.3	561.0	25

Figure 34 Mean monthly rainfall (mm) - Moree Airport

MOREE AERO

Mean total evaporation (mm)

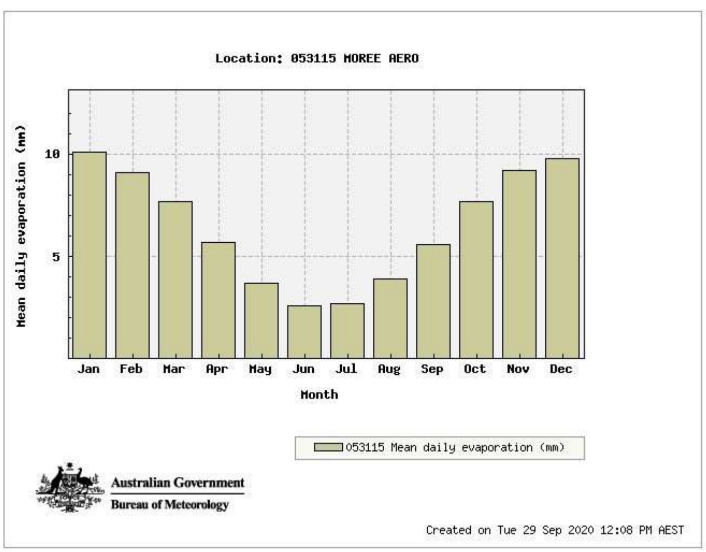
Site details

Site name: MOREE AERO **Site number:** 053115 **Commenced:** 1995
Latitude: 29.49 °S **Longitude:** 149.85 °E **Elevation:** 213 m **Operational status:** Still Open

Yearly data | 30 year statistics | Comparison site | First statistic | Second statistic

Note: Only one option can be redrawn at a time

Compare with statistics for the 30 year period: N/A Redraw



Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years
Mean daily evaporation (mm) for years 1995 to 2016	10.1	9.1	7.7	5.7	3.7	2.6	2.7	3.9	5.6	7.7	9.2	9.8	6.5	21

Figure 35 Mean daily evaporation (mm) - Moree Airport

4.3.4 Runoff and soil parameters

Runoff and soil parameters inform the amount of rainfall that can be stored and absorbed by the catchment surface. As rainfall is removed from the model through the catchment surface, there will be less runoff and less pollutants being mobilised within the catchment. Table 5 outlines the runoff and soil parameters adopted in the MUSIC models based on the WaterNSW Standard.

Table 5 Runoff and soil parameters

Parameter	Agricultural	Urban
Impervious area parameters:		
Rainfall threshold (mm)	1	1
Pervious area parameters:		
Soil storage capacity (mm)	120	120
Initial storage (% of capacity)	25	25
Field capacity (mm)	99	99
Infiltration capacity Coefficient a	180	180
Infiltration capacity Coefficient b	3	3
Groundwater properties:		
Initial depth (mm)	10	10
Daily recharge rate (%)	25	25
Daily base flow rate (%)	25	25
Deep seepage rate (%)	0	0

4.3.5 Land use surface runoff characteristics

The surface runoff characteristics typically inform the amount of runoff (flow and volume) from a catchment and are largely based on the proportion of impervious to pervious area (paved or hard surfaces compared to natural or vegetated). The percentage of imperviousness typically varies depending on the amount of development within the sub-catchment and the type of land use. The values applied within the MUSIC model for the different land use types are summarised in Table 6.

Table 6 Precinct land use – Assumed surface runoff characteristics

Precinct Land Use	% Imperviousness	% Pervious
Agricultural:		
Horticulture & Intensive Agriculture	40	60
Traditional Native Horticulture	5	95
Industrial/Commercial:		
Intermodal	90	10
Freight & Logistics	80	20
Resource Recovery	60	40
Value Add Agriculture	50	50
Bio Energy/ High Impact	60	40
Energy/Solar	5	95
Enterprise/Industrial	75	25
Hub	75	25

4.3.6 Pollutant source parameters

Pollutant source parameters inform the amount of pollutant material that is likely to be generated from a catchment and varies according to the physical characteristics of a catchment surface and its land use. Table 7 summarises the pollutant concentrations adopted in the MUSIC models based on the WaterNSW Standard.

Table 7 Pollutant source concentrations

Land use		Log10 Pollutant Concentration (mg/L)					
		TSS		TP		TN	
		Base Flow	Storm Flow	Base Flow	Storm Flow	Base Flow	Storm Flow
Agricultural	Median	1.40	2.30	-0.88	-0.27	0.074	0.59
	Std Dev	0.13	0.31	0.13	0.30	0.13	0.26
Vegetation (Forest)	Median	0.90	1.90	-1.50	-1.10	-0.14	-0.075
	Std Dev	0.13	0.20	0.13	0.22	0.13	0.24
Industrial/ Commercial	Median	1.10	2.20	-0.82	-0.45	0.32	0.42
	Std Dev	0.17	0.32	0.19	0.25	0.12	0.19

4.4 Existing Conditions

4.4.1 Sub-catchments and land uses

A MUSIC model representing the SAP site under existing conditions was established using the topography contour information indicated on Figure 36 with the associated land use for existing conditions inferred from the underlying aerial photo image (September 2015).

Across the overall SAP site there are three main catchments discharging to downstream waterways. There is a reasonably sized area in the north east corner of the SAP site that drains to the Mehi River and a large portion to the south that drains into Clarks Creek. Otherwise, the majority of the site drains into Halls Creek. The layout of the model has therefore been set up to represent and reflect the potential different runoff characteristics and impacts to these receiving environments.

4.4.2 Source nodes

Using the available topographic contour information and with due consideration of the likely maximum future land use development within the different precinct areas, the existing SAP study area was divided into 8 sub-areas to represent the different source node types. It should be noted that for the purposes of comparing overall result differences, the base case values representing existing conditions are taken from the MUSIC model associated with ultimate development layout. The MUSIC model source nodes and extents for each sub-precinct catchment are indicated in Figure 36.

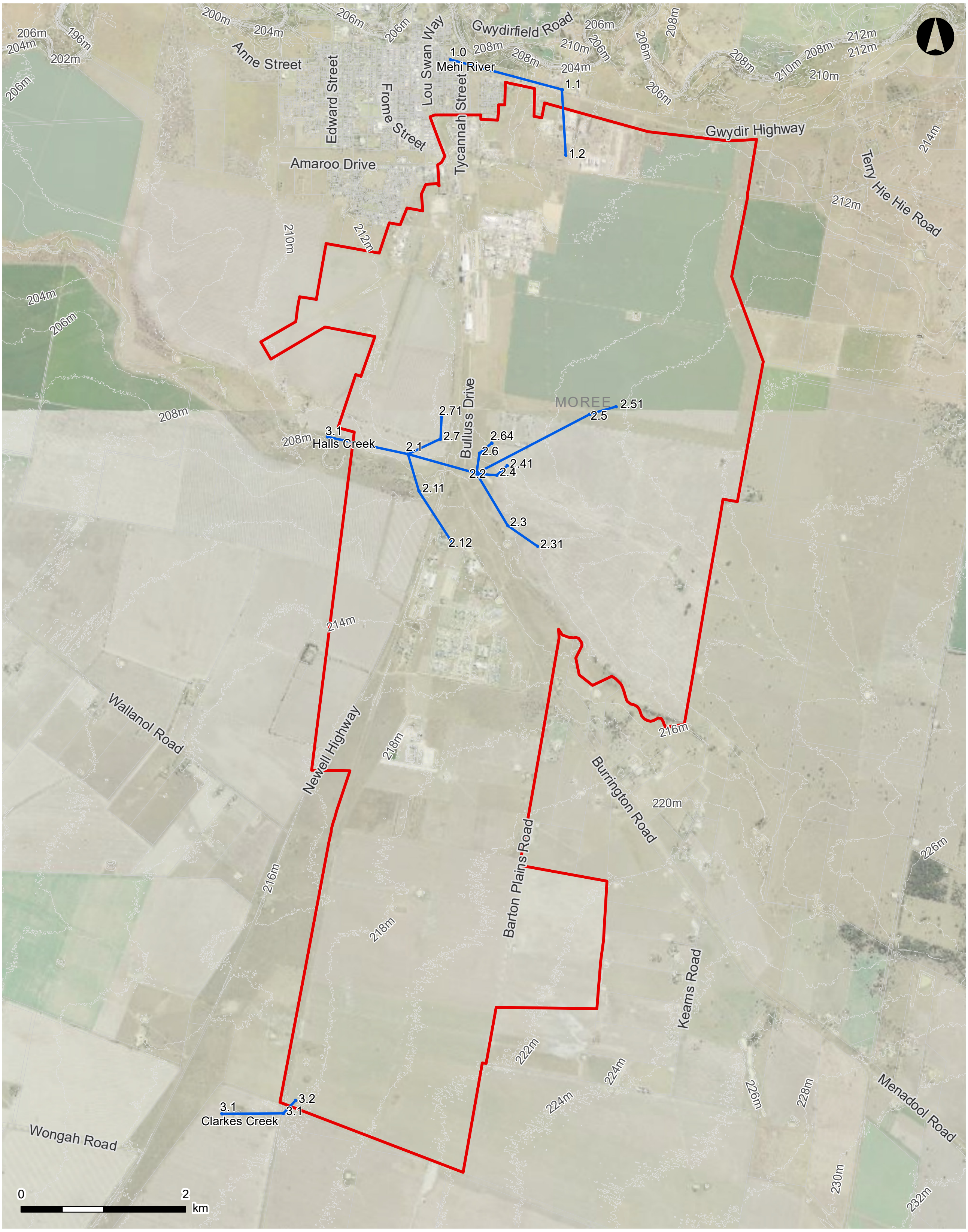
4.4.3 Results for existing conditions

A summary of flow volume and water quality results within the Moree SAP area under existing conditions is presented in Table 8. The results show a breakdown of the relative contributions from each of the three main sub-catchments as well as an overall total for comparative purposes to the proposed Master Plan conditions.

The results show that as to be expected, Halls Creek being the largest catchment generates the highest flow volumes and pollutant loads for all parameters.

Table 8 MUSIC modelling results – Existing conditions

Parameter	Units	Mehi River	Halls Creek	Clarks Creek	*Total*
Flow	ML/y	544	630	342	***1,516***
TSS	kg/y	101,000	112,000	59,100	***272,100***
TP	kg/y	422	473	269	***1,164***
TN	kg/y	1,930	22,300	1,190	***5,420***
Gross Pollutants	kg/y	19,200	22,200	12,100	***53,500***



LEGEND

Elevation contour (m)

MUSIC model layout

Proposed SAP boundary

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Aerial imagery supplied NSW LPI

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Figure 36 Existing Conditions MUSIC model

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Created by : NS Updated by : NS QA by : IR

4.5 Master Plan conditions – Unmitigated

4.5.1 Overview

In order to assess the relative merits and/or potential impacts of the proposed development for the Moree SAP, the sub-precinct catchments were modified to represent the assumed changes in impervious area associated with the different land use types. A summary breakdown of the precinct development areas with percentage imperviousness assumptions is provided in Table 10 for each sub-precinct land use. Details of the underlying assumptions associated with development of this table are provided separately in Table 11. The MUSIC model was then run without any mitigation measures in place so as to quantify the maximum potential changes in runoff volumes and water quality requiring treatment.

Following consideration of the unmitigated results and the development layout, the models were further modified to incorporate possible mitigation treatment measures and then rerun to confirm the required performance outcomes were achieved.

4.5.2 Unmitigated results

The MUSIC model layout for the Master Plan conditions including source nodes for each sub-precinct catchment is indicated in Figure 37.

A summary of the change in flow volume and water quality results within the Moree SAP area under the unmitigated Master Plan conditions is presented in Table 9**Error! Reference source not found.**. The results show a breakdown of the relative contributions from Mehi River and Halls Creek sub-catchments noting there was no development or change within the Clarks Creek catchment. Detailed results for each of the sub-precinct nodes under pre and post development conditions is included in Appendix C.

Table 9 MUSIC model results – unmitigated Master Plan conditions

Parameter	Units	Mehi River	Halls Creek	Clarks Creek	*Total*
Flow	ML/y	1,560	1,570	392	***3,532***
TSS	kg/y	335,000	340,000	85,400	***760,400***
TP	kg/y	787	647	184	***1,618***
TN	kg/y	4,220	3,740	998	***8,958***
Gross Pollutants	kg/y	54,300	46,900	10,600	***111,800***

Moree special activation precinct

Table 10 Assumed sub-precinct development breakdown

Precinct	Sub Precinct land use	Total Area (Ha)	Roads and other infrastructure (Ha)	[1]Assumed Land developed (Ha)	Net land developed in 40 years (Ha)	Assumed Impervious %	Impervious Area (Ha)
Enterprise (NE Precinct)	Intermodal	155	15 (10%)	70	100	90	88
	Freight & Logistics	195	20 (10%)	60	105	80	84
	Horticulture & Intensive Agriculture	240	25 (10%)	80	170	40	67
	Value Add Agriculture	145	15 (10%)	60	80	50	39
	Resource Recovery	110	10 (10%)	50	50	60	30
	Sub-total	***845***	***85***		***505***		***308***
High Impact (Central Precinct)	Value Add Agriculture	85	15 (15%)	60	40	50	21
	Intermodal	70	10 (10%)	70	40	90	38
	Bio Energy/ High Impact	35	5 (15%)	50	15	60	9
	Sub-total	***190***	***30***		***95***		***68***
High Impact (South)	Potentially Hazardous	25	1 (5%)	55	13	40	5
	Sub-total	***25***	***1***		***13***		***5***
Solar	Parcel 1	102	5 (5%)	75	70	5	4
	Parcel 2	235	10 (5%)	75	170	5	8
	Parcel 3	190	10 (5%)	75	135	5	7
	Parcel 4 (South)	475	25 (5%)	75	340	5	17
	Sub-total	***1,002***	***50***		***715***		***36***
Gateway	Hub	60	12 (20%)	50	24	75	18
	Sub-total	***60***	***12***		***24***		***18***
Total Developed Area		**2,122**	**178**		**1,352**		**435**

Note: 1. Percentages of land area developed within the various sub-precincts assumes a 40 year horizon based on findings and inputs from other economic and development studies prepared for the Moree SAP

Moree special activation precinct

Table 11 Precinct development assumptions[1]

[1]Precinct	Assumption details
Regional Enterprise (north-eastern precinct)	Net developed area = 462ha. The sum of the first 4 land uses in the notional land allocation table equates to 462ha and therefore it is assumed this precinct comprises these land types.
	Arrangement of land uses on parcel are not necessarily representative of their actual location.
	Intermodal has been split 70%:30% between the NE and Central precincts respectively.
	Value Add Agriculture has been split 65%:35% between the NE and Central precincts respectively. This redistributes the given net-developable land (after infrastructure allocations) so that both the NE and Central precincts are within the provided parcel size.
Regional Enterprise (central precinct)	This has been assumed to be the sum of the remaining land-uses.
	The bio protection area has not been modelled as it is assumed that it is a natural area that drains straight into the creek.
	Intermodal and Value Add areas have been split between the main precincts (refer above)
Regional Enterprise (Potentially hazardous)	The surface runoff characteristics assumed for this area is governed by the buffer zone as it is assumed that this would be much larger than the facility itself. The imperviousness factor is therefore assumed to be 40% to align with horticulture/intensive agriculture.
	The water demand requirement is assumed to be the same as energy/high impact land use
Solar	Parcel size for the third solar site that drains to Halls Creek was calculated to be 190Ha, as 527Ha was provided as the total north/central solar area (527 - 102 - 235 = 190Ha)
	Potentially hazardous land use has been modelled as horticulture & Intensive Agriculture because the buffer zone resembles these conditions. It is assumed that the buffer zone accounts for the majority of this land use.
	Hazardous land-use located in the southern solar parcel as per the provided map (see provided 95% Master Plan Map)
General	The storage requirements have been sized assuming a depth of 1m. This is considered to be conservative in quantifying a potential footprint area as it represents the worst-case scenario in terms of land take. The storages could be made deeper to reduce land take and also reduce evaporation losses.
	It is assumed that the solar development parcels may require some water (e.g. for cleaning the panels etc) and therefore storages have been included in order to also quantify the potential surface water runoff contribution that may be on offer for re-use from each area.
	The storages adopted for modelling purposes have been based on the minimum storage requirements.

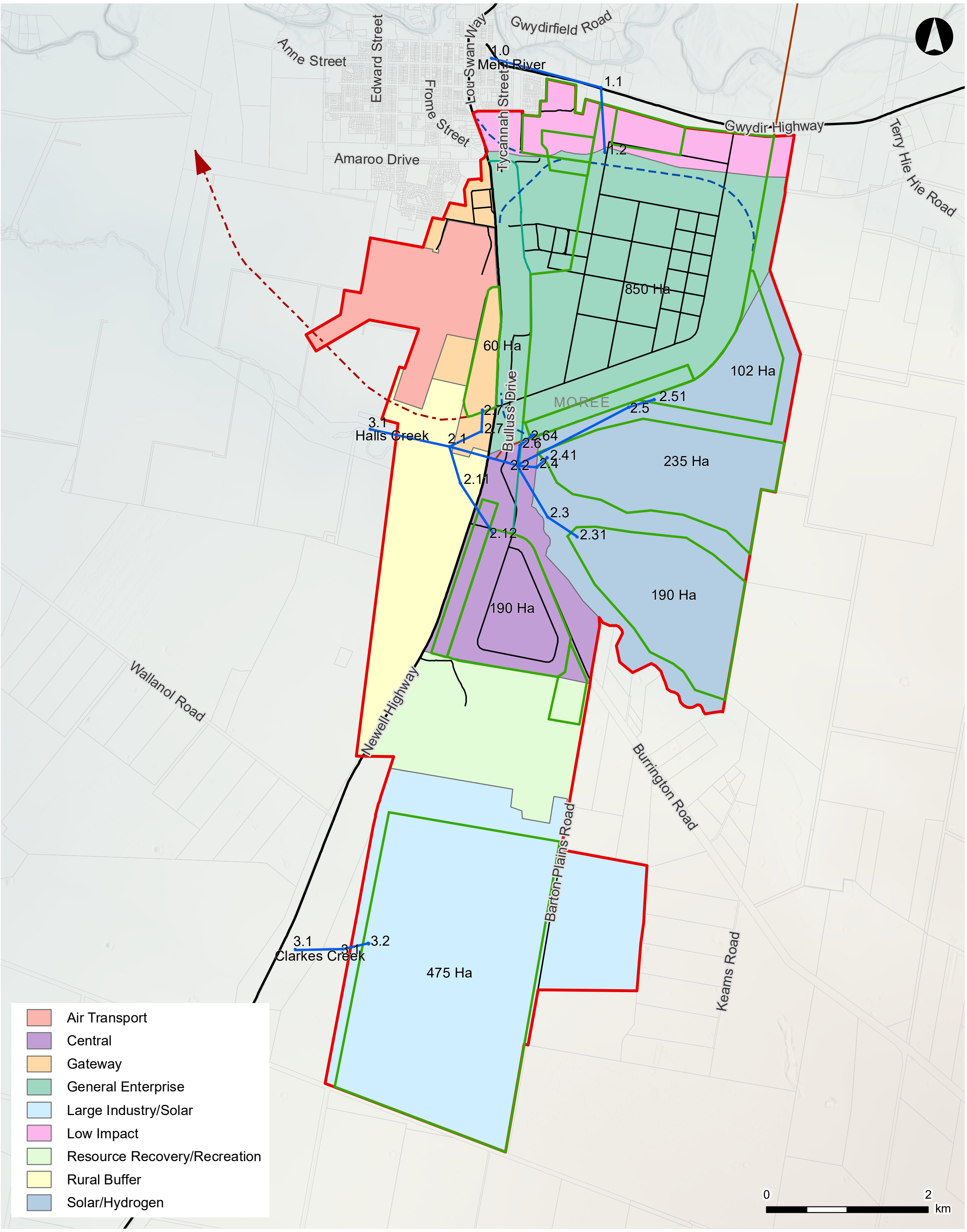
Note: 1. Refer to Table 10 for breakdown of assumed sub-precinct development details

Moree special activation precinct

Table 12 Summary details for water demand and storage requirements

Land use	*Total Area (ha)*	*Infrastructure allocation (ha)*	*Net developable (ha)*	*Annual area water demand (ML/ha/yr)*		*Annual water demand (ML/yr)*		*Daily water demand (kL/yr)*		*[1]Storage requirement (m^3)*	
				Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Regional Enterprise (north east precinct)											
Intermodal	155	15	140	3	3	420	420	1,151	1,151	34,530	34,530
Freight & logistics	195	20	175	3	3	525	525	1,438	1,438	43,140	43,140
Horticulture/native	240	25	215	5	9	1,150	2,070	3,151	5,671	88,350	159,030
Value add agriculture	145	15	130	3	82	360	9,840	986	26,959	32,040	876,150
Resource recovery	110	10	100	3	3	300	300	822	822	24,660	24,660
Sub-Totals	**845**	**85**	**760**							**188,190**	**1,102,980**
Regional Enterprise (central precinct)											
Value add agriculture	85	15	70	3	82	240	6,560	658	17,973	17,250	471,780
Intermodal	70	10	60	3	3	180	180	493	493	14,790	14,790
Bio-energy	35	5	30	5	7.5	150	225	411	616	12,330	18,480
Sub-Totals	**190**	**30**	**160**			**570**	**6,965**			**43,370**	**505,050**
Potentially hazardous	25	1	24	3	7.5	71	178	195	488	5,850	14,640
Gateway	60	12	48	3	3	144	144	395	395	11,850	11,850
Regional enterprise Totals	**1120**		**992**			**785**	**7,287**			**61,070**	**531540**
Solar											
Parcel 1	102	5	95								
Parcel 2	235	10	225								
Parcel 3	190	10	180								
South	475	25	450								
Solar Totals	**1002**	**50**	**950**								

Note: 1. Storage assumes capacity required to satisfy demand over 30 day period



LEGEND

MUSIC model layout

- Catchments
- Nodes
- Proposed SAP boundary
- Future Regional Road Corridor - Moree Bypass
- North-East Intermodal Loop
- North-South Connector
- Rail Bypass
- Inland Rail
- Road network (within SAP boundary)
- Highway

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Coordinate System: GDA 1994 MGA Zone 55
Date issued: February 18, 2021
Aerial imagery supplied NSW LPI

1:70,000 at A4

Figure 37 Master Plan MUSIC model layout

Date: 18/02/2021 Path: \\HC-AUS-NS-FS-01\jobs\30051523\D-DigitalEng\DG-GIS\A_Current\B_Maps\MSAP_Report\MSAP_037_MasterPlanMUSICLayout_A4P_v3.mxd
Created by : NS Updated by : NS QA by : IR

4.6 Mitigation treatment

4.6.1 Mitigation measures

A range of possible stormwater quantity and quality management measures (runoff detention and water quality treatment) were considered to mitigate the potential impacts associated with development of the Moree SAP. Such measures include:

- Rainwater tanks
- Detention/Retention basins
- Gross pollutant traps
- Proprietary treatment devices
- Vegetated swales
- Bioretention basins
- Wetlands
- Ponds

Based on these possible measures, an indication of a proposed mitigation strategy for the Moree SAP has been prepared. The proposed strategy is intended to satisfy both the demands for stormwater re-use as well as the water quality targets described in Section 4.2.2. In summary the strategy consists of the following integrated components:

- On-lot water quality controls for the industrial and enterprise land uses.
- A formal trunk drainage network, consisting of underground pipes and vegetated swales and channels, is proposed to collect and convey runoff from the public domain infrastructure as well as the pre-treated site runoff from the industrial/commercial catchments into the retention storages and their co-located treatment ponds.
- Retention/detention basins to reduce the increase in flow volumes associated with development such that they would be similar to existing pre-developed conditions prior to discharging to downstream areas. The basins would also provide storage capacity to satisfy demands for stormwater re-use within the development area.
- Water quality control ponds to manage the runoff from agricultural and intermodal uses and the remainder of the industrial/enterprise areas. These would typically be co-located within the retention/detention basins.

The MUSIC models established to represent existing (refer Section 4.4) and then unmitigated development conditions (Section 4.5) were further modified to assess the performance of the proposed water cycle management strategy. In this case the proposed development areas were further subdivided with general provision for roads and public domain open space, the developed industrial/enterprise land use itself and then the remainder of the site represented as a separate node. These developed industrial/enterprise areas were then managed assuming on-lot water quality treatment measures. The remaining area consisting of the public domain infrastructure, open space and less developed areas is then directed to the site/sub-precinct treatment pond. It should be noted that the on-lot treatment runoff is also directed to the storage basin and treatment pond.

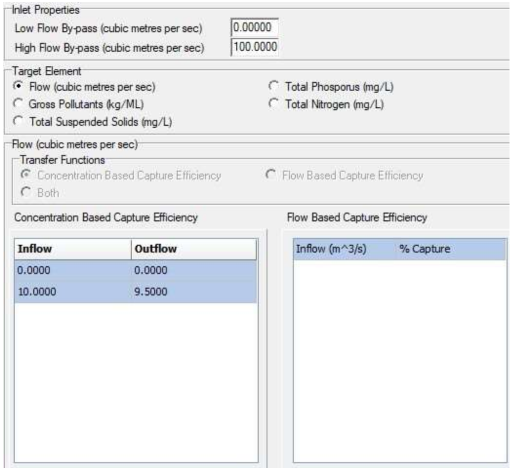
4.6.2 Treatment node parameters

4.6.2.1 On-lot treatment

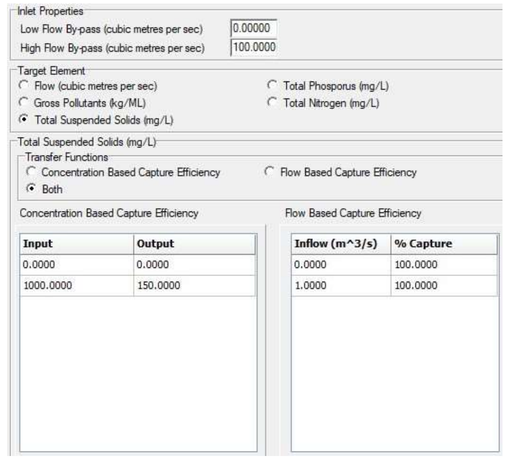
A generic treatment node, representing the on-lot/site treatment for industrial/enterprise development, was defined and incorporated into the MUSIC model. This node acknowledges that there will be some form of on-lot treatment provided that will enable the water quality objectives to be met but does not specify how this will be achieved leaving this choice to the future developer of the site. Details of the assumed transfer functions used in the generic node are summarised in Table 13. Applying these transfer functions allows the node to achieve the required water quality objectives of 85% TSS, 65% TP and 45% TN. Additionally, the flow transfer function includes allowance for capturing up to 5% of runoff to account for the possible implementation of local on-lot/site rainwater tanks.

Table 13 – MUSIC model transfer functions - On-lot treatment

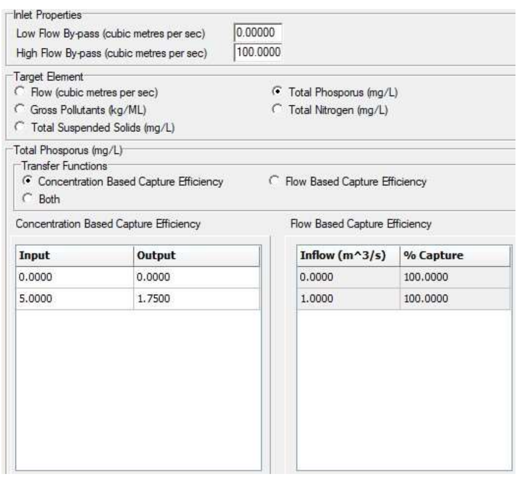
Flow:



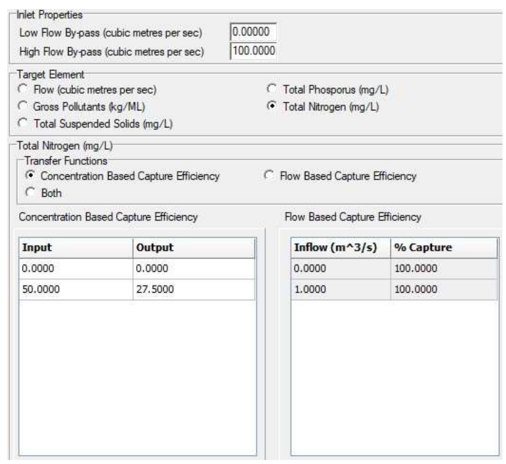
TSS:



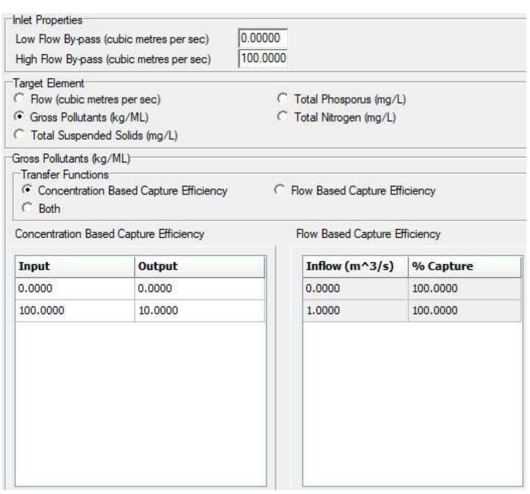
Total Phosphorus (TP):



Total Nitrogen (TN):



Gross Pollutants:



4.6.2.2 Treatment ponds

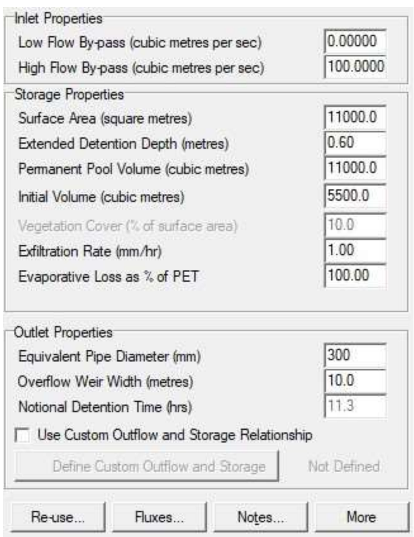
For the management of runoff from the remainder of the site/sub-precinct it was decided to use treatment ponds as the primary mitigation measure. Treatment ponds were selected over the typical bioretention or wetland options in order to assist in provisioning for the estimated water demand (water reuse) for the various land uses.

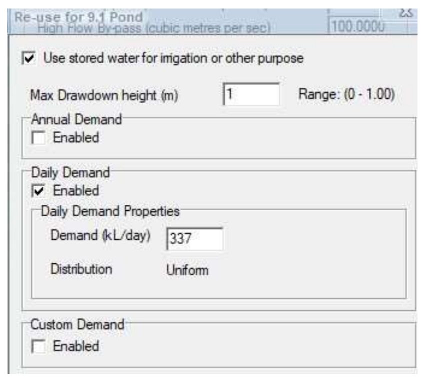
An indication of the water demand for the various land uses was obtained from the *Moree SAP_Water Demand Estimate (Preliminary 14102020)* and *Stage 3 Draft Water Balance 041220* prepared by WSP as part of this project. The ponds were initially sized based on satisfying the minimum demand rate from the estimate and then providing up to 30 days storage in an effort to provide some means of security for the supply.

This initial pond sizing was then entered into the MUSIC model and run to determine if the water quality objectives would also be achieved. Where the objectives were not satisfied, the pond size was then increased as much as practical to try and achieve compliance.

A summary of the typical properties and performance characteristics assumed for the treatment ponds within the MUSIC model is presented in Table 14.

Table 14 MUSIC model characteristics - Treatment ponds





4.6.3 Master Plan conditions – Mitigated

The established MUSIC model representing the development extent for the Master Plan was further modified to incorporate and represent the proposed mitigation treatment measures described in Section 4.6.1. A summary of the indicative details for water quality treatment ponds associated with these mitigated conditions is provided in Table 15 with the size and locations indicated on Figure 38.

The model was run with the proposed mitigation treatment measures in place and the resulting change in flow volume and water quality within the Moree SAP area from unmitigated to mitigated Master Plan conditions is presented in Table 16. The results provide a breakdown of the relative contributions from each of the three main sub-catchments.

Detailed results for each of the sub-precinct nodes under existing (Pre), unmitigated developed (Dev) and developed with mitigation (Post) conditions are included in Appendix C. Also included in Appendix C for reference purposes are a series of graphs that compare the change in runoff outflow hydrographs (under pre, developed and post mitigation conditions) for an indicative period of one year (1999) broken into the different seasons.

Table 15 Summary details for indicative treatment ponds – Master Plan conditions

Node	Precinct	Surface area (m^2)	[1]Width (m)	[1]Length (m)	[2]Depth (m)	Permanent pool volume (m^3)
1.2	NE Enterprise	110,000	200	550	1.0	110,000
2.71	Hub/Gateway	10,000	65	150	1.0	10,000
2.64	NE Enterprise (Intermodal)	60,000	120	500	1.0	60,000
2.12	High Impact	30,000	100	300	1.0	30,000
3.2	Solar & High Impact Industry	500	10	50	1.0	500

Note: 1. The width and length of ponds are provided as an estimate of the footprint only and while a single pond size is provided this could ultimately be split into a number of ponds to suit the urban design outcome or development layout.
2. The total depth is assumed to comprise up to 1.0m of retention storage depth for stormwater re-use. The pond also incorporates provision for an additional 0.6m of extended detention for water quality treatment.

Table 16 MUSIC model results – mitigated Master Plan conditions

Parameter	Units	Unmitigated	Treated Residual	% reduction
Mehi River				
Flow	ML/y	1,560	579	63
TSS	kg/y	335,000	28,800	91
TP	kg/y	787	116	85
TN	kg/y	4,220	1,010	76
Gross Pollutants	kg/y	54,300	33	100
Halls Creek				
Flow	ML/y	1,570	731	53
TSS	kg/y	340,000	104,000	69
TP	kg/y	647	253	61
TN	kg/y	3,740	1,540	59
Gross Pollutants	kg/y	46,900	9,930	79
Clarks Creek				
Flow	ML/y	402	358	11
TSS	kg/y	85,400	52,600	38
TP	kg/y	184	140	24
TN	kg/y	998	743	26
Gross Pollutants	kg/y	10,600	1	100

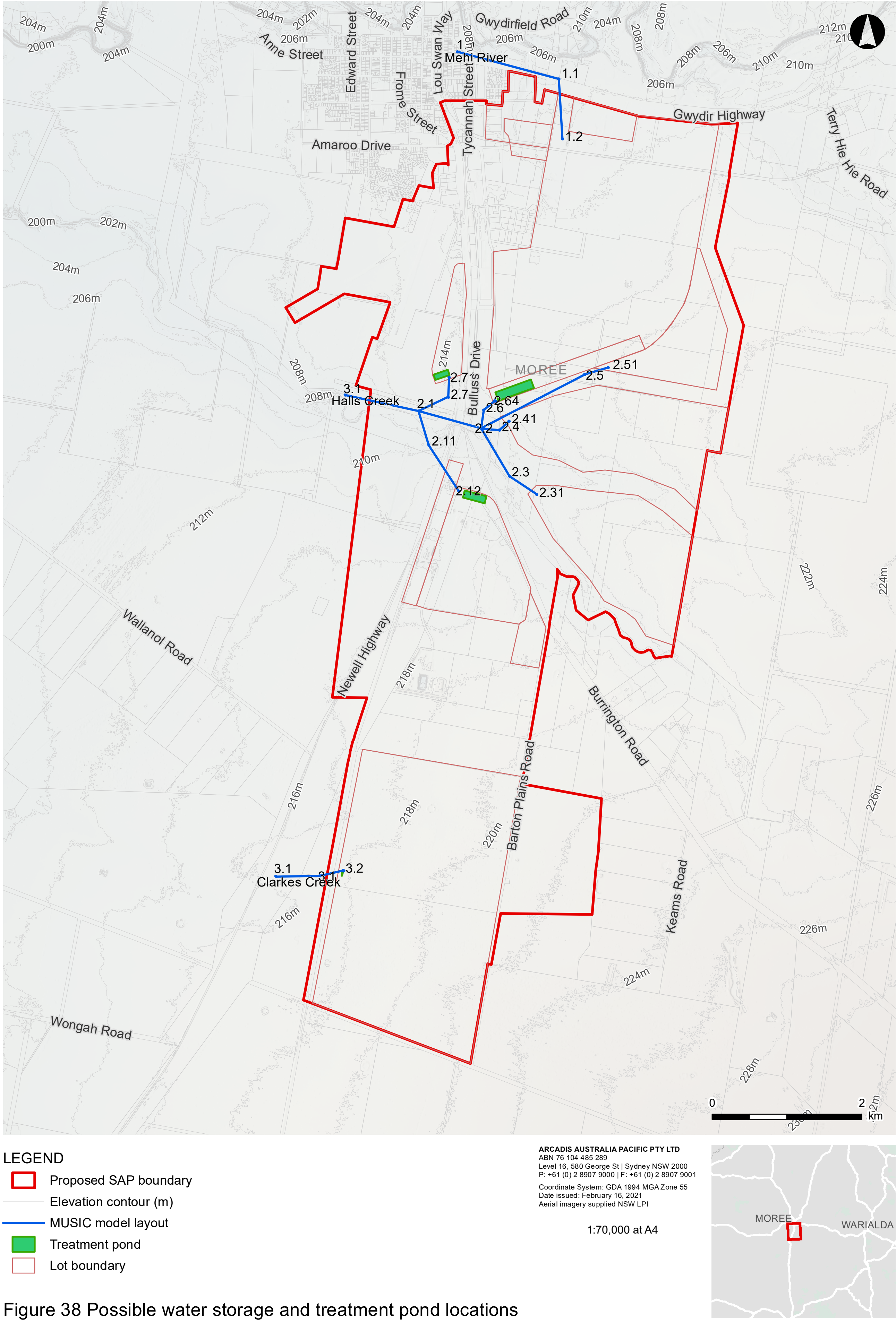


Figure 38 Possible water storage and treatment pond locations

4.7 Summary of stormwater management results for Moree SAP

For ease of comparing the relative flow and water quality implications for water cycle management associated with the alternative states of development within the Moree SAP area, a condensed summary of results is provided in Table 17. A more detailed breakdown of water balance and quality treatment results are included in Appendix C.

Overall the results indicate that the proposed water cycle management measures for flow mitigation and water quality treatment should help to satisfy water demand requirements as well as provide sufficient pollutant removal that generally exceeds the target rates and objectives. While it is noted that the TSS result is slightly less than the target nominated in Section 3.6.2, one of the underlying or overarching objectives is also to ensure that conditions are at least better or no worse than existing situation (in accordance with the NORBE principle) as indicated in Section 4.2.1. The 76% reduction shown is a considerable improvement compared to existing conditions and greater than what has in many instances been used or considered as a reasonable target of 75%. It is envisaged that the required target will be able to be satisfied by the development with further design optimisation of the treatment storages and/or the incorporation of appropriate controls into the masterplan.

Table 17 Summary of stormwater management results for the overall Moree SAP

Parameter	Units	Existing (Pre)	Developed (unmitigated)	Mitigated (Post)	% Reduction
Flow	ML/y	1,520	3,540	1,670	53
TSS	kg/y	273,000	761,000	186,000	76
TP	kg/y	1,160	1,620	509	69
TN	kg/y	5,460	8,960	3,290	63
Gross Pollutants	kg/y	53,500	112,000	9,970	91

5 PLANNING CONSIDERATIONS

A summary of the main planning considerations from a flooding and water cycle management perspective is outlined below.

Water cycle management:

- Implementation of an integrated water cycle management strategy across the larger precinct catchments (Mehi River and Halls Creek) that includes the capture, treatment and re-use of stormwater wherever possible and practical.
- A regional trunk drainage approach is recommended such that runoff is accumulated across larger sub-catchments and conveyed to a combined pond/basin location for water quality treatment prior to stormwater harvesting and reuse and/or discharging to the downstream receiving environment.
- Development of the various sub-precincts is to be controlled such that there would be no net increase in peak flows discharged from the SAP site compared to the existing situation. That is, development within each sub-precinct will be responsible for managing its own runoff through implementation of stormwater harvesting and/or on-site detention.
- Encourage and/or condition the use of rainwater tanks for on-site stormwater re-use, particularly for the larger development sites.
- Adopt and implement measures for new development requiring stormwater pollution control to be managed on site wherever possible and practical. Encourage the use of vegetation buffers and the like.

Flooding:

- Riparian corridors (alignment and width) should be defined to correspond with the 1% AEP flood extent for the main waterways. Appropriate development controls or restrictions should also be established to correlate with and protect the values of these existing waterways and the associated floodplain extents.
- Flood planning conditions should be developed in consideration of the existing Moree Council LEP.
- Flood compatible building controls similar to the existing Moree Council DCP should be developed.
- The adoption of an appropriate Flood Planning Area applicable to development within the SAP should be cognisant of the flood risk and hazards presented to the specific nature and extent of proposed development and land use.
- The model results and mapping for the southern part of the SAP (Clarkes Creek area) indicate relatively shallow depths of inundation that could potentially spread over a broad area. The area is currently proposed for solar development which would be a compatible land use in these circumstances. The formalisation of flow path(s) through this area may however be worthy of some consideration to better contain the extent of inundation.
- Further flood modelling may still be required as the SAP development is implemented depending on the nature and extent of the development and any associated staging. Should this be necessary, the opportunity to update and refinements the definition of culvert/waterway structures for the highway and rail embankments in the Clarks Creek area may be worthy of consideration.

APPENDIX A - LIST OF ABBREVIATIONS

AAD - Annual Average Damages

AEP - Annual Exceedance Probability

AHD - Australian Height Datum

ARI - Average Recurrence Interval

AWRC - Australian Water Resources Council

BoM - Bureau of Meteorology

CMA - Catchment Management Authority

CMB - Catchment Management Board

DCP - Development Control Plan

DEC - Department of Environment and Conservation

DISPLAN - Local Disaster Plan

DPIE - Department of Planning, Industry and Environment

EP&A Act - Environmental Planning and Assessment Act, 1979

EPAR - Environmental Planning and Assessment Regulation, 2000

EPI - Environmental Planning Instruments including SEPPs and LEPs

ESD - Ecologically Sustainable Development

FPL - Flood Planning Level

LEP - Local Environmental Plan

LG Act - Local Government Act, 1993

Local Policy - Local flood risk management policy

Management Committee - Floodplain Risk Management Committee

Management Plan - Floodplain Risk Management Plan

Management Study - Floodplain Risk Management Study

Manual - Floodplain Development Manual, 2005

NP&W Act - National Parks and Wildlife Act, 1974

NSW - New South Wales

NVC Act - Native Vegetation Conservation Act, 1997

PMF - Probable Maximum Flood

PMP - Probable Maximum Precipitation

Policy - NSW Government's Flood Prone Land Policy

RCP – Representative Concentration Pathways

SEPP - State Environmental Planning Policy

SES - State Emergency Service

TSC Act - Threatened Species Conservation Act, 1995

Water Act - Water Act, 1912

Water Management Act - Water Management Act, 2000

149(2) - Section 149 part 2 of the Environmental Planning and Assessment Act

149(5) - Section 149 part 5 of the Environmental Planning and Assessment Act

APPENDIX B - GLOSSARY

acid sulfate soils are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.

annual exceedance probability (AEP) the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).

Australian Height Datum (AHD) a common national surface level datum approximately corresponding to mean sea level.

average annual damage (AAD) depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.

average recurrence interval (ARI) the long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

catchment the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

consent authority the council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DIPNR, as having the function to determine an application.

development is defined in Part 4 of the EP&A Act

- *infill development:* refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.
- *new development:* refers to development of a completely different nature to that associated with the former land use. Eg, the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.
- *redevelopment:* refers to rebuilding in an area. Eg, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.

disaster plan (DISPLAN) a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ESD using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act, 1993.

effective warning time the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

flood fringe areas the remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land is synonymous with flood prone land (ie) land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).

flood mitigation standard the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.

floodplain area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.

floodplain risk management options the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

floodplain risk management plan a management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local) A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.

flood planning area the area of land below the FPL and thus subject to flood related development controls.

flood planning levels (FPLs) are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.

flood proofing a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land is land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.

flood readiness Readiness is an ability to react within the effective warning time.

flood risk potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into 3 types, existing, future and continuing risks. They are described below.

- *existing flood risk:* the risk a community is exposed to as a result of its location on the floodplain.
- *future flood risk:* the risk a community may be exposed to as a result of new development on the floodplain.
-

- *continuing flood risk:* the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room

- *in a residential situation:* a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.
- *in an industrial or commercial situation:* an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard a source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (2005) the hazard is flooding which has the potential to cause damage to the community.

hydraulics term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage smaller scale problems in urban areas.

mainstream flooding inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of the NSW Floodplain Development Manual (2005) major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.

minor, moderate and major flooding both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

- *minor flooding:* causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.
- *moderate flooding:* low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.
- *major flooding:* appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures are measures that modify either the flood, the property or the response to flooding.

peak discharge the maximum discharge occurring during a flood event.

probable maximum flood the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

probable maximum precipitation the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability a statistical measure of the expected chance of flooding (see AEP).

risk chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the NSW Floodplain Development Manual (2005) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage equivalent to water level (both measured with reference to a specified datum).

stage hydrograph a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan a plan prepared by a registered surveyor.

water surface profile a graph showing the flood stage at any given location along a watercourse at a particular time.

APPENDIX C – MUSIC MODEL RESULTS

Moree SAP - Master Plan Pre and Post Development Comparison

Node	Description	Total Flow			Base Flow			TSS			TP			TN			Gross Pollutant		
		Pre	Dev	Post	Pre	Dev	Post	Pre	Dev	Post	Pre	Dev	Post	Pre	Dev	Post	Pre	Dev	Post
		(ML/yr)	(ML/yr)	(ML/yr)	(ML/yr)	(ML/yr)	(ML/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)	(kg/yr)
1	Mehi River	544	1560	579				101000	335000	28800	422	787	116	1930	4220	1010	19200	54300	33.1
1.1	NE Precinct	544	1560	579				101000	335000	28800	422	787	116	1930	4220	1010	19200	54300	33.1
1.2	Junction		1560	579					335000			787			4220			54300	33.1
1.21	Agricultural	544	155	155	4.14255	1.17811	1.17811	101000	26900	27500	422	122	119	1930	565	577	19200	5460	5460
1.22	Roads		302	302		0.87038	0.87038		107000	105000		179	177		718	723		9050	9050
1.4	Junction		406	406					73500	75800		118	121		900	892		12800	12800
1.41	Logistics		406	406		2.61114	2.61114		73500	75800		118	121		900	892		12800	12800
1.6	Junction		149	149					27500	27500		43.9	43.3		324	327		5250	5250
1.61	Resource Recovery		149	149		2.4868	2.4868		27500	27500		43.9	43.3		324	327		5250	5250
1.7	Junction		203	203					37100	36800		59.6	59.8		440	445		7580	7580
1.71	VA Agricultural		203	203		4.9736	4.9736		37100	36800		59.6	59.8		440	445		7580	7580
1.8	Junction		351	351					63300	65500		265	275		1270	1260		14100	14100
1.81	Agricultural - intensive (nat. hort)		351	351		0.621018	0.621018		63300	65500		265	275		1270	1260		14100	14100
2	Halls Creek	630	1570	731				112000	340000	104000	473	647	253	2300	3740	1540	22200	46900	9930
2.1	Junction	630	1570	731				112000	340000	104000	473	647	253	2300	3740	1540	22200	46900	9930
2.11	Central Precinct	137	494	191				24100	112000	12200	101	205	40.2	495	1170	325	4830	16100	0
2.13	Junction		172	172					31500	32300		50.3	50.9		377	379		5170	5170
2.14	Intermodal		172	172		0.497361	0.497361		31500	32300		50.3	50.9		377	379		5170	5170
2.15	Junction		101	101					18500	18500		29.6	29.6		221	220		3790	3790
2.16	VA Agricultural		101	101		2.4868	2.4868		18500	18500		29.6	29.6		221	220		3790	3790
2.17	Junction		44.7	44.7					8100	8160		13.2	13.2		96.4	97.2		1580	1580
2.18	Bio Energy		44.7	44.7		0.74604	0.74604		8100	8160		13.2	13.2		96.4	97.2		1580	1580
2.19	Agricultural	137	46.8	46.8	1.04112	0.356172	0.356172	24100	9150	8220	101	36.6	35.4	495	165	171	4830	1650	1650
2.2	Roads		129	129		0.37302	0.37302		45100	45000		75.1	74.9		310	313		3880	3880
2.2	Junction	587	922	493				104000	191000	87900	440	372	200	2140	2200	1120	20700	25800	9930
2.3	Solar 3	137	147	147				24500	31100	31500	102	69.2	68.9	501	362	364	4830	3700	3700
2.33	Roads		43.1	43.1		0.12434	0.12434		15200	15200		25.5	24.7		102	103		1290	1290
2.34	Agricultural	137	32.4	32.4	1.04112	0.24658	0.24658	24500	5770	5790	102	24.8	24.9	501	116	116	4830	1140	1140
2.35	Solar		71.9	71.9		15.9466	15.9466		10100	10600		19	19.3		144	144		1270	1270
2.4	Solar 2	169	173	173				30100	35800	36400	129	80.5	79.2	618	428	429	5970	4290	4290
2.43	Roads		43.1	43.1		0.12434	0.12434		14900	15300		25.8	25.3		103	104		1290	1290
2.44	Agricultural	169	39.6	39.6	1.2877	0.301376	0.301376	30100	7560	7490	129	31.1	29.3	618	144	143	5970	1400	1400
2.45	Solar		90.5	90.5		20.0809	20.0809		13300	13600		23.6	24.6		181	182		1600	1600
2.5	Solar 1	72	76.8	76.8				12900	16000	16200	53.7	36.5	36.8	264	190	191	2540	1940	1940
2.53	Roads		21.6	21.6		0.06217	0.06217		7470	7620		12.6	12.9		51.5	52		646	646
2.54	Agricultural	72	18	18	0.547956	0.136989	0.136989	12900	3240	3260	53.7	13.5	14.3	264	64.7	64	2540	635	635
2.55	Solar		37.3	37.3		8.26862	8.26862		5290	5340		10.4	9.71		74	74.8		658	658
2.6	Junction	72	525	95.4				12700	108000	3700	53.6	186	15	262	1220	139	2540	15900	0
2.61	Intermodal		431	431		1.2434	1.2434		80100	78400		127	127		953	951		12900	12900
2.62	Agricultural	72	28.8	28.8	0.547956	0.219183	0.219183	12700	5080	5440	53.6	21.2	22	262	107	100	2540	1020	1020
2.63	Roads		64.7	64.7		0.18651	0.18651		22600	22700		38	38.4		155	154		1940	1940
2.7	Junction	43.2	156	47.7				7930	37600	4330	33.3	69.9	12.9	155	376	91.4	1520	5000	0
2.71	Junction		156	47.7					37600			69.9			376			5000	0
2.73	Agricultural		17.3	17.3		0.13151	0.13151		3040	3130		14	13.1		60.6	62.3		610	610
2.74	Roads	43.2	51.7	51.7	0.328774	0.149208	0.149208	7930	18500	18100	33.3	30.3	30	155	125	125	1520	1550	1550
2.75	Enterprise/Hub		87.4	87.4		0.74604	0.74604		16000	16100		25.6	25.7		191	194		2840	2840
3	Clarks Creek	342	402	358				59100	85400	52600	269	184	140	1190	998	743	12100	10600	1.28
3.1	Solar South	342	402	358				59100	85400	52600	269	184	140	1190	998	743	12100	10600	1.28
3.21	Roads		108	108		0.31085	0.31085		38000	38300		62.9	64.7		260	260		3230	3230
3.22	Agriculture	342	86.4	86.4	2.60279	0.657548	0.657548	59100	15300	15400	269	64.8	67.4	1190	304	317	12100	3050	3050
3.34	Junction		27.1	27.1					4860	4770		7.82	7.86		57.8	58		1080	1080
3.35	Potentially Hazardous		27.1	27.1		0.969853	0.969853		4860	4770		7.82	7.86		57.8	58		1080	1080
3.36	Junction		181	181					27300	26100		48.6	49.4		376	360		3200	3200
3.37	Solar		181	181		40.1618	40.1618		27300	26100		48.6	49.4		376	360		3200	3200
4	Post-Development	1520	3540	1670				273000	761000	186000	1160	1620	509	5420	8960	3290	53500	112000	9970

Summary of Water Balance Results (in ML/yr)

Model Output Parameter	Mehi River			Halls Creek			Clarks Creek		
Overall Catchment	**Pre**	**Dev**	**Post**	**Pre**	**Dev**	**Post**	**Pre**	**Dev**	**Post**
Rain In	4,012	3,662	3,662	4,643	4,935	4,935	2,521	2,643	2,643
ET Loss	3,469	2,097	2,097	4,015	3,363	3,363	2,179	2,241	2,241
Imp. Stormflow Out	*359*	*1,457*	*1,457*	*416*	*1,383*	*1,383*	*226*	*270*	*270*
Perv. Stormflow Out	*181*	*95*	*95*	*209*	*137*	*137*	*114*	*91*	*91*
Total Stormflow Out	540	1,552	1,552	625	1,520	1,520	339	360	360
Baseflow Out	4	13	13	5	52	52	3	42	42
Total Catchment Outflow	544	1,565	1,565	630	1,573	1,573	342	402	402
Bypass Flow direct to d/s			-			397			-
Storage Ponds									
Pond Flow In			1,507			1,133			391
ET Loss			184			137			0
Infiltration Loss			673			488			2
High Flow Bypass Out			7			-			1
Orifice / Filter Out			261			196			102
Weir Out			311			138			256
Reuse Supplied			*77*			*182*			*31*
Reuse Requested			*110*			*329*			*110*
Pond Flow Out			579			334			358

Detailed Water Balance Results

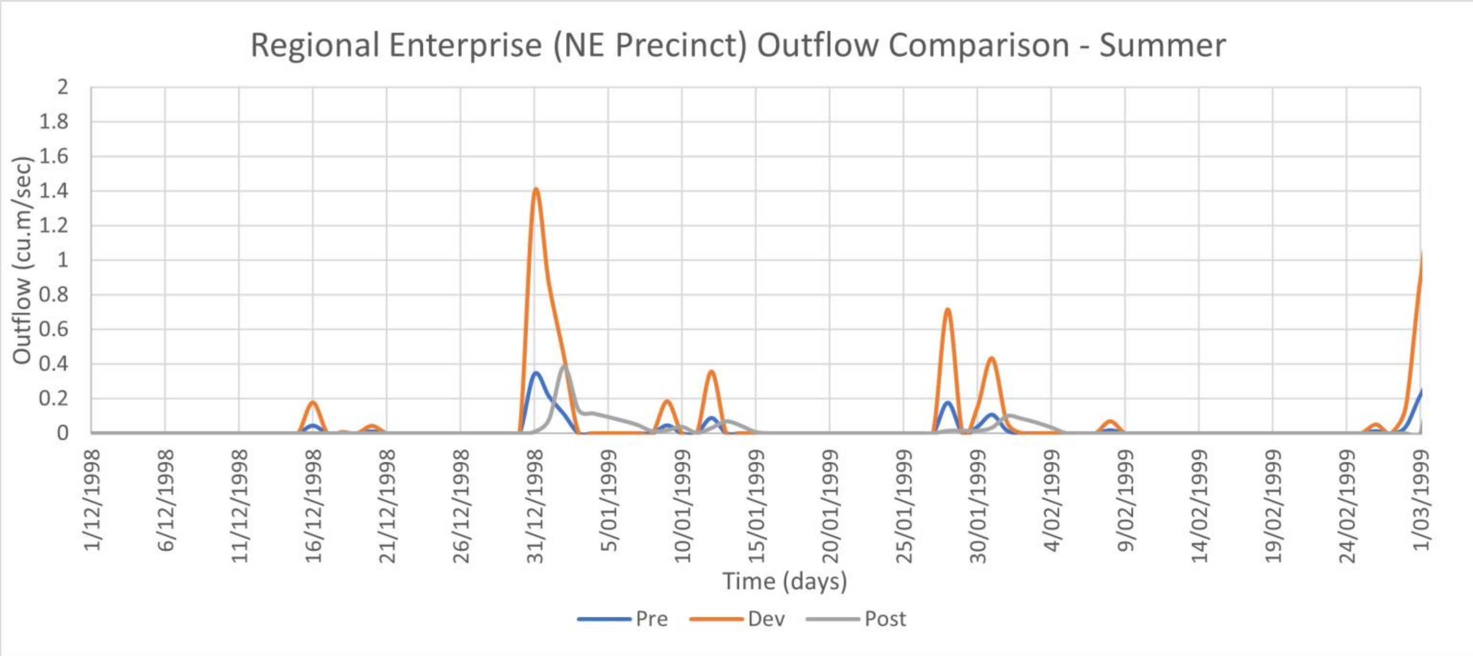
Pre Conditions									
	Rain In (ML/yr)	ET Loss (ML/yr)	Deep Seepage Loss (ML/yr)	Baseflow Out (ML/yr)	Imp. Stormflow Out (ML/yr)	Perv. Stormflow Out (ML/yr)	Total Stormflow Out (ML/yr)	Total Outflow (ML/yr)	*CHECK-Out Mean Annual Flow*
Mehi River									
1.21 Agricultural	4012	3469	0	4	359	181	540	544	*544*
Total	***4012***	***3469***	***0***	***4***	***359***	***181***	***540***	***544***	***544***
1.0 Mehi River									***544***
Halls Creek									
2.19 Agricultural	1008	872	0	1	90	45	136	137	*137*
2.54 Agricultural	531	459	0	1	48	24	71	72	*72*
2.44 Agricultural	1247	1078	0	1	112	56	168	169	*169*
2.34 Agricultural	1008	872	0	1	90	45	136	137	*137*
2.74 Agricultural	318	275	0	0	29	14	43	43	*43.2*
2.62 Agricultural	531	459	0	1	48	24	71	72	*72*
Total	***4643***	***4015***	***0***	***5***	***416***	***209***	***625***	***630***	***630***
2.0 Halls Creek									***630***
Clarks Creek									
3.22 Agriculture	2521	2179	0	3	226	114	339	342	*342*
Total	***2521***	***2179***	***0***	***3***	***226***	***114***	***339***	***342***	***342***
3.0 Clarks Creek									***342***

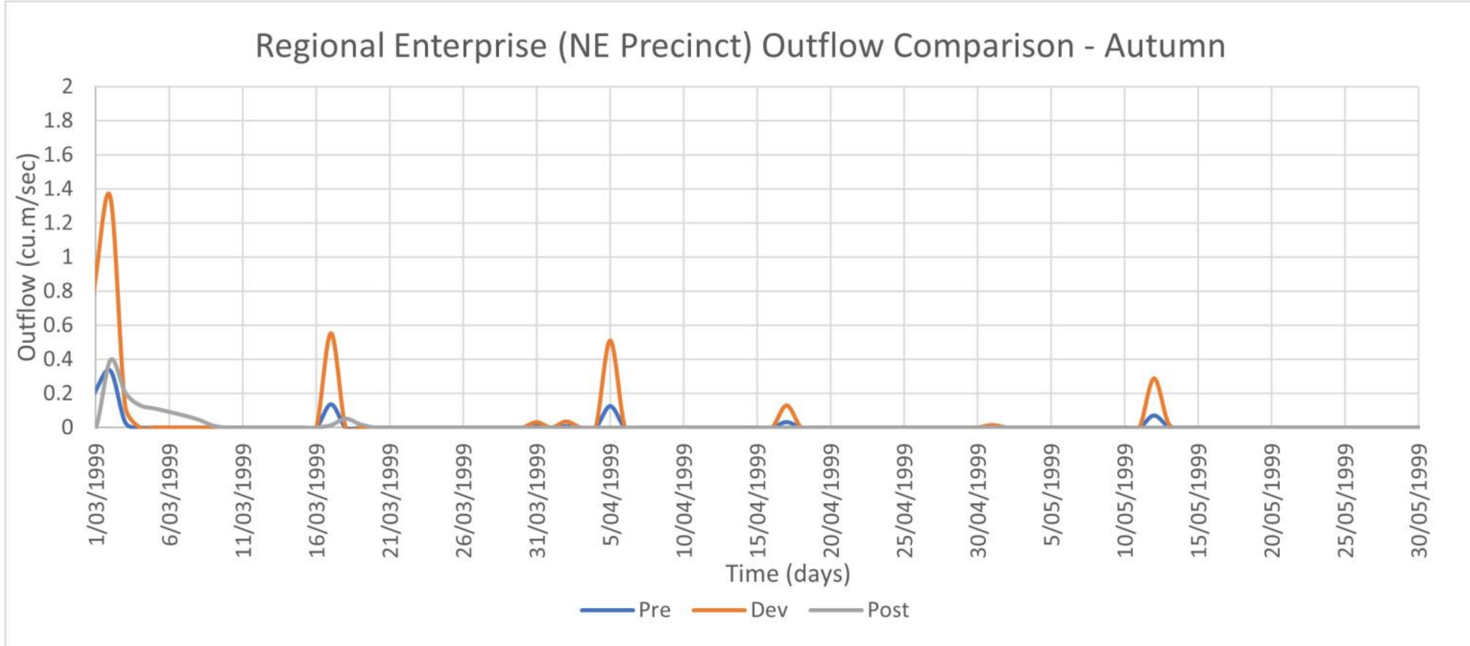
Detailed Water Balance Results

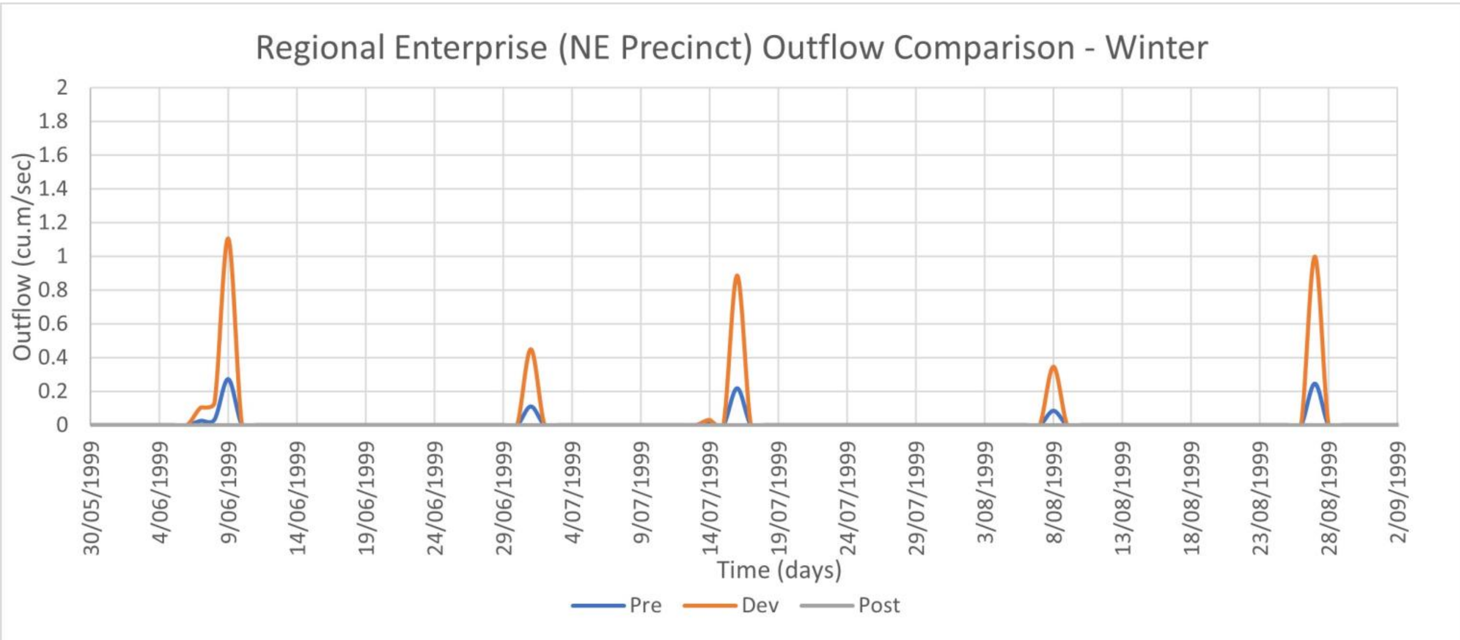
Dev Conditions									
	Rain In (ML/yr)	ET Loss (ML/yr)	Deep Seepage Loss (ML/yr)	Baseflow Out (ML/yr)	Imp. Stormflow Out (ML/yr)	Perv. Stormflow Out (ML/yr)	Total Stormflow Out (ML/yr)	Total Outflow (ML/yr)	*CHECK-Out Mean Annual Flow*
Mehi River	0	1	2	3	4	5	6	7	*0*
1.41 Logistics	557	151	0	3	399	4	403	406	*406*
1.61 Resource Recovery	265	117	0	2	143	4	146	149	*149*
1.71 VA Agricultural	425	222	0	5	190	7	198	203	*203*
1.81 Agricultural - intensive (nat. hort)	902	551	0	1	323	27	350	351	*351*
1.21 Agricultural	1141	986	0	1	102	51	154	155	*155*
1.22 Roads	371	70	0	1	300	1	301	302	*302*
Total	***3662***	***2097***	***0***	***13***	***1457***	***95***	***1552***	***1565***	***1566***
1.0 Mehi River									***1560***
Halls Creek									
2.61 Intermodal	531	100	0	1	428	2	430	431	*431*
2.55 Solar	371	334	0	8	17	12	29	37	*37.3*
2.45 Solar	902	812	0	20	40	30	70	90	*90.5*
2.35 Solar	716	645	0	16	32	24	56	72	*71.9*
2.14 Intermodal	212	40	0	0	171	1	172	172	*172*
2.16 VA Agricultural	212	111	0	2	95	4	99	101	*101*
2.19 Agricultural	345	298	0	0	31	16	46	47	*46.8*
2.20 Roads	159	30	0	0	128	1	129	129	*129*
2.54 Agricultural	133	115	0	0	12	6	18	18	*18*
2.44 Agricultural	292	252	0	0	26	13	39	40	*39.6*
2.34 Agricultural	239	206	0	0	21	11	32	32	*32.4*
2.53 Roads	27	5	0	0	21	0	21	22	*21.6*
2.43 Roads	53	10	0	0	43	0	43	43	*43.1*
2.33 Roads	53	10	0	0	43	0	43	43	*43.1*
2.75 Enterprise/Hub	127	40	0	1	86	1	87	87	*87.4*
2.73 Agricultural	127	110	0	0	11	6	17	17	*17.3*
2.74 Roads	64	12	0	0	51	0	52	52	*51.7*
2.18 Bio Energy	80	35	0	1	43	1	44	45	*44.7*
2.62 Agricultural	212	184	0	0	19	10	29	29	*28.8*
2.63 Roads	80	15	0	0	64	0	64	65	*64.7*
Total	***4935***	***3363***	***0***	***52***	***1383***	***137***	***1520***	***1573***	***1572***
2.0 Halls Creek									***1570***
Clarks Creek									
3.37 Solar	1804	1624	0	40	81	60	141	181	*181*
3.35 Potentially Hazardous	69	42	0	1	25	1	26	27	*27.1*
3.21 Roads	133	25	0	0	107	0	107	108	*108*
3.22 Agriculture	637	551	0	1	57	29	86	86	*86.4*
Total	***2643***	***2241***	***0***	***42***	***270***	***91***	***360***	***402***	***403***
3.0 Clarks Creek									***402***

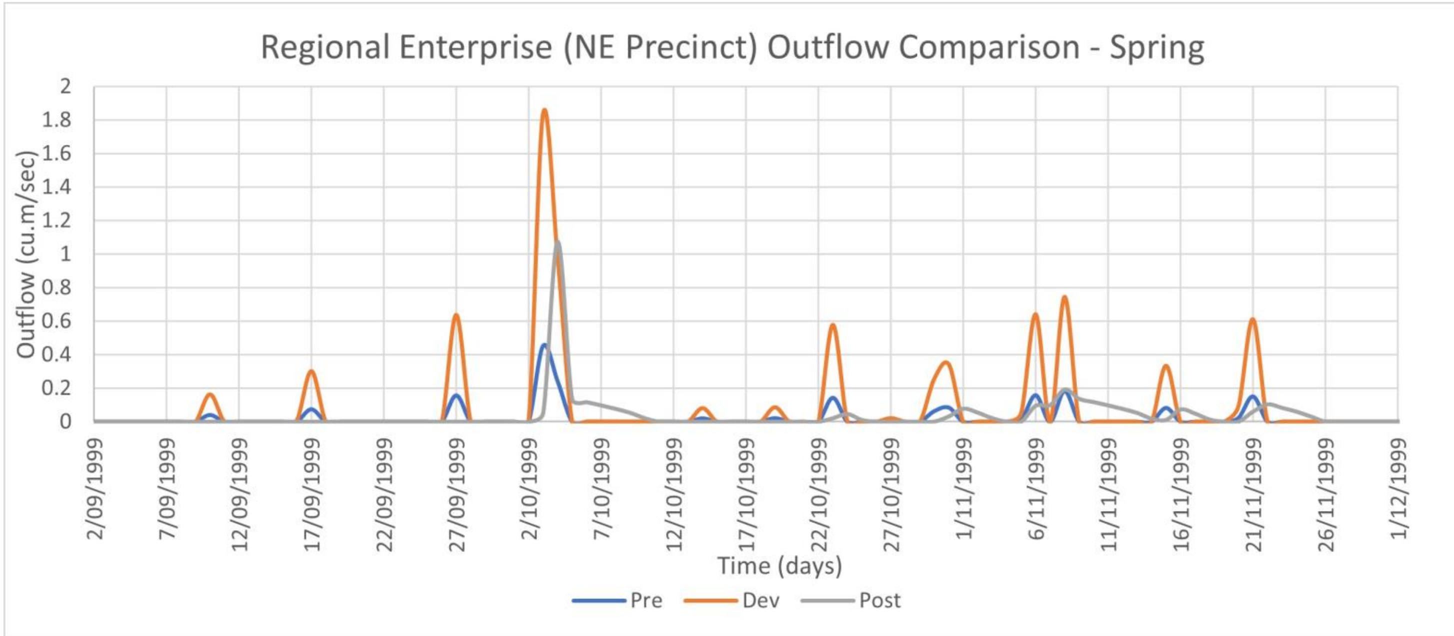
Detailed Water Balance Results

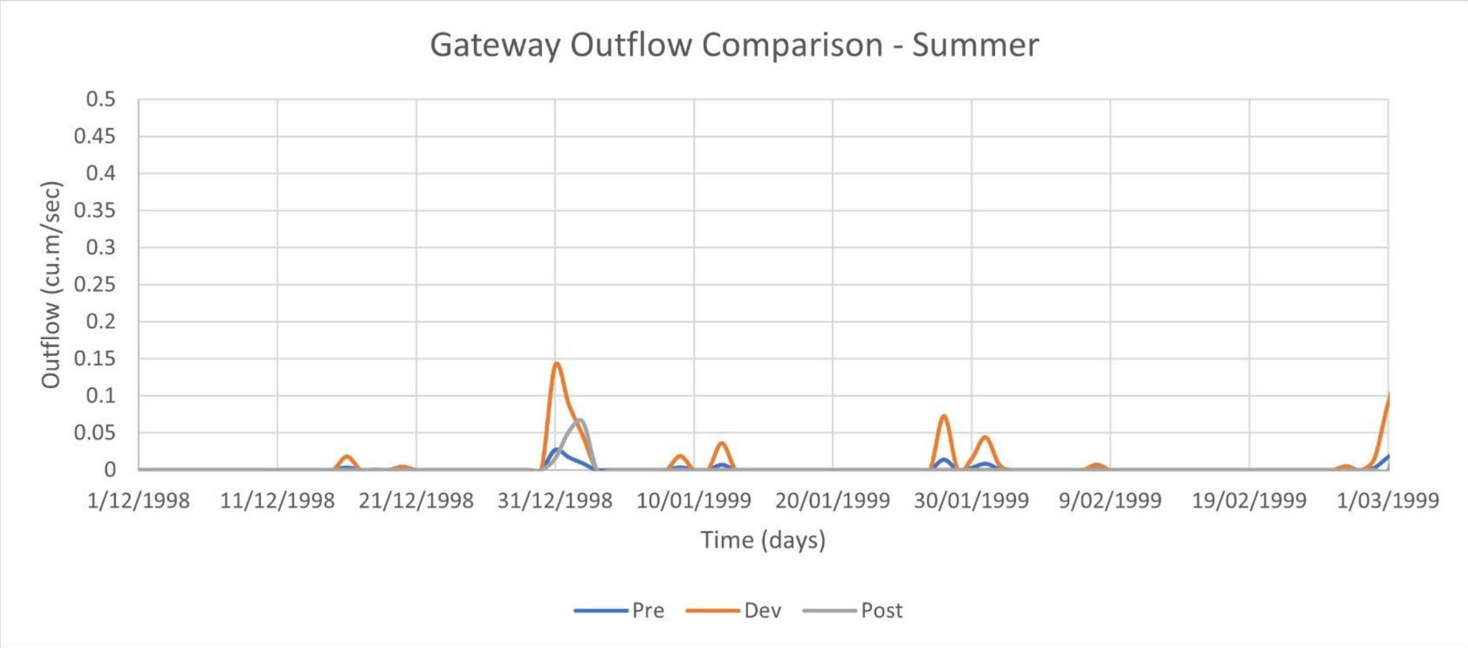
Post Conditions									
	Rain In (ML/yr)	ET Loss (ML/yr)	Deep Seepage Loss (ML/yr)	Baseflow Out (ML/yr)	Imp. Stormflow Out (ML/yr)	Perv. Stormflow Out (ML/yr)	Total Stormflow Out (ML/yr)	Total Outflow (ML/yr)	*CHECK-Out Mean Annual Flow*
Mehi River	0	1	2	3	4	5	6	7	*0*
1.41 Logistics	557	151	0	3	399	4	403	406	*406*
1.61 Resource Recovery	265	117	0	2	143	4	146	149	*149*
1.71 VA Agricultural	425	222	0	5	190	7	198	203	*203*
1.81 Agricultural - intensive (nat. hort)	902	551	0	1	323	27	350	351	*351*
1.21 Agricultural	1141	986	0	1	102	51	154	155	*155*
1.22 Roads	371	70	0	1	300	1	301	302	*302*
1.0 Mehi River	***3662***	***2097***	***0***	***13***	***1457***	***95***	***1552***	***1565***	**1566**
Halls Creek									
2.61 Intermodal	531	100	0	1	428	2	430	431	*431*
2.55 Solar	371	334	0	8	17	12	29	37	*37*
2.45 Solar	902	812	0	20	40	30	70	90	*91*
2.35 Solar	716	645	0	16	32	24	56	72	*72*
2.14 Intermodal	212	40	0	0	171	1	172	172	*172*
2.16 VA Agricultural	212	111	0	2	95	4	99	101	*101*
2.19 Agricultural	345	298	0	0	31	16	46	47	*47*
2.20 Roads	159	30	0	0	128	1	129	129	*129*
2.54 Agricultural	133	115	0	0	12	6	18	18	*18*
2.44 Agricultural	292	252	0	0	26	13	39	40	*40*
2.34 Agricultural	239	206	0	0	21	11	32	32	*32*
2.53 Roads	27	5	0	0	21	0	21	22	*22*
2.43 Roads	53	10	0	0	43	0	43	43	*43*
2.33 Roads	53	10	0	0	43	0	43	43	*43*
2.75 Enterprise/Hub	127	40	0	1	86	1	87	87	*87*
2.73 Agricultural	127	110	0	0	11	6	17	17	*17*
2.74 Roads	64	12	0	0	51	0	52	52	*52*
2.18 Bio Energy	80	35	0	1	43	1	44	45	*45*
2.62 Agricultural	212	184	0	0	19	10	29	29	*29*
2.63 Roads	80	15	0	0	64	0	64	65	*65*
2.0 Halls Creek	***4935***	***3363***	***0***	***52***	***1383***	***137***	***1520***	***1573***	**1572**
Clarks Creek									
3.37 Solar	1804	1624	0	40	81	60	141	181	*181*
3.35 Potentially Hazardous	69	42	0	1	25	1	26	27	*27*
3.21 Roads	133	25	0	0	107	0	107	108	*108*
3.22 Agriculture	637	551	0	1	57	29	86	86	*86*
3.0 Clarks Creek	***2643***	***2241***	***0***	***42***	***270***	***91***	***360***	***402***	**403**
Ponds	Flow In (ML/yr)	ET Loss (ML/yr)	Infiltration Loss (ML/yr)	High Flow Bypass Out (ML/yr)	Orifice / Filter Out (ML/yr)	Weir Out (ML/yr)	Reuse Supplied (ML/yr)	Reuse Requested (ML/yr)	Flow Out (ML/yr)
Mehi River	0	1	2	4	5	6	8	9	
1.2 Pond	***1507***	***184***	***673***	***7***	***261***	***311***	***77***	***110***	
Total Flow Out									**579**
Halls Creek	0	1	2	4	5	6	8	9	
2.12 Pond	478	47	170	0	107	83	72	110	
2.71 Pond	152	12	41	0	31	16	52	110	
2.64 Pond	502	78	276	0	58	38	58	110	
Total Flow Out	***1133***	***137***	***488***	***0***	***196***	***138***	***182***	***329***	**334**
Clarks Creek	0	1	2	4	5	6	8	9	
3.2	***391***	***0***	***2***	***1***	***102***	***256***	***31***	***110***	
Total Flow Out									**358**


Regional Enterprise (NE Precinct) Outflow Comparison - Summer
Outflow (cu.m/sec)
Time (days)
Pre
Dev
Post

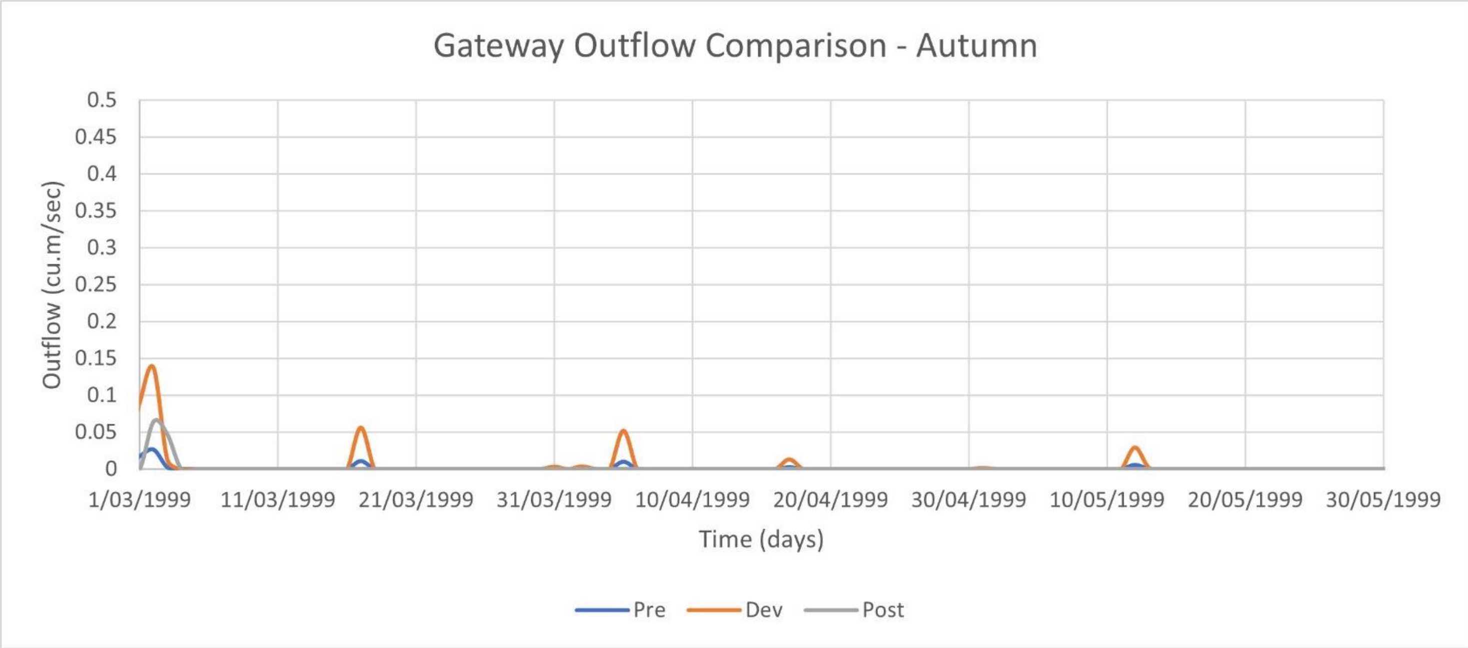

Regional Enterprise (NE Precinct) Outflow Comparison - Autumn
Outflow (cu.m/sec)
Time (days)
Pre
Dev
Post


Regional Enterprise (NE Precinct) Outflow Comparison - Winter
Outflow (cu.m/sec)
Time (days)
Pre
Dev
Post

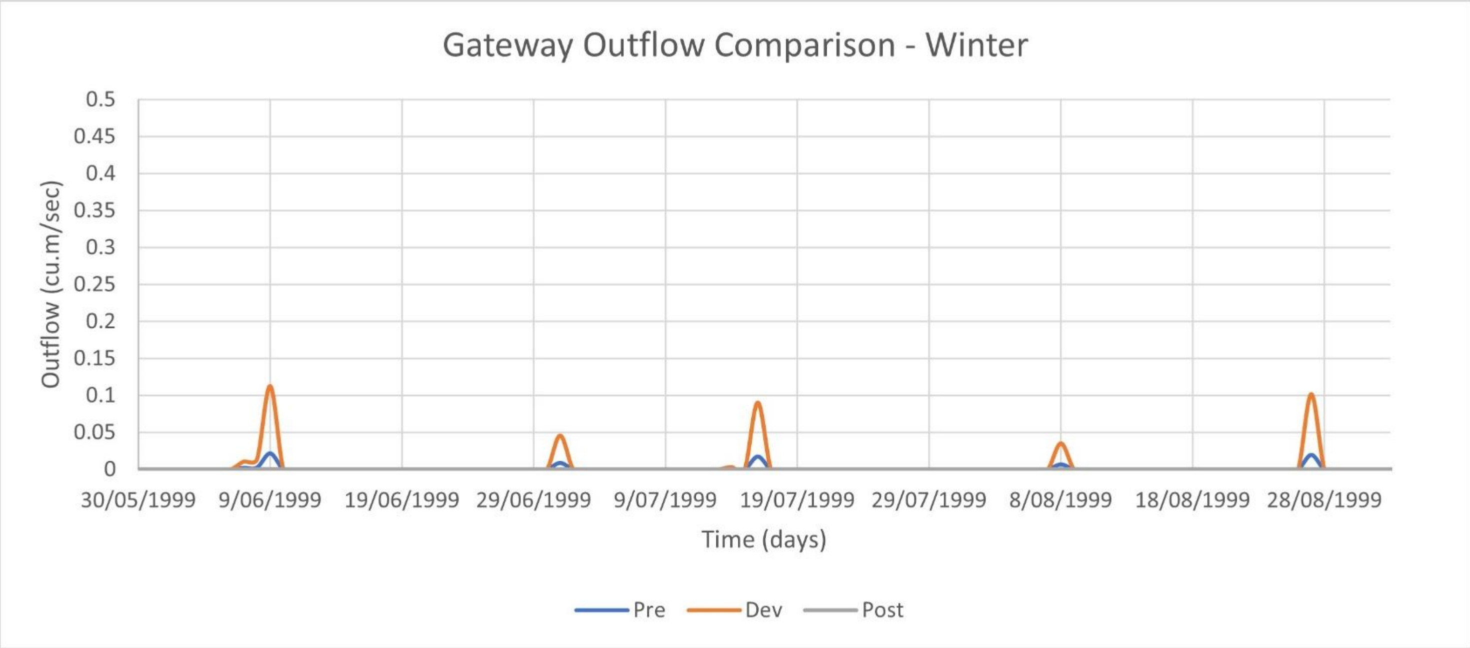

Regional Enterprise (NE Precinct) Outflow Comparison - Spring
Outflow (cu.m/sec)
Time (days)
Pre
Dev
Post



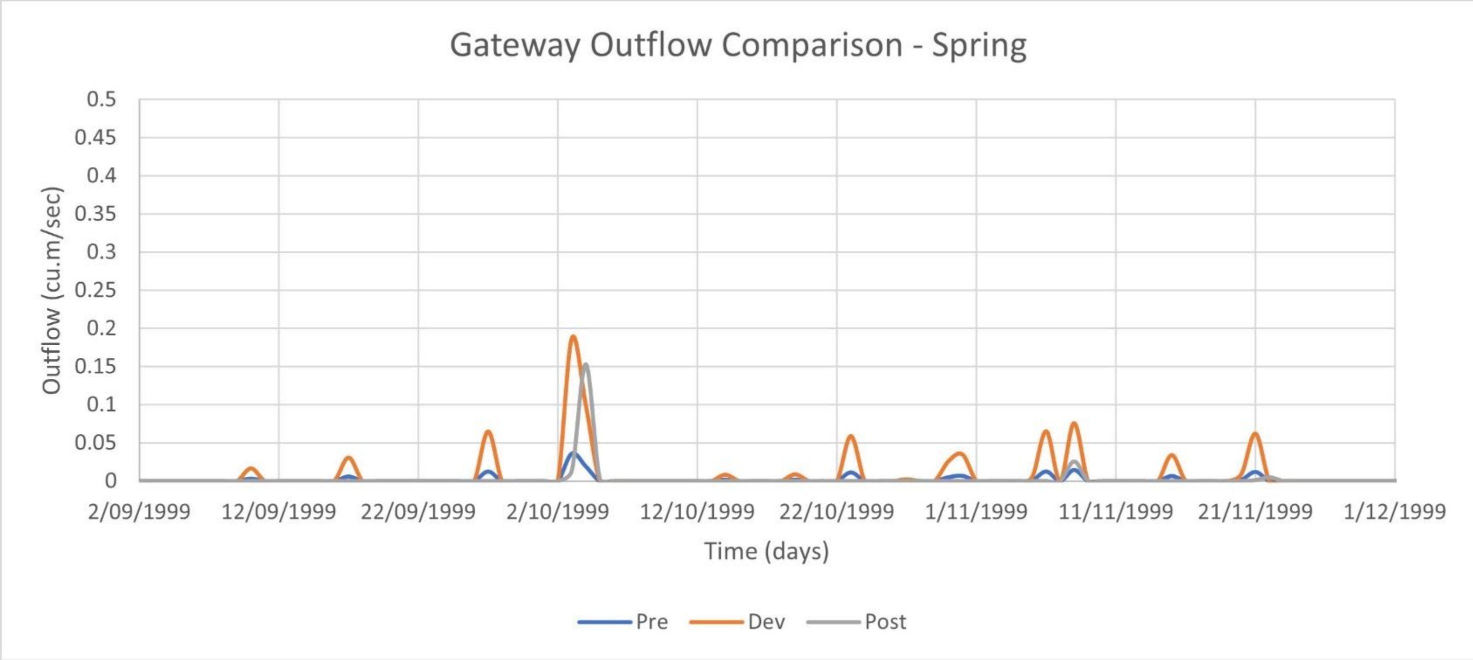
Gateway Outflow Comparison - Summer
Outflow (cu.m/sec)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/12/1998
11/12/1998
21/12/1998
31/12/1998
10/01/1999
20/01/1999
30/01/1999
9/02/1999
19/02/1999
1/03/1999
Time (days)
Pre
Dev
Post



Gateway Outflow Comparison - Autumn
Outflow (cu.m/sec)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1/03/1999
11/03/1999
21/03/1999
31/03/1999
10/04/1999
20/04/1999
30/04/1999
10/05/1999
20/05/1999
30/05/1999
Time (days)
Pre
Dev
Post



Gateway Outflow Comparison - Winter
Outflow (cu.m/sec)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
30/05/1999
9/06/1999
19/06/1999
29/06/1999
9/07/1999
19/07/1999
29/07/1999
8/08/1999
18/08/1999
28/08/1999
Time (days)
Pre
Dev
Post



Gateway Outflow Comparison - Spring
Outflow (cu.m/sec)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2/09/1999
12/09/1999
22/09/1999
2/10/1999
12/10/1999
22/10/1999
1/11/1999
11/11/1999
21/11/1999
1/12/1999
Time (days)
Pre
Dev
Post

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