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Griffith Main Drain J and Mirrool Creek Floodplain Risk Management Study and Plan

Reference: R.N20024.002.03.docx

Date: August 2015

Final Report

Griffith Main Drain J and Mirrool Creek Floodplain Risk Management Study and Plan

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Document:	R.N20024.002.02.docx
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Synopsis: **This report documents the Griffith Main Drain J and Mirrool Creek Floodplain Risk Management Study and Plan which investigates and presents a flood risk management strategy for the catchment. The study identifies the existing flooding characteristics and canvasses various measures to mitigate the effects of flooding.**

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	01/04/2015	DJL		DJL	
1	28/04/2015	DJL		DJL	
2	18/05/2015	DJL		DJL	
3	28/08/2015	DJL		DJL	

DISTRIBUTION

Destination	Revision										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
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Executive Summary

Introduction

The Griffith Floodplain Risk Management Study and Plan were completed by Worley Parsons for Council in 2011. Following the completion of the study the Riverina region suffered from some of the worst flooding in recorded history. During the March 2012 flood event the community of Yenda was severely impacted. The source of flooding in Yenda was from Mirrool Creek flood waters overtopping the irrigation infrastructure and spilling into the catchment of Main Drain J. The existing Floodplain Risk Management Study had only considered flooding from runoff within the Main Drain J catchment and not from external sources. A review of the Study was therefore required to investigate the implications of flood contributions from Mirrool Creek.

The Griffith Main Drain J and Mirrool Creek Flood Study was prepared for Griffith City Council (Council) by BMT WBM in 2014 to define the flood behaviour of the catchment, both in terms of local catchment runoff and flood flow contributions from Mirrool Creek. The study produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions.

The outcomes of the revised Flood Study established the basis for subsequent floodplain management activities. The Floodplain Risk Management Study (FRMS) aims to derive an appropriate mix of management measures and strategies to effectively manage flood risk in accordance with the NSW Government Floodplain Development Manual. The findings of the study will be incorporated in a Plan of recommended works and measures and program for implementation.

The objectives of the Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan are to:

- Identify and assess measures for the mitigation of existing flood risk;
- Identify and assess planning and development controls to reduce future flood risks; and
- Present a recommended floodplain management plan that outlines the best possible measures to reduce flood damages in the Main Drain J catchment.

This report documents the Floodplain Risk Management Study and presents a recommended Floodplain Risk Management Plan for the Main Drain J catchment.

The following provides an overview of the key findings and outcomes of the study, incorporating a review of design flood conditions within the catchment, assessment of potential floodplain management measures and a recommended Floodplain Management Plan.

This project has been conducted under the State Assisted Floodplain Management Program and received State financial support.

Flooding Behaviour

There are effectively two different catchments driving flood behaviour in the study area – Main Drain J and Mirrool Creek.

The Main Drain J catchment itself is more accurately described as two separate catchments – one upstream of the Main Canal, draining to Myall Park and one downstream of the canal, draining to Mirrool Creek via Main Drain J. Historically the flood storage area of Myall Park would have been a terminal ephemeral wetland, receiving catchment runoff from the western slopes of the Cocoparra Range. However, the development of the regional irrigation has included a drainage connection from the Myall Park storage through to Main Drain J catchment. Despite this connectivity, the two systems still operate essentially independently in terms of flood behaviour.

The most extensive area of out-of-bank flooding occurs between Hanwood and Mirrool Creek. It is typically no more than 0.5m deep and has minimal flow velocities. Additional localised out-of-bank flooding is known to occur, most notably at Yoogali, which is located near the confluence of Main Drain J and DC 605 J. Here flows spilling from DC 605 J are impeded by the railway and are contained by the raised banks of Main Drain J. Flooding can also occur from the local drainage network becoming 'locked' by elevated water levels within Main Drain J, as occurred in March 1989. Out-of-bank flooding is also known to occur around Bilbul.

Flood conditions along Main Drain J would be expected to occur within 12 hours of the onset of the rainfall event. Elevated water level conditions may be maintained for a day or two following the event.

The Mirrool Creek catchment is some 6,500km^2 in size upstream of the East Mirrool Regulator. This catchment area can be divided into two main sub-catchments. Mirrool Creek drains the upland areas around Ariah Park and the Barellan flats to the south of the Griffith Temora Railway, with a total contributing catchment area of around 2,500km^2. Binya Creek joins Mirrool Creek a few kms upstream of the East Mirrool Regulator. It drains the upland areas to the north of Ardlethan, the eastern slopes of the Cocoparra Range and the Barellan flats to the north of the Griffith Temora Railway, with a total contributing catchment area of around 4,000km^2.

Flood waters arrive at the EMR firstly from Binya Creek, followed by runoff from the Colinroobie area and finally from Mirrool Creek, as the flood level begins to rise behind the Main Canal. Flood waters can be conveyed to the downstream Mirrool Creek floodplain through the siphon structures and the operation of flood gates to allow flood flows into the canal and then out again through the downstream side. When the capacity of these structures is exceeded then flood waters can spill over the Northern Branch Canal and proceed to the township of Yenda.

The flood gates with full operational capacity provide of the order of 2% AEP flow capacity and accordingly this represents the relative design flood immunity standard for Yenda under these conditions. In its current decommissioned state, however, the flood immunity is reduced to something of the order of a 5% AEP event with only the capacity of the siphon to transfer Mirrool Creek flows.

The Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) defined design flood levels within Woolgoolga for a range of design event magnitudes. The detailed hydraulic model (TUFLOW) was calibrated and verified to March 2012, March 1989 and March 1931 historical event data.

A flood damages database has been developed to identify potentially flood affected properties and to quantify the extent of damages in economic terms for existing flood conditions. Key results from the flood damages database indicate:

- 332 residential homes and 11 commercial buildings would be flooded above floor level in a 1% AEP flood;
- 496 residential homes and 23 commercial buildings would be flooded above floor level in a 0.5% AEP flood (the March 2012 event is approximated by a 0.5% AEP design flood condition);
- The predicted flood damage costs for the 1% AEP flood is in the order of $28M, increasing to $45M for the 0.5% AEP event.

Floodplain Management Options Considered

The Griffith FRMS&P (Worley Parsons, 2011) identified a number of structural and planning options to address flooding risk. The Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) was initiated to revise the design flooding conditions through the study area and inform an update to the Griffith FRMS&P. The undertaking the revised flood study provides the opportunity to reassess the structural options considered as part of the Griffith FRMS&P assessed in light of the updated design flood conditions.

The Floodplain Risk Management Study considered and assessed a number of revised structural floodplain management measures, summarised below.

Table E-1 Summary of Potential Structural Flood Mitigation Options

Location / Option	Comments
Yoogali	
Yoogali Levee	Involves the construction of an earth embankment along the northern side of McCormack Road (along the alignment of DC605J/DC621J) and the western side of Yenda Road (along the alignment of Main Drain J). The embankment function is to contain waters within the existing drainage channels and prevent floodwaters exceeding the drain capacity and entering Yoogali during major floods.
DC 605J Structure Upgrades	Existing cross drainage structures at Yenda Road and Bosanquet Road provide flow capacity restrictions to DC 605J. Upgrade of these structures is considered to provide additional in-bank capacity along the drain alignment and further reduce opportunity for spills across McCormack Road and through to Yenda.
Main Drain J Structure Upgrades	The Griffith-Temora Railway bridge and Griffith Road bridge have been identified by the community as potential constraints on the capacity of Main Drain J. The study has investigated the merits of increasing capacity at these structures and potential reduction in spills from Main Drain J into Yoogali village.

Location / Option	Comments
Upstream Detention	Some parts of the community consider development within Collina and other local catchments upstream of Yoogali as contributing to local flooding. Flood detention basins providing additional temporary flood storage are identified by the community as a potential measure. The Main Canal embankment and siphon structure on DC Collina effectively provide a detention function by limiting flows through to Yoogali. Similarly, the broader storage of Myall Park and other siphons on drainage channels through the Main Canal also provide existing storage function. Accordingly, investigation of further detention would not provide any major benefit and therefore not considered further in the FRMS.
Yenda	
EMR Flood Gate Reinstatement	With the EMR flood escape decommissioned only the capacity of the existing siphon are available to transfer Mirrool Creek flows across the Main Canal. Reinstatement of the flood escape to fully operational status provides for an approximate 2% AEP (50-year ARI) capacity and flood immunity to the Yenda community.
EMR Flood Gate Upgrade	The EMR Flood Gate upgrade considers the construction of new flood escapes with increased discharge capacity. The upgrade works require new enhanced structures on both the right and left bank of the Main Canal to provide conveyance of the Mirrool Creek flows. The minimum design capacity to be considered would be the 1% AEP event plus appropriate freeboard, noting that the March 2012 event is representative of a design 0.5% AEP magnitude.
EMR “Lawson Siphon”	A “Lawson Siphon” arrangement (similar to Mulwala Canal across the Edward River floodplain at Deniliquin) would convey the Main Canal flows beneath the floodplain of Mirrool Creek. The siphon width would provide a clear floodplain opening for effective conveyance of Mirrool Creek flows. The option can be considered an alternative to the Flood Gate upgrade, with the siphon width providing similar flow capacity to provide the desired flood immunity for Yenda.
Northern Branch Canal Bank Raising	The discharge capacity of the EMR flood gates or siphon type arrangement is defined by the maximum flood level at the structure before overtopping of the NBC occurs at which point flows to Yenda are initiated. This allowable maximum water level is currently limited by the low points in the NBC bank level. Raising of the NBC bank levels will provide for additional flow capacity at the EMR structure before overtopping occurs, or alternatively be considered as additional freeboard above existing arrangements.
Main Canal Emergency Breaching	Significant breaching of the Main Canal occurred during the March 2012 event. These breaches conveyed a significant amount of flow and also served to reduce the flow towards Yenda. Given the potential for significant reductions to flows at the EMR, controlled breaching through formalised protocols/flood planning may be considered as a future emergency management measure.

Location / Option	Comments
Hanwood	
Local Drainage Works	Elevated Main Drain J levels reduce the effectiveness of the local drainage system in Hanwood. In major events, there is a backwater influence from Main Drain J through the connected drainage network. Local drainage enhancements such as minor bunding, one-directional drainage can provide for some local protection.
Main Drain J Capacity Increase	The existing capacity of Main Drain J is of the order of 1% AEP capacity. Accordingly, extensive works to increase capacity are not considered necessary. Localised spilling occurs at low points along the bank profiles providing for much of the overbank flooding downstream of Yoogali. Targeted bank raising/reinstatement at identified low points would provide for the local increase in capacity to prevent major spilling.

The Recommended Floodplain Management Plan and Implementation

A key outcome of the current study is the review of the adopted Griffith Floodplain Management Plan in the context of changes in design flood behaviour established as part of the 2014 Flood Study. A number of the planning options recommended in the previous Plan remain appropriate, including

- Council adopt draft On-site Stormwater Detention Policy.
- Council and MI adopt drainage channel ownership, maintenance and upgrade Memorandum of Understanding (MoU).
- Council & MI implement outcomes from the MoU
- Community Education and Flood Awareness Program for emergency response precincts
- Update Griffith Local Flood Plan to include evacuation centres for Yenda and Hanwood.
- Investigate installation of real time rainfall gauge in the upper catchment.
- Review and update flood related information on Section 149 certificates as required
- Review the estimate of flood damages for the Main Drain ‘J’ floodplain

In addition the above planning measures, revised recommendations have been made with respect to structural options to address flood risks, in addition to flood warning and emergency response updates. The key features of the plan are tabulated below with indicative costs and priorities for implementation.

Table E-2 Recommended Flood Plan Options

Option	Estimated Cost	Priority
Yoogali Structural Options		
Levee and Culvert Option - construction of earth embankment/bund along Main Drain 'J', DC 605 'J' and DC 621 'J' and upgrade to culverts on Yenda Road and Bosanquet Road	$500K	High
Yenda Structural Options Consists of a package of measures to be progressively implemented		
Northern Branch Canal Works – localised bank raising along the NBC to provide required design flood immunity relative to design standard of recommended EMR upgrades	$500K	High
Reinstatement of Decommissioned Flood Gates – initially incorporates appropriate structural/condition assessments to establish the viability of a refurbished structure. A potential outcome of this investigation may be to proceed directly to a preliminary design of a full structure replacement as per the subsequent components of the proposed works package Note that this option initially only provides for feasibility assessment. Detailed design and construction costs, subject to option feasibility, are estimated to be in excess of $2M.	$200K	High
Preliminary Design of EMR Upgrade (either gate upgrade or Siphon option) – progression through pre-feasibility design and identification of preferred configuration of EMR upgrade to preliminary design. o Technical support studies - e.g. survey, geotechnical, economic appraisal o Concept design and options assessment leading to preferred option o Environmental impact assessment o Planning Approvals	$600K	Medium
Detailed Design and Construction of EMR Upgrade - progression of the preferred upgrade option (e.g. gates or siphon type structure) through to detailed design and construction	$10M	Medium
Hanwood		
Hanwood Local Drainage Works - construction of earthen bund along the left bank alignment of DC 'DA' and DC 'HANDEPOT', provision of one-way flow structures on DC '0491D' and DC 'HANDEPOT' to prevent Main Drain 'J backflow, and installation of pumps or suitable alternative to discharge local catchment runoff from behind the bund into DC 'DA'.	$250K	Medium

Option	Estimated Cost	Priority
Main Drain 'J' Works - Channel works are proposed along the reach of Main Drain 'J' between Kidman Way and Walla Avenue to increase bank heights.	$250K	Medium
Flood Warning and Emergency Response		
Improve flood warning system - recommends further investigation of the existing gauging network and strategic locations for new gauges in order to provide a more formal flood warning system. This would provide local reference points for the Griffith community as well as the SES to gauge the imminent flood risk, and respond accordingly.	$50k	Low
Update Local Flood Plan - Information from the current floodplain management study and flood damages database to be incorporated into the Local Flood Plan (LFP) and updates as necessary to emergency response protocols linked to updated flood intelligence data	Staff costs	High

The steps in progressing the floodplain management process from this point forward are as follows:

1. Council allocates priorities to components of the Plan, based on available sources of funding and budgetary constraints;

2. Council negotiates other sources of funding as required such as through OEH and the "Natural Disaster Mitigation Package" (NDMP); and

3. as funds become available, implementation of the Plan proceeds in accordance with established priorities.

The Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include new flood events and experiences, legislative change, alterations in the availability of funding or changes to the area's planning strategies. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

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Glossary

annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a flood that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year ARI flood' or '1 in 100 year flood'. The term 100 year ARI flood has been used in this study. See also average recurrence interval (ARI).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
attenuation	Weakening in force or intensity
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe flood size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The term 100 year ARI flood has been used in this study. See also annual exceedance probability (AEP).
catchment	The catchment at a particular point is the area of land that drains to that point.
design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
development	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
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).
flood	A relatively high stream flow that 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 behaviour	The pattern / characteristics / nature of a flood.
flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
flood hazard	The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.The degree of flood hazard varies with circumstances across the full range of floods.

flood level	The height of the flood described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian Height Datum (eg the flood level was 7.8 mAHD). Terms also used include flood stage and water level.
flood liable land	see flood prone land
floodplain	Land susceptible to flooding up to the probable maximum flood (PMF). Also called flood prone land. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level.
floodplain risk management study	Studies carried out in accordance with the Floodplain Development Manual (NSW Government, 2005) that assesses options for minimising the danger to life and property during floods. These measures, referred to as 'floodplain risk management measures / options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a Floodplain Risk Management Plan.
floodplain risk management plan	The outcome of a Floodplain Risk Management Study.
flood planning levels (FPL)	The combination of flood levels and freeboards selected for planning purposes, as determined in Floodplain Risk Management Studies and incorporated in Floodplain Risk Management Plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies..
flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
flood stage	See flood level.
flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
flood study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways 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	A factor of safety usually expressed as a height above the adopted flood level thus determing the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.

high flood hazard	For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydrology	The term given to the study of the rainfall-runoff process in catchments.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	metres Australian Height Datum (AHD).
m/s	metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or ‘cumecs’. A unit of measurement for creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as ‘overland flows’, may or may not re-enter the main channel from which they left; they may be diverted to another water course.
peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
probability	A statistical measure of the likely frequency or occurrence of flooding.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
stage	See flood level.
topography	The shape of the surface features of land
velocity	The term used to describe the speed of floodwaters, usually in m/s.

water level	See flood level.

1 Introduction

The Griffith Floodplain Risk Management Study and Plan were completed for Council in 2011. Following the completion of the study the Riverina region suffered from some of the worst flooding in recorded history. During the March 2012 flood event the community of Yenda was severely impacted. The source of flooding in Yenda was from Mirrool Creek flood waters overtopping the irrigation infrastructure and spilling into the catchment of Main Drain J. The existing Floodplain Risk Management Study had only considered flooding from runoff within the Main Drain J catchment and not from external sources. A review of the Study was therefore required to investigate the implications of flood contributions from Mirrool Creek.

BMT WBM was commissioned by Council in early 2013 to undertake a review of the Griffith Floodplain Risk Management Study and Plan, with consideration of flooding from Mirrool Creek. A requirement of the study brief was to convert the existing Main Drain J catchment hydraulic model from the RMA-2 modelling software to TUFLOW modelling software (recognised as a typical current industry standard). Having undertaken this process the results from the two models were compared to confirm their consistency. However, significant differences were found between the existing flood modelling and the updated results. The observations of flooding during the March 2012 event were more consistent with the updated modelling than those of the existing flood study.

In order to fully understand the differences in the model outputs and to have confidence in the model moving forward in the Floodplain Risk Management process, it was necessary to undertake a full model calibration process. The scope of works undertaken was far beyond a simple model conversion and review. It was therefore appropriate that a flood study report be produced to properly document the model development and calibration process.

The Griffith Main Drain J and Mirrool Creek Flood Study was prepared for Griffith City Council (Council) by BMT WBM in 2014 to define the flood behaviour of the catchment, both in terms of local catchment runoff and flood flow contributions from Mirrool Creek. The study produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions.

The outcomes of the Flood Study (BMT WBM, 2014) form the basis for the Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan. This study will aim to derive an appropriate mix of management measures and strategies to effectively manage flood risk in accordance with the Floodplain Development Manual. The findings of the study will be incorporated in a Plan of recommended works and measures and program for implementation.

The objectives of the Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan are to:

- Identify and assess measures for the mitigation of existing flood risk;
- Identify and assess planning and development controls to reduce future flood risks; and
- Present a recommended floodplain management plan that outlines the best possible measures to reduce flood damages in the Main Drain J catchment.

This report documents the Floodplain Risk Management Study and presents a recommended Floodplain Risk Management Plan for the Main Drain J catchment.

1.1 Study Location

The Main Drain J catchment is around 550km^2 in size and drains the western slopes of the Cocoparra Range. Much of the catchment drainage has been modified by irrigation infrastructure. The principal irrigation drain is Main Drain J, which discharges to Mirrool Creek some 15km upstream of Barren Box Swamp. The city of Griffith is situated within the Main Drain J catchment, as shown in Figure 1-1.

The Mirrool Creek draining to Barren Box Swamp is around 8,500km^2 in size, some 6,500km^2 of which is situated upstream of Yenda. The Murrumbidgee Irrigation Main Canal provides irrigation water supply for the regions agriculture. It crosses Mirrool Creek upstream of Yenda and has a significant influence on flood behaviour in the Mirrool Creek catchment. The Mirrool Creek flows are transferred under the canal by means of a siphon structure located at the East Mirrool Regulator. It is the interaction of the Mirrool Creek floodplain with the irrigation infrastructure at this location that presents a flood risk in Yenda and resulted in the flooding during the March 2012 event.

1.2 The Need for Floodplain Management of Main Drain J / Mirrool Creek

As evidenced in the March 2012 flood event, there are a substantial number of properties within the communities of Yoogali and Yenda that are at risk of flooding from both local catchment runoff and Mirrool Creek flooding, respectively. Appropriate floodplain risk management activities need to be identified in order to reduce the flood risk that these communities are exposed to.

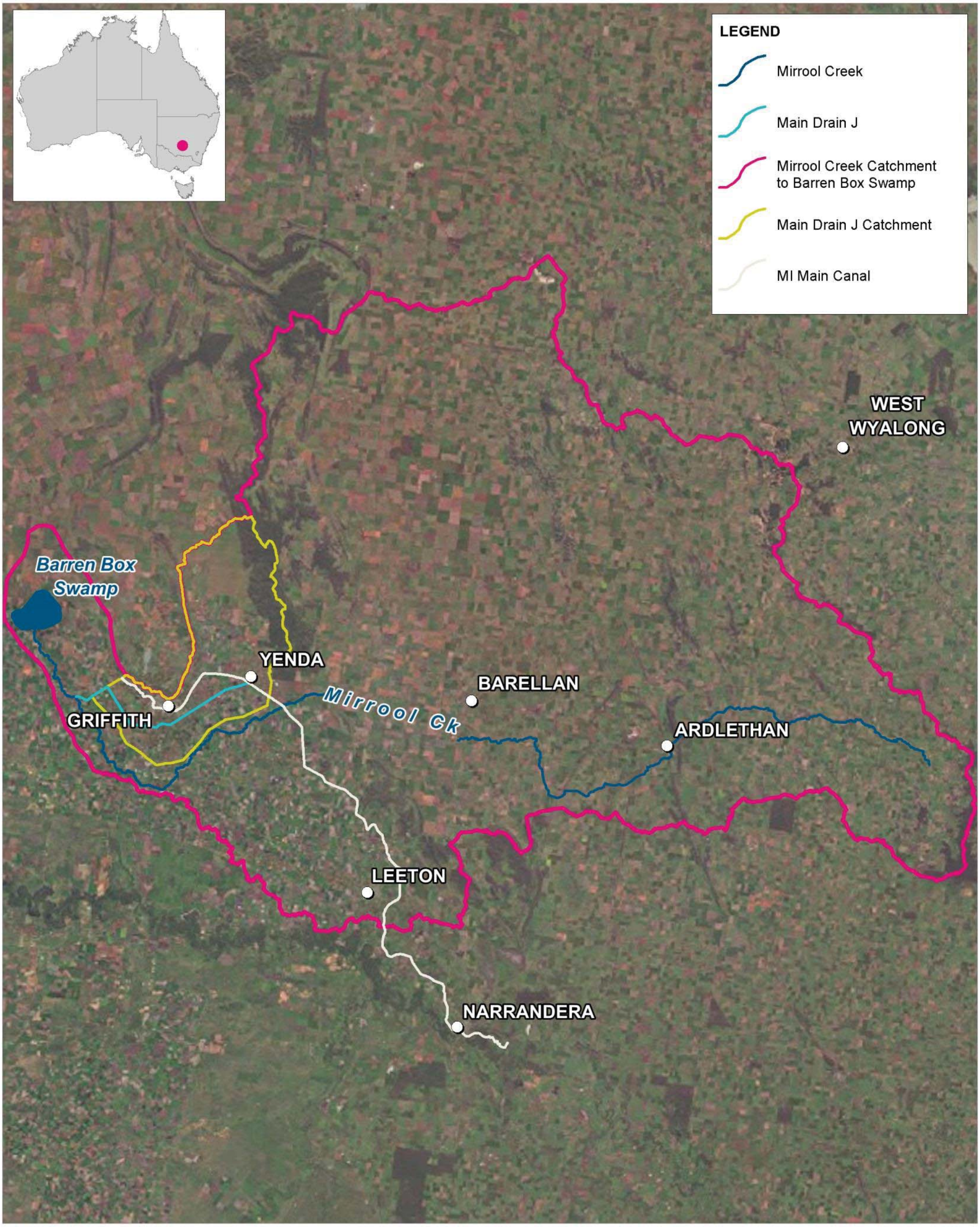
Within Council's Growth Strategy 2030 there is planned future development within the Main Drain J catchment, particularly around the localities of Yoogali, Collina and South Griffith. An understanding of the flood behaviour and associated risks is required to effectively plan and manage this future development.

Floodplain risk management considers the consequences of flooding on the community and aims to develop appropriate floodplain risk management measures to minimise and mitigate the impact of flooding. This incorporates the existing flood risk associated with current development, and future flood risk associated with future development and changes in land use.

Accordingly, Council desires to approach local floodplain risk management in a considered and systematic manner. This study comprises the initial stages of that systematic approach, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the Main Drain J catchment.

1.3 The Floodplain Management Process

The State Government's Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (2005).



Title:
Study Locality

Figure: 1-1

Rev: A

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0 15 30km

Approx. Scale

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Under the Policy the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain risk management responsibilities. The Policy provides for technical and financial support by the State Government through the following six sequential stages:

Table 1-1 Stages of Floodplain Risk Management

	Stage	Description
1	Formation of a Committee	Established by Council and includes community group representatives and State agency specialists.
2	Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3	Flood Study	Determines the nature and extent of the flood problem.
4	**Floodplain Risk Management Study**	**Evaluates management options for the floodplain in respect of both existing and proposed developments.**
5	**Floodplain Risk Management Plan**	**Involves formal adoption by Council of a plan of risk management for the floodplain.**
6	Implementation of the Floodplain Risk Management Plan	Construction of flood mitigation works to protect existing development. Use of environmental plans to ensure new development is compatible with the flood hazard.

The Griffith Main Drain J and Mirrool Floodplain Risk Management Study and Plan (this document) constitutes the fourth and fifth stages of the management process. It has been prepared for Griffith City Council to provide the basis for future management of flood liable land within the catchment.

1.4 Structure of Report

This report documents the Study's objectives, results and recommendations.

Section 1 introduces the study.

Section 2 provides background information including a catchment description, history of flooding and previous investigations.

Section 3 outlines the community consultation program undertaken.

Section 4 describes the design flooding behaviour in the catchment.

Section 5 provides a summary of the flood damages assessment including identification of property potentially affected by flooding.

Section 6 provides a review of relevant existing planning measures and controls.

Section 7 provides an overview of potential floodplain risk management measures.

Section 8 presents the recommended measures and an implementation plan.

2 Background Information

2.1 Catchment Description

The study catchment totals an area of around 550km^2 and incorporates the city of Griffith, the communities of Yenda, Bilbul, Beelbangera, Yoogali and Hanwood and numerous agricultural properties.

The topography of the study area including the Main Drain J catchment is shown in Figure 2-1. The upper catchment, which forms the western slopes of the Cocoparra Range, is steep and largely elevated above 200m AHD. The lower section of the catchment is a relatively flat expanse, which is heavily influenced by the regional irrigation infrastructure. Elevations are typically between 120m AHD to 150m AHD.

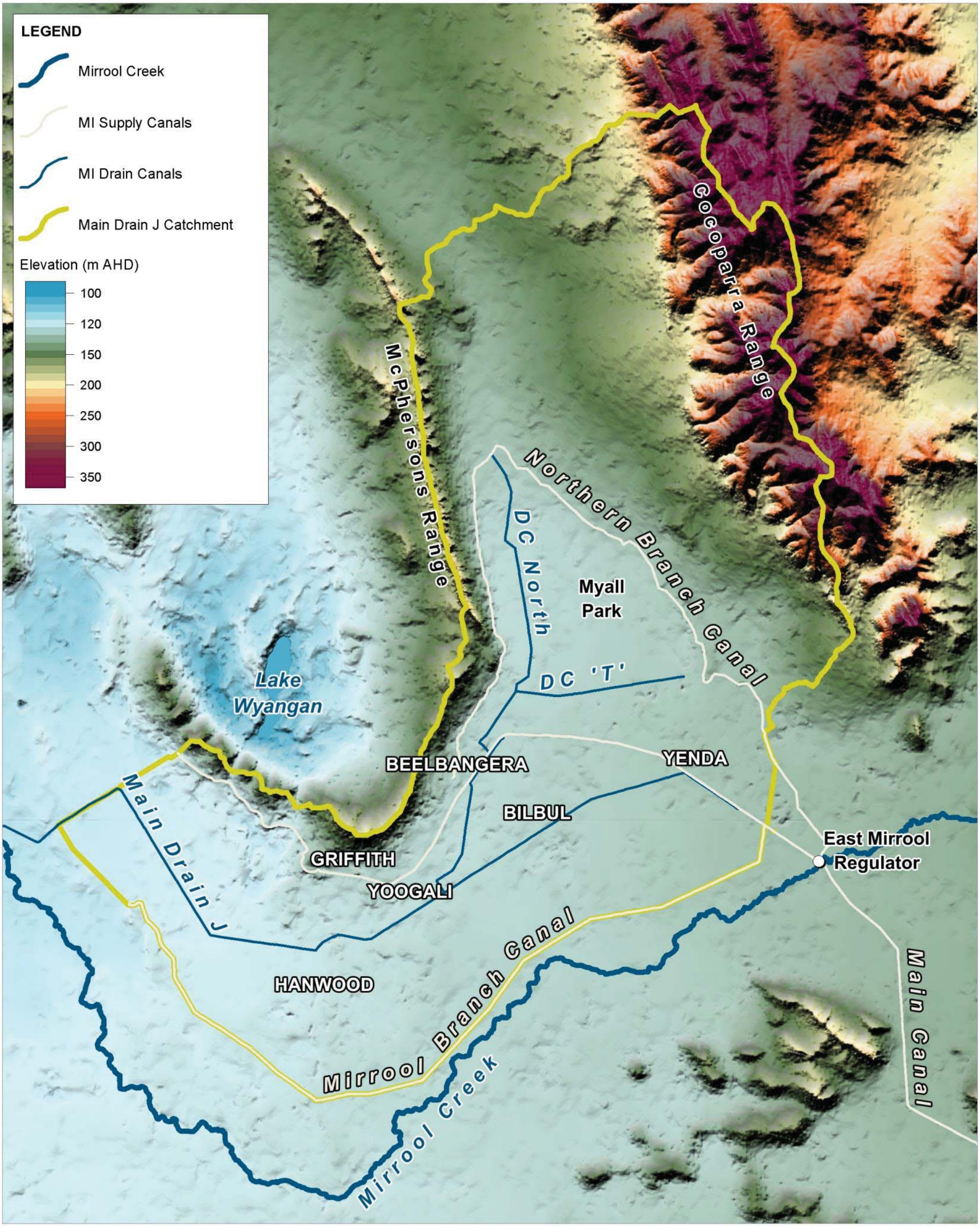
The western slopes of the Cocoparra Range and eastern slopes of the McPhersons Range drain to a naturally occurring topographic depression, situated in the locality of Myall Park. The flat fertile land between Yenda and Hanwood would have formed part of the broader Mirrool Creek floodplain.

Substantial irrigation supply and drainage infrastructure has modified the natural drainage of the catchment. The principal drainage channel for the catchment is Main Drain J, which extends from Yenda, through Bilbul and Yoogali, before discharging to Mirrool Creek some 14km to the west of Griffith. The DC North and DC 'T' now drain the topographic depression of Myall Park, connecting through to Main Drain J via Beelbangera and Yoogali.

The Mirrool Branch Canal forms the southern limit of the Main Drain J catchment, separating it from the broader Mirrool Creek floodplain. The Main Canal is the principal irrigation supply for the region and crosses Mirrool Creek at the East Mirrool Regulator, some 5km to the east of Yenda. The flows of Mirrool Creek are passed under the canal via means of a siphon structure. However, large flood flows on Mirrool Creek exceed the capacity of this structure and cause flood waters to back up behind the Main Canal and Northern Branch Canal. During the March 2012 event this caused flood waters to breach the canal and flow through to Myall Park via Yenda.

The Mirrool Creek catchment drains an area of approximately 6,500km^2 to the East Mirrool Regulator, on the Main Canal. The extent of the hydrologic catchment is shown in Figure 2-2. Much of the catchment runoff is generated from the upland ranges draining to Mirrool Creek and Sandy Creek. Additional upland areas contributing to catchment runoff are the eastern slopes of the Cocoparra Range. These steeper upland areas drain into a large and relatively flat expanse, centred around Barellan, in which the main stream alignments are much less well defined.

Within the flat floodplain expanse the Griffith to Temora railway has a significant influence on catchment hydrology. It is elevated above the floodplain and essentially divides the Mirrool Creek floodplain from that of the Binya Creek – Sandy Creek system to the north. The Mirrool Creek catchment is some 2,500km^2 in size and drains to the siphons under the Main Canal at the East Mirrool Regulator. The Binya Creek catchment is some 4,000km^2 in size and drains to Mirrool Creek around 6km upstream of the Main Canal.



Title:
Topography of the Main Drain J Catchment

Figure: 2-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 3.75 7.5km

Approx. Scale

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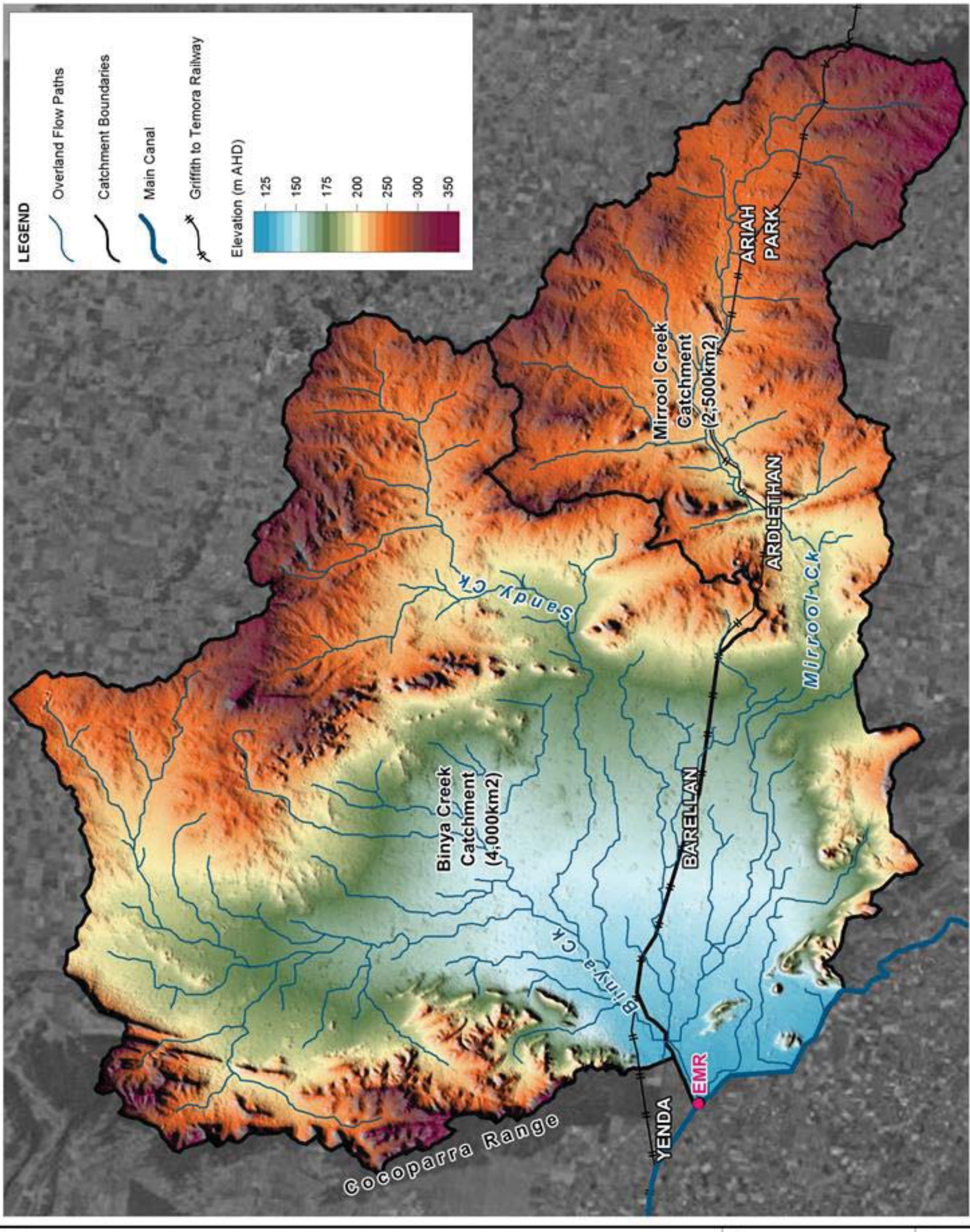

Title:

Mirrool Creek Catchment Boundary to EMR and Overland Flow Paths

Figure: 2-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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2.2 History of Flooding

A number of floods have been experienced in the study catchment since European settlement and the construction of the irrigation system in 1912. Major floods are known to have occurred in 1931, 1956, 1989 and most recently in 2012.

The June 1931 event was not in itself overly severe, with rainfall records indicating a daily total of 53mm being recorded at Yenda on 24th. This constitutes less than a 20% AEP rainfall event when compared to standard intensity frequency duration (IFD) curves. However, a similar amount of rainfall occurred across the Mirrool Creek catchment. More significant was the rainfall in preceding months, which totalled around 100mm across the Mirrool Creek catchment in the month preceding the event and around 200mm for the two months preceding the event. This represents an extremely wet antecedent condition, when compared to the average annual rainfall of around 450mm. These conditions resulted in the highest flow conditions in Mirrool Creek on record prior to the March 2012 event. The Mirrool Creek flood flows exceeded the available capacity of the siphon under the Main Canal and resulted in the breaching of the Northern Branch Canal and subsequent flooding in Yenda and Myall Park. The flood gates at the East Mirrool Regulator were installed in response to this event, preventing a similar occurrence during the following flood of March 1939.

Less is known about the flood of 1956. It caused substantial flooding within Griffith, with depths of over 1m being reported in Yambil Street. Examination of the rainfall record from Hanwood shows a peak daily rainfall depth of 58mm on 12th March.

The March 1989 flood is one of the largest recorded within the study catchment. The continuous rainfall record at Hanwood indicates that a total of 103mm fell in a 15-hour period on 14th, which is the equivalent of a 1% AEP magnitude design event when compared to the IFD curves. A rainfall depth of 93mm was recorded at Yenda. Flooding is understood to have occurred in Yenda, Bilbul, Yoogali, Griffith in Hanwood. The partial blockage of the siphon structures at Yenda may have made a significant contribution to the severity of flooding at that location.

The March 2012 flood was the largest in recorded history. The continuous rainfall record at Griffith Airport indicates that a total of 147mm fell in a 16-hour period, which is in excess of a 0.1% AEP magnitude design event when compared to the IFD curves. A similar rainfall depth was recorded at Yenda, but total rainfall depths reduced to around half of this amount at the eastern edge of the Mirrool Creek catchment. Flooding in Bilbul, Yoogali, Griffith and Hanwood resulted from the local catchment runoff exceeding the capacity of the available drainage. The flood flow from the Mirrool Creek catchment also exceeded the capacity of the siphon structure at the East Mirrool Regulator. This resulted in breaching of the Northern Branch Canal and subsequent flooding of Yenda.

The most significant inundation in terms of property flood affectation was in the villages of Yenda and Yoogali. Figure 2-3 and Figure 2-4 show photographs of the March 2012 flood inundation at Yenda and Yoogali respectively.

Figure 2-3 Flooding of Yenda village March 2012

Figure 2-4 Flooding of Yoogali village March 2012

2.3 Previous Studies

2.3.1 Guidelines for Mirrool Creek Floodplain Development Barellan to Yenda (Water Resources Commission, 1978)

The floodplain development guidelines were prepared for landholders on the Mirrool Creek floodplain between Barellan and the East Mirrool Regulator. Damage from previous flood events had led to landholders constructing levees to protect certain areas and drains to improve the drainage of other areas. However, these works were undertaken without coordination and resulted in other landholders becoming disadvantaged at the expense of the protection of others.

The guidelines sought to address the problem of uncoordinated flood protection works by defining a system of floodways that were seen as the most efficient way to convey floodwaters through the area. It also suggested areas that could be protected by the construction of levees if the land holders desired. Guidance was provided in relation to appropriate development of agricultural land within the area and included mapping of the defined floodways.

2.3.2 MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works Options on Floodway Lands (Water Resources River Management Branch, 1994)

The options study was initiated in response to the flooding of Murrumbidgee Irrigation Area lands during March and April of 1989. The study had a particular focus on the Mirrool Creek floodplain from Barren Box Swamp downstream to the Lachlan River, as flooding further up the catchment was less severe. However, it also included some assessment for improvements in flood management upstream of Barren Box Swamp.

For the Barellan to Yenda section of the floodplain the study advised that the 1978 guidelines were the most suitable means for managing flood risk. For the Yenda to Barren Box Swamp floodplain, considered during the current study, various potential upgrade options at the East Mirrool Regulator were assessed. A flood frequency analysis was undertaken to estimate likely peak design discharges and flow hydrographs at the regulator. A hydraulic model was constructed to test the potential impacts of upgrade options on downstream flood levels. The largest upgrade option considered was a 68m long siphoning of the Main Canal under the Mirrool Creek floodplain, which was found to produce a typical 0.1m increase in downstream peak flood levels.

2.3.3 Griffith Floodplain Risk Management Study and Plan (Worley Parsons, 2011)

The Griffith Floodplain Risk Management Study and Draft Floodplain Risk Management Plan builds on the findings of the Griffith Flood Study. It identifies the various issues associated with the risk of flooding and options to manage flood risk. Central to this was the calculation of Average Annual Damages caused by flooding and the investigation of a range of structural options to reduce the impact of flooding. The study also included the mapping of floodways (hydraulic categorisation) and flood hazards (hazard categorisation).

2.3.4 Griffith CBD Floodplain Risk Management Study and Plan (WMA Water, 2013)

The Griffith CBD Floodplain Risk Management Study and Plan builds on the findings of the Griffith CBD Overland Flow Study (WMAwater, 2012). It identifies the various issues associated with the risk of overland flooding in the CBD catchment areas and options to manage flood risk.

Following the completion of the current study and future update of the Floodplain Risk Management Study and Plan, the Griffith Floodplain Risk Management Study and Plan will become superseded. However, the Griffith CBD Floodplain Risk Management Study and Plan is complementary to this and will continue to be used for the management of flood risk within the city of Griffith.

2.3.5 Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014)

BMT WBM was commissioned by Council in early 2013 to undertake a review of the Griffith Floodplain Risk Management Study and Plan, with consideration of flooding from Mirrool Creek. A requirement of the study brief was to convert the existing Main Drain J catchment hydraulic model from RMA-2 to TUFLOW. Having undertaken this process the results from the two models were compared to confirm their consistency. However, significant differences were found between the existing flood modelling and the TUFLOW results. The observations of flooding during the March 2012 event were more consistent with the updated modelling than those of the existing flood study.

In order to fully understand the differences in the model outputs and to have confidence in the model moving forward in the Floodplain Risk Management process, it was necessary to undertake a full model calibration process. The scope of works undertaken was far beyond a simple model conversion and review. It was therefore appropriate that a flood study report be produced to properly document the model development and calibration process. This essentially provides for an updated Griffith Main Drain J Flood Study incorporating Mirrool Creek.

3 Community Consultation

3.1 The Community Consultation Process

Community consultation has been an important component of the floodplain risk management study update. The consultation has aimed to inform the community about the development of the floodplain risk management study and its likely outcome as a precursor to the development of the floodplain risk management plan. It has provided an opportunity to collect information on their flood experience, their concern on flooding issues and to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process have been as follows:

- Feedback through the Floodplain Management Committee meetings;
- Meetings with community members; and
- Public exhibition of the draft Flood Study.

These elements are discussed in detail below.

3.2 The Floodplain Management Committee

The study has been overseen by the Griffith Floodplain Management Committee (Committee). The Committee has assisted and advised Council in the development of the Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan.

The Committee is responsible for recommending the outcomes of the study for formal consideration by Council.

3.3 Community Meetings

Following the initial data compilation and model development phases a number of meetings were held with key community groups. The purpose of these meetings was to provide the community with an appreciation of how the study was being approached and to understand the catchment flood behaviour from those that had experienced it first-hand. Meetings were held with the Yenda Flood Working Group, Yoogali Progress Association and individual landholders from other flood affected locations within the catchment.

The meetings were highly successful as valuable qualitative information regarding flood depths, timings and durations was gathered. Additional flood photograph and video data was also provided by some individuals, including Paul Rossetto, David Rossetto, Craig Bardney, Peter Budd, Tiz Forlico and the Andreazza's. The descriptions of flood behaviour that had been observed during the March 2012 and March 1989 flood events matched reasonably well with what was being produced by the modelling undertaken for the 2014 Flood Study.

3.4 Public Exhibition

The Draft Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan was placed on public exhibition 28th May 2015 with the report being made available at Council's website, Griffith City Library and the Council Administration Building. A copy of the media release is provided in Appendix D. Landowners, residents and businesses were invited to participate in the study by providing comment on the Draft report with submissions closing 7th July 2015.

As part of the public exhibition of the Draft, public workshops/community information sessions were held at:

- Griffith City Library - 10:00am Tuesday 16th June 2015
- Yoogali Club - 6:00pm Tuesday 16th June 2015
- Yenda Diggers Club - 7:30pm Tuesday 16th June 2015

Each of the sessions were well patronised by the local community.

Following the close of public exhibition, fifteen (15) submissions were received from the community as below:

- 2 Yoogali residents;
- 1 Myall Park resident;
- 9 Yenda residents;
- Yenda Progress Association;
- Yenda Flood Victims Association; and
- Carrathool Shire Council

A summary of the key issues arising from the submissions is provided in Appendix E.

4 Existing Flood Behaviour

4.1 Flood Behaviour

There are effectively two different catchments driving flood behaviour in the study area – Main Drain J and Mirrool Creek.

The Main Drain J catchment itself is more accurately described as two separate catchments – one upstream of the Main Canal, draining to Myall Park and one downstream of the canal, draining to Mirrool Creek via Main Drain J. Historically the flood storage area of Myall Park would have been a terminal ephemeral wetland, receiving catchment runoff from the western slopes of the Cocoparra Range. However, the development of the regional irrigation has included a drainage connection from the Myall Park storage through to Main Drain J catchment. Despite this connectivity, the two systems still operate essentially independently in terms of flood behaviour.

Flooding within Main Drain J is driven principally by runoff from the farm drainage in the area bounded by the Main Canal and Mirrool Branch Canal. It is a relatively small catchment (80km^2 to Yoogali and 120km^2 to Hanwood) compared to that of Myall Park and the critical flood conditions are driven by shorter duration storm events. There are additional runoff contributions from the southern slopes of the McPherson Range, which are attenuated to some degree by the Main Canal and associated cross-drainage infrastructure. Flows also enter the system from the Myall Park storage area, but would be restricted to a baseflow contribution during the flood recession, rather than driving the peak flood conditions.

There is no well-defined natural drainage line evident in the catchment topography. The provision of drainage infrastructure has therefore provided capacity above that which naturally existed. Even in large flood events, such as March 2012, the drainage network conveys around 90% of the flood flows.

The most extensive area of out-of-bank flooding occurs between Hanwood and Mirrool Creek. It is typically no more than 0.5m deep and has minimal flow velocities. Additional localised out-of-bank flooding is known to occur, most notably at Yoogali, which is located near the confluence of Main Drain J and DC 605 J. Here flows spilling from DC 605 J are impeded by the railway and are contained by the raised banks of Main Drain J. Flooding can also occur from the local drainage network becoming 'locked' by elevated water levels within Main Drain J, as occurred in March 1989. Out-of-bank flooding is also known to occur around Bilbul.

Flood conditions along Main Drain J would be expected to occur within 12 hours of the onset of the rainfall event. Elevated water level conditions may be maintained for a day or two following the event.

The Mirrool Creek catchment is some 6,500km^2 in size upstream of the East Mirrool Regulator. This catchment area can be divided into two main sub-catchments. Mirrool Creek drains the upland areas around Ariah Park and the Barellan flats to the south of the Griffith Temora Railway, with a total contributing catchment area of around 2,500km^2. Binya Creek joins Mirrool Creek a few kms upstream of the East Mirrool Regulator. It drains the upland areas to the north of Ardlethan, the eastern slopes of the Cocoparra Range and the Barellan flats to the north of the Griffith Temora Railway, with a total contributing catchment area of around 4,000km^2.

Flood flows through the floodplain area are often characterised by a dual response. Rainfall over the Barellan floodplain and Colinroobie produces an early response, which is then followed by a second flood wave from the upper Mirrool Creek (dependant on the rainfall distribution). This was evidenced by the March 2012 flood event. Runoff from the Colinroobie area will typically reach the Barellan floodplain within a day of the rainfall. Flow from the upper Mirrool Creek catchment may take a few days to arrive. Rainfall occurring over specific locations within the catchment at different times will produce a different response, representative of the spatial and temporal rainfall distribution. As flood flows are attenuated through the Barellan floodplain the flood peak is typically reduced and occurs a day later than the flows entering the floodplain.

Figure 4-1 shows two satellite images during the March 2012 flood event. The Landsat 7 image taken on 4th March shows floodwaters in the Barellan floodplain and local runoff around Merribee Hill. Floodwaters have arrived at the EMR with no inundation to Yenda at this stage.

Figure 4-1 March 2012 Flood progression through Satellite Imagery

The Deimos satellite image some 4 days later on the 8th March 2012 shows the subsequent flooding of Yenda township as floodwaters are pushed over the Northern Branch Canal and to North Yenda via overtopping of the railway.

Flood waters arrive at the EMR firstly from Binya Creek, followed by runoff from the Colinroobie area and finally from Mirrool Creek, as the flood level begins to rise behind the Main Canal. Flood waters can be conveyed to the downstream Mirrool Creek floodplain through the siphon structures and the operation of flood gates to allow flood flows into the canal and then out again through the downstream side. When the capacity of these structures is exceeded then flood waters can spill over the Northern Branch Canal and proceed to the township of Yenda.

The flood gates with full operational capacity provide of the order of 2% AEP flow capacity and accordingly this represents the relative design flood immunity standard for Yenda under these conditions. In its current decommissioned state, however, the flood immunity is reduced to something of the order of a 5% AEP event with only the capacity of the siphon to transfer Mirrool Creek flows.

Flood waters spilling into Yenda from Mirrool Creek will build up behind the railway before overtopping and progressing into the Myall Park floodplain storage area. The Myall Park storage area is a natural topographic depression that collects runoff from the western slopes of the Cocoparra Range, in what would have historically been a terminal ephemeral wetland. However, the area is now drained by the irrigation infrastructure and is conveyed along Main Drain J and into Mirrool Creek upstream of Barren Box Swamp.

4.2 Existing Flooding “Hot Spots”

The 2014 Flood Study identified a number of flooding “hot-spots” within the study area. The March 2012 event was estimated to be representative of approximately a 0.5% AEP such that the on-ground conditions experienced during this event provides confirmation of the highest at risk areas. The areas principally affected during the March 2012 event are summarised below along with identification of the key flooding mechanism at each site.

Yenda

The principal flooding driver for the Yenda township is flows emanating from the Mirrool Creek catchment. Flooding from Mirrool Creek will occur at Yenda when the cross-drainage capacity of the Main Canal structures is exceeded. Flood flows are pushed over the Northern Branch Canal into Yenda where floodwaters back up behind the elevated railway embankment.

Yoogali

Yoogali village flooding occurs when the capacity of DC 605 J is exceeded. Water then spills over McCormack Road and inundates the village, backing up behind the railway embankment. Flooding may last for a few days, until the tailwater level in Main Drain J lowers to enable drainage out of Yoogali.

Hanwood

In Hanwood flooding occurs when the fields adjacent to DC A flood to a level which is sufficient to overtop Kidman Way. There is only a small gradient between flood levels at Hanwood and in Main Drain J and so the tailwater level in the drain has a significant influence on flooding here.

4.3 Flood Risk Mapping

The flood results from the 2014 Flood Study were presented in a flood mapping series for each design event magnitude simulated, incorporating a map of peak flood depth, velocity and hydraulic hazard within study catchment. Additional mapping was also undertaken to define the hydraulic category and flood hazard distributions across the study area in addition to the definition of Flood Planning Area. These mapping outputs are relevant to flood related development controls referenced in the Griffith LEP and DCP discussed in Section 6.4.

4.3.1 Hydraulic Categorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the study catchment. Given the nature of flooding in the Main Drain J catchment, the different methods for defining floodways produce the same result – floodways are essentially restricted to the drainage channels because little flow is conveyed within the floodplain. Flood storage areas were defined using the modelled peak flood depth.

The adopted hydraulic categorisation is defined in Table 4-1.

Hydraulic category mapping for the 1% AEP event derived using the 2014 Flood Study results included in Appendix A. A single map coverage is provided for the study areas. Detailed mapping of localities is provided in Mapping Compendium of the Griffith Main Drain J and Mirrool Creek Flood Study, BMT WBM (2014).

The floodway is contained within the banks of the irrigation drainage channels. Most of the inundated floodplain is classified as flood fringe but there are areas of flood storage, most notably Myall Park but also in the vicinity of Bilbul Yoogali and Hanwood and the area downstream of Walla Avenue.

Table 4-1 Hydraulic Categories

Hydraulic Category	Categorisation Criteria	Description
Floodway	Velocity * Depth > 0.1 at the 1% AEP event	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.1 and Depth > 0.3 at the 1% AEP event	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Flood extent of the 1% AEP event	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

4.3.2 Flood Hazard

The NSW Governments Floodplain Development Manual (2005) defines flood hazard categories as follows:

- **High hazard** – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low hazard** – should it be necessary, trucks could evacuate people and their possessions; able bodied adults would have little difficulty in wading to safety.

Hazard categorisation is carried out to establish how hazardous (i.e. dangerous) various parts of the floodplain are. Primarily the hazard is a function of the depth and velocity of floodwater, however, the hazard categorisation considers a wider range of flood risks, particularly those relating to personal safety and evacuation. These hazard factors are derived from both hydraulic risk factors (such as depths and velocities) and human / behavioural issues (such as flood readiness).

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Flood Depth and Velocity
- Flood Readiness
- Rate of Rise - Effective Warning Time
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

4.3.2.1 Size of Flood

The size of flood will have an obvious and significant influence on the degree of flood risk. Relatively frequent or minor floods would typically be associated with a low flood hazard, whilst the major or rare flood events are likely to provide for high hazard flood conditions.

The 2014 Flood Study indicated a relatively low level of flood affectation in minor flood events. The Main Drain J system in particularly has close to the 1% AEP drainage capacity such that extensive out of bank flooding for lower order events would not be expected. For the Mirrool Creek, and in particular the flood contribution to Yenda, significant flows to Yenda may be initiated for the events in excess of the 5% AEP flood condition dependent on the influence of the EMR flood relief structures. Due to the influence of surrounding controls such as the elevated Griffith-Temora Railway embankment, flood depths in Yenda can rise to similar levels across a range of design event magnitudes. The nature of the flooding however is typically low velocity, such that there is not a significant increase in flood risk with increasing flow through Yenda

4.3.2.2 Depth and Velocity

Depth and velocity hazards have been identified according to the provisional hydraulic hazard categories provided in the Floodplain Development Manual. This has been further sub-categorised to show the predominant 'type' of hydraulic hazard (i.e. high velocity, depth, or combination) as shown in Figure 4-2 below.

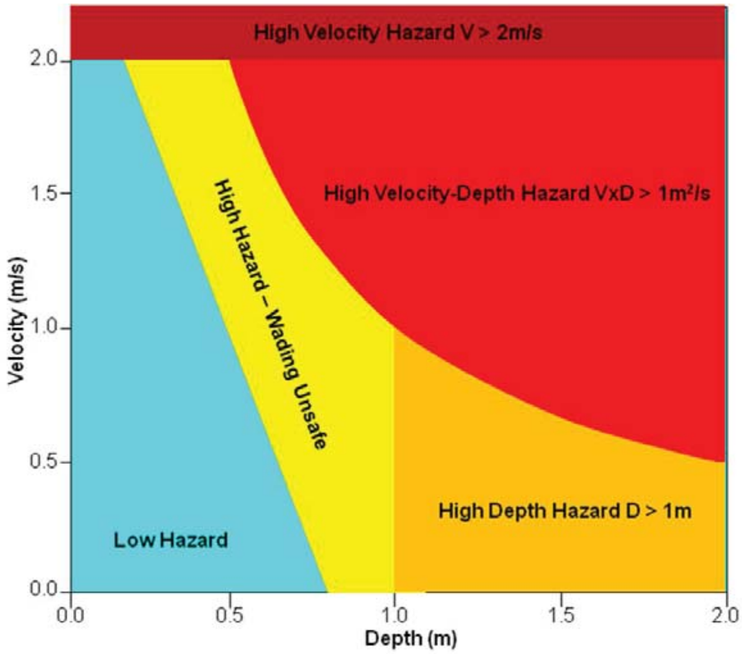


Figure 4-2 Hydraulic Hazard as a Function of Depth and Velocity

4.3.2.3 Flood Readiness

The term 'flood readiness' encompasses a broad range of factors, including familiarity with flooding in the catchment, awareness of evacuation procedures and preparation for a flood (e.g. development of flood plans). Flood readiness can refer to individuals, organisations, communities and businesses.

The relatively recent March 2012 event flood provided for first-hand experience of major flooding and indication to the community of the potential flood risk. Combined with a number of catchment flood events in decades past, many landowners affected by these events would have a reasonable level of flood awareness, particularly in relation to flood effects on their own property.

4.3.2.4 Rate of Rise

The rate of rise of floodwaters is typically a function of the catchments topographical characteristics such as size, shape and slope, and also influences such as soil types and land use. Flood levels rise faster in steep, constrained areas and slower in broad, flat floodplains. A high rate of rise adds an additional hazard by reducing the amount of time available to prepare and evacuate.

The relatively flat nature of the study and large contributing catchments provides for extended periods of rise of floodwaters. The urban areas such as the Griffith CBD may experience more rapid inundation during flash flood events, however, for Main Darin J and Mirrool Creek catchment flooding, the typical rates of rise of floodwater don’t pose significant additional flood risk.

4.3.2.5 Duration of Flooding

The greater duration of flood inundation, the greater potential impacts on damages and disruption to the community. This was evidenced during the March 2012 event, particularly in relation to Yenda, in which inundation affected extensive parts of the township for days. Similar extended duration flooding conditions were experienced in other localities such as Yoogali, Hanwood and the rural areas.

4.3.2.6 Flood Warning Times

The amount of warning available for an approaching flood can have a significant impact on the risk to life. Less warning time clearly represents a greater risk to the community as there is less opportunity to respond appropriately and implement risk-reduction measures. Minimal warning time also means that emergency services are unlikely to be able to provide any assistance or direction for affected communities.

To assess flood warning opportunity for the study area, consideration has been given to the levels of warning times as defined in Table 4-2.

Flooding in Yoogali and across the broader Main Drain J system may occur relatively rapidly in comparison to Mirrool Creek flooding, however, warning times are expected to be of the order of 6-12 hours. Rising flood conditions in the drainage system is observable. For Mirrool Creek, there is typically days of travel time for the majority of the catchment before floodwaters impact significantly at the EMR.

Table 4-2 Flood Warning Time Categories

No effective warning	<1 hr	No time for pro-active and systematic organisation of flood mitigation, evacuation, emergency response etc. Individuals would be self-directed in regards to emergency response.
Minimal warning	1-6 hrs	Limited assistance and direction likely from emergency services. Measures requiring minimal time for implementation may be appropriate for flood management.
Moderate warning	6-12 hrs	Potential assistance and direction from emergency services, depending on time of day. Measures requiring moderate time, or less, for implementation may be appropriate for flood management.
Good warning	12+ hrs	Significant assistance and direction from emergency services may be available, including assistance with evacuation. Most measures requiring some form of on-demand implementation would be appropriate for flood management.

4.3.2.7 Effective Flood Access

Access and evacuation difficulties arise from:

- high depths and velocities of floodwaters over access routes;
- difficulties associated with wading (uneven ground, obstruction such as fences);
- the distance to higher, flood free ground;
- the number of people and capacity of evacuation routes;
- the inability to communicate with evacuation and emergency services;
- the availability of suitable equipment (e.g. heavy vehicles, boats);
- a low level of community awareness of evacuation procedures or requirements; and
- a willingness of residents to remain at their property.

As evident from March 2012 flood event, a number of roads in the local area are expected to be inundated in major flood events. Road inundation can potentially result in the isolation of flood affected property and have serious implications for emergency response.

Even for the highest order events, the flooding behaviour in the major residential areas, e.g. Yenda, Yoogali, Hanwood poses limited restriction to safe evacuation and egress. Certainly some local flow conditions in the vicinity of the channels poses higher risks, however, in general the majority of major urban development is affected by more backwater type inundation.

4.3.2.8 Adopted Flood Hazard Categories

Hazard category mapping for the 1% AEP event derived using the 2014 Flood Study results included in Appendix A. A single map coverage is provided for the study areas.

The high flood hazard areas are typically confined to the main waterways, with existing development areas typically defined as low hazard. This is consistent with the hydraulic category mapping with floodways (typically high depth and velocity) generally contained within the banks of the irrigation drainage channels.

4.3.3 Flood Planning Area

The Flood Planning Area encompasses the land below the Flood Planning Level, i.e. the 1% AEP flood level plus 0.5m freeboard. The Flood Planning Area typically defines the areas of the catchment subject to flood related development controls in accordance with the Griffith LEP and DCP.

The Flood Planning Area mapping is shown in Appendix A derived from the derived using the 1% AEP results from the 2014 Flood Study.

5 Property Inundation and Flood Damages Assessment

A flood damage assessment has been undertaken to identify flood affected property, to quantify the extent of damages in economic terms for existing flood conditions and to enable the assessment of the relative merit of potential flood mitigation options by means of benefit-cost analysis.

The general process for undertaking a flood damages assessment incorporates:

- Identifying properties subject to flooding;
- Determining depth of inundation above floor level for a range of design event magnitudes;
- Defining appropriate stage-damage relationships for various property types/uses;
- Estimating potential flood damage for each property; and
- Calculating the total flood damage for a range of design events.

5.1 Property Data

5.1.1 Location

Property locations have been derived from Council's cadastre information and associated detailed aerial photography of the catchment. Linked within a GIS system, this data enables rapid identification and querying of property details.

A property database has been developed detailing individual properties subject to flood inundation.

5.1.2 Land Use

For the purposes of the flood damage assessment, property was considered as residential, commercial or light industrial. Commercial and industrial properties were identified using aerial photography during the 2011 FRMS&P.

There is no data available to define the extent of the public and corporate infrastructure that could be damaged as a result of flooding. Accordingly, infrastructure damages were determined to be 30% of the total direct and indirect residential (including dwellings and property damages) and industrial/commercial costs. This is in keeping with the 2011 study and approaches employed for other areas of NSW.

5.1.3 Ground and Floor Level

Ground levels for individual properties have been determined using the LiDAR DEM, which is the best available comprehensive dataset of ground elevations in the catchment. Detailed floor level survey information is not available for the majority of properties located within the floodplain. In the absence of such information the floor levels for individual properties are assumed to be situated 0.3m above ground level.

5.1.4 Flood Level

The design flood levels across the catchment were adopted from the Griffith Main Drain J and Mirrool Flood Study (BMT WBM, 2014) as discussed in Section 2. The flood modelling results, derived on a 20m x 20m grid, were used to generate a continuous flood profile across the floodplain. Flood levels calculated from the TUFLOW model were queried from TUFLOW's GIS output at each property reference point. The resulting output was used to identify flooding characteristics such as the number and type of properties affected, frequency of inundation and the depth of inundation.

5.2 Property Inundation

A summary of the number of properties potentially affected by above floor flooding for a range of flood magnitudes is shown in Table 5-1. The table distinguishes between residential property and industrial/commercial enterprise. The distribution by locality of the affected properties for each design flood event is shown in Table 5-3. Given the nature of the local catchment flooding, only a limited number of properties have been identified at risk of above floor flooding.

Table 5-1 Number of Properties Affected by Above Floor Flooding

Design Event	Building	
	Residential	Commercial
5% AEP	0	0
2% AEP	38	2
1% AEP	332	11
0.5% AEP	496	23
Extreme Flood	1040	60

5.3 Flood Damages Assessment

5.3.1 Types of Flood Damage

The definitions and methodology used in estimating flood damage are summarised in the Floodplain Development Manual. Figure 5-1 summarises the "types" of flood damages as considered in this study. The two main categories are 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages relate to the loss, or loss in value, of an object or a piece of property caused by direct contact with floodwaters. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

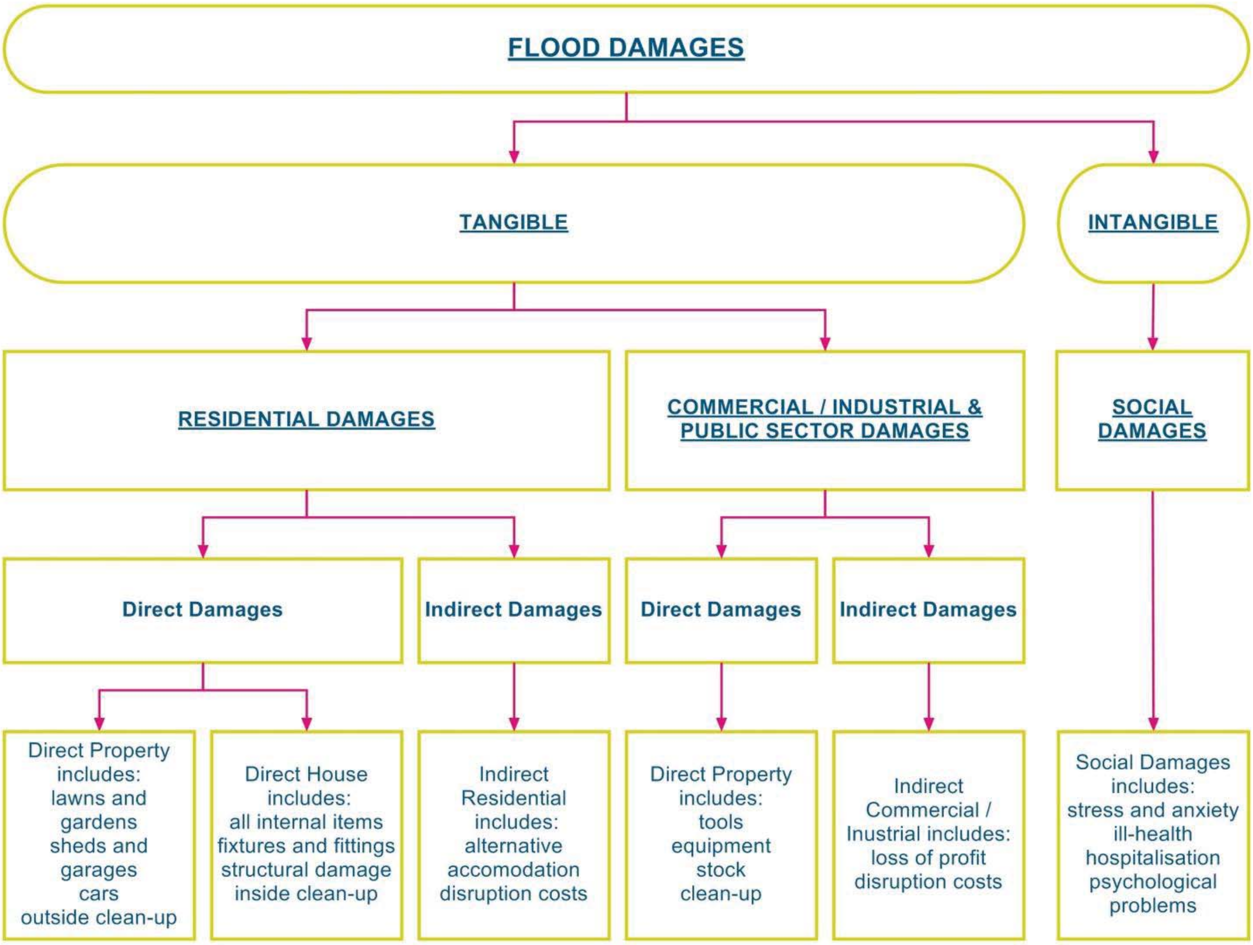


Figure 5-1 Types of Flood Damage

5.3.2 Basis of Flood Damage Calculations

Flood damages have been calculated using the data base of potentially flood affected properties and a number of stage-damage curves derived for different types of property within the catchment. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type. Residential damage curves are based on the OEH guideline stage-damage curves for residential property.

Different stage-damage curves for direct property damage have been derived for:

- Residential dwellings (categorised into small, typical or raised categories);
- Commercial premises (categorised into low, medium or high damage categories); and
- Light industrial premises.

Apart from the direct damages calculated from the derived stage-damage curves for each flood affected property, other forms of flood damage include:

- Indirect residential, commercial and industrial damages, taken as a percentage of the direct damages; and

- Infrastructure damage, based on a percentage of the total value of residential and business flood damage.

Intangible damages relate to the social impact of flooding and include:

- inconvenience,
- isolation,
- disruption of family and social activities,
- anxiety, pain and suffering, trauma,
- physical ill-health, and
- psychological ill-health

The damage estimates derived in this study are for the **tangible damages only**. Whilst intangible losses may be significant, these effects have not been quantified due to difficulties in assigning a meaningful dollar value.

5.3.3 Summary of Flood Damages

The peak depth of flooding was determined at each property for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events and the Extreme Flood Event. The associated flood damage cost to each property was subsequently estimated from the stage-damage relationships. Total damages for each flood event were determined by summing the predicted damages for each individual property.

Table 5-2 provides a summary of the flood damages calculations for the Main Drain J Catchment.

The Average Annual Damage (AAD) is the average damage in dollars per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the AAD).

Table 5-2 Predicted Flood Damages for Existing Conditions

Damage Sector	Damage in Flood Event ($,000)					Average Annual Damage
	5% AEP	2% AEP	1% AEP	0.5% AEP	Extreme Flood	
Direct Residential	0	1916	17439	27611	63675	463
Indirect Residential	0	96	872	1381	3184	23
Direct Commercial	0	986	2252	3605	14485	90
Indirect Commercial	0	493	1126	1803	7243	45
Infrastructure and Public Sector	0	1047	6507	10320	26576	186
Total	**0**	**4538**	**28196**	**44720**	**115163**	**807**

The total estimated flood damage to occur in a 1% AEP (100-year ARI) flood event is $28.2M, increasing to an estimated $115M worth of damage for the Extreme Flood.

The distribution of the total damages across the village areas is summarised in

Table 5-3 Predicted Flood Damages by Locality for Existing Conditions

Location	Damage in Flood Event ($,000)					Average Annual Damage
	5% AEP	2% AEP	1% AEP	0.5% AEP	Extreme Flood	
Yenda	0	4372	26862	40248	74913	672
Yoogali	0	59	549	2834	20046	70
Beelbangera	0	0	0	8	6464	17
Bilbul	0	8	8	114	1309	4
Griffith	0	59	339	615	6972	25
Hanwood	0	38	430	716	4629	20
Tharbogang	0	3	8	183	437	3
Total	**0**	**4538**	**28196**	**44720**	**115163**	**807**

The different components of flood damage in the study area are shown in Figure 5-2.

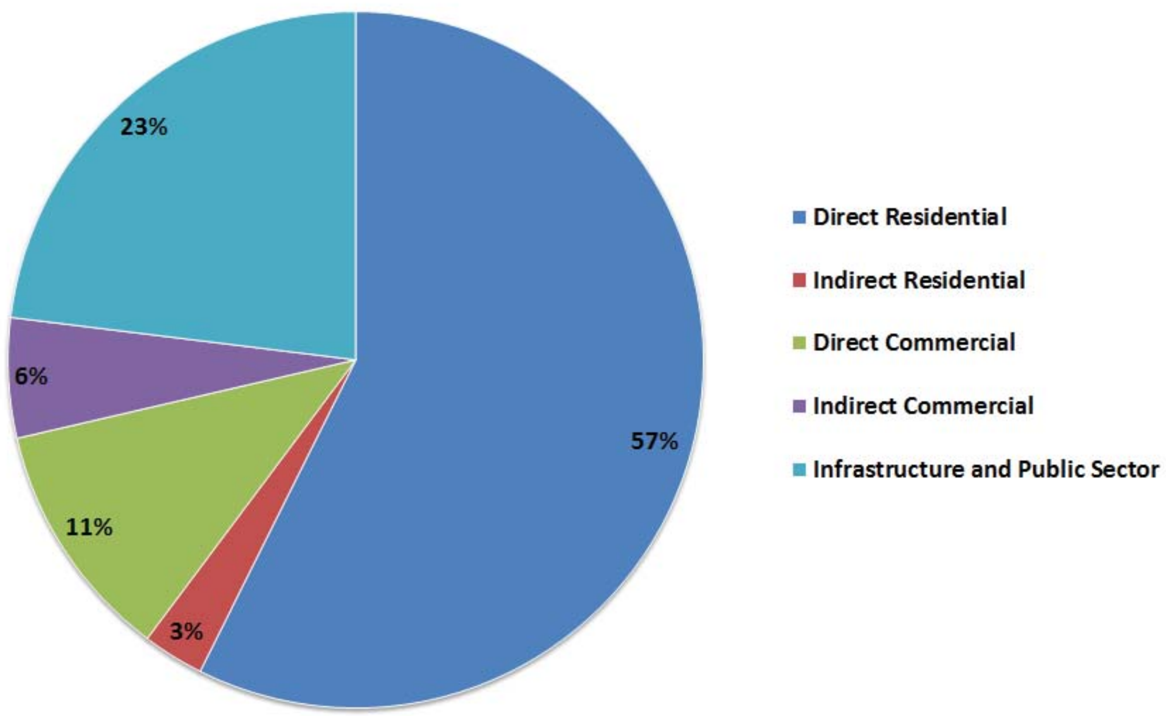


Figure 5-2 Flood Damage Components for Main Drain J / Mirrool Creek (Average Annual Damage)

6 Review of Griffith Floodplain Risk Management Plan

6.1 Context of Plan

The Griffith Floodplain Risk Management Study and Draft Floodplain Risk Management Plan (Worley Parsons 2011) builds on the findings outlined in the Griffith Flood Study (Worley Parsons, 2006). It identifies the various issues associated with the risk of flooding and the options available to manage the existing, future and continuing flood risk. Specifically the study aimed to:

- identify and evaluate management options (structural and non-structural) for the floodplain in terms of their capacity to reduce existing and potential future flooding problems;
- provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed; and
- provide a framework for revisions to planning instruments such as Local Environmental Plans (LEPs), so that land use controls are consistent with flood risk and flood hazard.

A total of eight structural options were investigated as part of the Griffith Floodplain Risk Management Study. Two options were recommended in the Plan with the other options excluded as a result of undesirable flood impacts or excessive costs for the configuration assessed. Five planning options were considered and include in the Plan recommendations.

The draft study and plan was placed on public exhibition in December 2010 and was exhibited for a period of 3 months, until the 11th March 2011. During the exhibition, comment was invited and received from the community. A number of concerns were raised from the community in regard to the extensive floodway zones through the Min Drain 'J floodplain and implications for future land use and development.

Subsequent to the public exhibition, a revision of the modelling was undertaken to address some inconsistencies in contributing catchment areas. The model changes provided for some significant reductions in peak flood levels through the Main Drain 'J' catchment, including for the 100-year ARI event being the key reference event for flood planning. Revisions in the final documents were made to the hydraulic and hazard categorisation mapping and the Flood Planning Area map to reflect the results of the revised modelling.

Whilst the revised modelling undertaken for the reduced catchment area informed the study and plan, some aspects were not reviewed as an outcome updated modelling results in the interests of moving forward with the flood planning process through adoption of the study. The performance of structural options was not reassessed in light of the updated modelling and the flood damages assessment was not updated. Accordingly, the Draft Plan included recommendations for these aspects be reviewed in the context of the revised catchment modelling results.

The March 2012 flood event provided a further trigger to reassess flood conditions particularly in regards to the significant impacts on the communities of Yenda and Yoogali. The source of flooding in Yenda was from Mirrool Creek flood waters overtopping the irrigation infrastructure and spilling into the catchment of Main Drain J. The existing Floodplain Risk Management Study had only considered flooding from runoff within the Main Drain J catchment and not from external sources. A review of the Study was therefore required to investigate the implications of flood contributions from Mirrool Creek.

The Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) was initiated to revise the design flooding conditions through the study area and inform an update to the Griffith FRMS&P. The undertaking the revised flood study provides the opportunity to reassess the structural options considered as part of the Griffith FRMS&P.

6.2 Key Changes in Flood Behaviour from 2014 Flood Study

The Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) revised the design flood conditions as determined through the previous Griffith FRMS&P and Griffith Flood Study. The updated flood study provided for some significant changes in simulated design flood behaviour from the previous assessments, largely through consideration of the contributions of Mirrool Creek (largely impacting on Yenda), but also changes in localised flood behaviour through a refined representation the Main Drain 'J' system.

The changes in simulated design flood behaviour have significance in the assessment of potential floodplain risk management options as considered in the Griffith FRMS&P. Some of the assumptions/conclusions for specific options require revisiting as a result of the updated flood behaviour.

A summary of the key changes emanating from the 2014 Flood Study relating to specific localities within the study area is provided below.

Yenda

The most significant change to the design flood behaviour at Yenda was through the inclusion of Mirrool Creek flood flow contributions not considered in the previous studies. The experiences of the March 2012 flood event highlighted the vulnerability of the Yenda community to Mirrool Creek discharges bypassing the flood escape structure at the East Mirrool regulator.

In order to model the Mirrool Creek system inflows, the study area for the updated flood study extends well beyond that of the previous assessments. The revised study area now incorporates North Yenda and the broader floodplain of the Mirrool Creek, particularly downstream of the Main Canal.

The design flood conditions at Yenda with consideration of the Mirrool Creek contributions provides for significant greater flood risks to those identified in the previous assessments. Accordingly, different structural options require to be assessed to manage these flow contributions, including assessment of changes to the configuration of the East Mirrool regulator flood control structures.

Beelbangera

The previous study identified major floodway areas through Beelbangera from flows emanating in the upper Main Drain 'J' catchment. These conditions are not reflected in the revised flood study with the updated results providing for significantly lower flood conditions. On the basis of the previous results, there was significant concern for Beelbangera during the March 2012 flood event, with significant inundation and high hazard flood conditions anticipated from flows emanating out of the Myall Park area. The expected conditions were not experienced in March 2012.

The updated flood study results provides for a better representation of the flood conditions through Beelbangera and is more representative of the March 2012 event experience. Accordingly, flood risk mapping has been updated and the requirement for major structural options to address flooding in this area largely negated.

Yoogali

Similar to Beelbangera, the updated flood study provides for a better representation of design flood conditions and reflective of conditions in March 2012. The updated results provide for less extensive floodway and high hazard flood zones through Yoogali. These changes have been represented in the updated flood risk mapping. However, there remains a flood inundation risk to Yoogali due to local conditions.

A number of structural options were assessed in the Griffith FRMS&P to reduce flooding in Yoogali. These options need to be re-assessed in light of the updated flood behaviour. The changed flood conditions potentially influence the scale of works required and relative impact of proposed works on existing flood behaviour. It is noted that some options previously assessed for Yoogali were discounted based on adverse flood impacts and unfavourable benefit-cost due to construction costs.

Hanwood

The floodway and high hazard flood zones have also been reduced throughout the Hanwood locality. The main difference between the previous studies and the updated flood study is the distribution of flow between the Main Drain 'J' channel and the floodplain. The updated study provided for lower out-of-bank flows in the Hanwood area and corresponding lower flood risk.

The Griffith FRMS&P noted that Hanwood was largely subject to a backwater influence form Main Drain 'J'. This is confirmed in the updated flood study.

Rural Areas

Similar inundation extents are identified in the rural areas across the studies, albeit some differences in relative flow magnitudes and associated flood hazard. Flood conditions on a lot scale can be significantly influenced by floodwater connectivity through the supply and drainage channels and elevated embankments (e.g. access roads, farm bunds). Often these features are beyond the scale of representation of the models. In assessing local flood conditions, consideration should be given to peak flood levels in adjacent major channels as represented by the model results, and interpretation of local embankments as hydraulic controls.

CBD

The revised flood study does consider the CBD catchments in detail. Flood management in the CBD areas has been addressed at the appropriate local scale in the Griffith CBD Catchment Overland Flow Flood Study (WMAwater, 2012) and Griffith CBD Floodplain Risk Management Study and Plan (WMAwater, 2013).

6.3 Structural Options Considered

The Griffith FRMS&P (Worley Parsons, 2011) identified a number of structural options to modify the existing flood behaviour and reduce overall flooding risk. Options were assessed using the established hydraulic model to determine relative impact of implementing works in reducing flood damages in concert with a cost benefit analysis. A summary of the potential structural options considered is provided below.

Option S1A - Flood Protection Levee at Yoogali

- Option 1 involves the construction of a levee adjacent to the northern side of McCormack Road and the western side of Yenda Road. The proposed levee would prevent floodwaters exceeding the capacity of DC 605 'J' and Main Drain 'J' from entering Yoogali during floods up to and including the 100 year recurrence event. Incorporating a freeboard of 400mm, the proposed levee will be elevated up to 2 metres above the natural surface elevation of the floodplain.
- Inundation of the village could still occur due to floodwaters 'backing up' and overtopping Burley-Griffin Way could be avoided by extension of the proposed levee to include raising of Burley-Griffin Way.
- Hydraulic assessment indicated typical reduction in peak flood level throughout Yoogali is between 0.5 and 0.6m. However, peak flood level increases of up 0.7m immediately upstream of the levee and about 200 metres north from the intersection McCormack and Yenda Roads.
- It was recommended that Option S1A not be pursued further due to the adverse hydraulic impacts on adjoining lands.

Option S1B - Realignment of Griffith-Yanco Railway Incorporating a Flood Protection Levee

- A feasibility study which investigated a number of options to realign the railway was completed by Thompson Stanbury & Associates in 2006. One alignment ran to the north of Yenda approximately around Ross Road. The realignment of the railway creates an opportunity to integrate a flood protection levee to reduce flooding in Yoogali.
- Hydraulic assessment indicated typical reduction in peak flood level throughout Yoogali is around 0.15m. However, the modelling predicted peak flood level increases of up 0.8m upstream of the levee which would occur along most of the length of the levee between Yenda Road and the Main Branch Canal.
- As per Option S1A, it was recommended that Option S1B not be pursued further due to the adverse hydraulic impacts on adjoining lands.

Option S2 - New CBD Subway and Flood Detention Basin

- Option S2 involves the construction of a new subway underneath the Main Branch Canal to convey flows from Canal Street to Bromfield Street. From there, floodwaters would be discharged to a proposed detention basin that is to be located adjacent to Bromfield Street.
- Hydraulic assessment indicated substantial reductions in peak 100 year ARI flood levels in the area bounded by Yambil Street, Canal Street, Fielder Lane and Kooyoo Street. Peak 100 year ARI levels are predicted to be reduced by up to 0.5 metres.
- Construction costs for the option were estimated at $1.13M and provided for a net reduction in flood damages of approximately $0.15M for a 100 year ARI event.

Option S3 - Flood Detention Basin for North-East of Beelbangera

- Option S3 involves the excavation of a flood detention basin in an area located to the northeast of Beelbangera. The detention basin has been sized to store flows from the upper catchment (i.e. Myall Park) and prevent flooding of Beelbangera in events up to and including the 100 year ARI flood.
- Hydraulic modelling showed widespread reductions in peak flood 100 year recurrence flood levels across the floodplain of Main Drain 'J'. Flood levels in and around DC '605J' are predicted to decrease by 0.3 to 0.4 metres. Flood levels in the vicinity of Yoogali are predicted to decrease by about 0.25 metres. Further downstream, flood levels in and around Walla Avenue are predicted to decrease by 0.1 metres.
- Construction costs for the option were estimated at $38M and providing for a net reduction in flood damages of approximately $11.8M for a 100 year ARI event.
- Given the scale of construction and land requirements, recommended that Option S3 should not be pursued further as a floodplain management solution due to it excessive cost.

Option S4 - Upgrade of Yenda Subway

- Option S4 involves upgrading the Yenda subway to increase its discharge capacity and reduce the frequency of backing up and flooding of the town.
- Hydraulic modelling predicted reduction in the peak 100 year ARI flood level at Yenda is predicted to be about 0.15 metres. By increasing discharges to DC 'TJ' and Main Drain 'J', water level increases in downstream areas were predicted but noted to occur predominantly on farming land
- Construction costs for the option were estimated at $0.6M and providing for a net reduction in flood damages of approximately $2.4M for a 100 year ARI event.
- A modified version of Option S4 was constructed independent of the Griffith FRMS by Murrumbidgee Irrigation involving the installation of a new subway at Yenda near the upstream end of Main Drain 'J.

Option S5 - Upgrade CBD Stormwater Drainage System (including revised version of Option S2)

- Option S5 involves upgrade of a stormwater drainage line located along the centre of Yambil Street which extends from Bonegilla Road in the east to Ulong Street. The drainage system upgrade is largely to address local flooding conditions in the CBD area.
- The drainage upgrades were found to target the 5 year ARI design event with limited benefit to the 10 and 20 year ARI events.
- It was noted that significant issues relating to the discharge of overland flow within the CBD catchment remain.

Option S6 - Upgrade of Main Drain 'J' between Bilbul and Yoogali

- Option S6 involves widening of a 1.7km reach of Main Drain 'J' between McCormack Road and Morley Road and associated upgrades of the rail and road bridge crossings at the intersection of Burley Griffin Way and Yenda Road. The works also include widening a 0.5km reach of DC 605 ‘J’ along McCormack Road and upgrades to local culverts.

- Hydraulic modelling predicted reductions in peak 100 year ARI flood levels by a maximum of 0.1m, the most significant reduction occur around the intersection of Yenda Road and Irrigation Way. Predicted peak flood level reductions throughout Yoogali were around 0.03m.
- Construction costs for the option were estimated at $3M and providing for a net reduction in flood damages of approximately $0.6M for a 100 year ARI event. A detailed cost-benefit analysis including average annual estimates based on the full range of design flood events provided for a cost benefit ratio of approximately 0.5.

Option S7 - Channel Widening in the Vicinity of Yoogali and Hanwood

- Option S7 involves widening Main Drain ‘J’ between Yoogali and Hanwood to increase the in-channel capacity of the drainage system and reduce the frequency of flooding. The works incorporate widening a 9km reach from Burley Griffin Way to Walla Avenue. The widening assumes the existing channel can be widened to the maximum that the drainage easement allows with side slopes and channel depths similar to the existing channel. The works also incorporate the upgrade of some 8 bridge structures to improve conveyance.
- Hydraulic modelling predicted a maximum decrease in peak 100 year ARI flood level of 0.45m just downstream of Old Willbriggie Road on the floodplain south of Main Drain ‘J’. Other peak flood level reductions predicted were between 0.15 and 0.20m between Hanwood Road and Walla Avenue, and generally less than 0.05m between Irrigation Way and Old Willbriggie Road.
- Construction costs for the option were estimated at $11.7M and providing for a net reduction in flood damages of approximately $0.9M for a 100 year ARI event. A detailed cost-benefit analysis including average annual estimates based on the full range of design flood events provided for a cost benefit ratio of 0.25.

6.4 Flood Planning Options Considered

The Griffith FRM&S identified potential planning measures for consideration in management of future flood events and for ensuring future development is compatible with the flood risk. A summary of the potential planning options considered is provided below.

Option P1 - Review of flood emergency response protocols and provision of recommendations for updates to the SES’s Local Flood Plan

- The existing flood emergency response protocols were reviewed including the latest version of the ‘Griffith Local Flood Plan’ (2008). Emergency response precincts were defined based on the flood hazard. Yoogali, Yenda and the Griffith CBD were identified as the three precincts.
- A number of changes are recommended for the Griffith Local Flood Plan which include identifying flood evacuation centres at Yenda and Hanwood; and inclusion of flood warning data for Yoogali relative to Yenda and the upstream end of DC ‘605 J’.
- Investigation of the installation of an automatic water level recorder at Yenda, along with a real time rainfall gauge in the upper Main Drain ‘J’ catchment

Option P2 - Determination of protocols for ownership, maintenance and development/ upgrade of the floodplain drainage system and related infrastructure

- A review was conducted of the protocols for management of drainage channels in the Griffith area, including ownership, maintenance and upgrade. A number of changes were recommended to the current system for managing the drainage channels. Consequently, Griffith City Council and Murrumbidgee Irrigation discussed the issue of drainage channel management, including the sections of drainage channels each organisation is responsible for.
- The discussions resulted in the development of a draft Memorandum of Understanding (MoU), which outlined protocols to guide Council & MI's management of the drainage channels.

Option P3 - Preparation of a Flood Liable Lands Policy

- A Flood Liable Lands Policy was prepared as part of the Griffith FRMS&P and subsequently adopted by Council within its planning system.
- The policy aims to guide proposed development with due consideration of the flood risks. A key component of the policy is the recommendation of Flood Planning Levels (FPLs) dependent on the land use / development type and location within the floodplain with respect to flood risk categories.
- The Residential Flood Planning Level has been adopted as the 100 year ARI flood event plus an allowable freeboard of 500 mm.

Option P4 - Identification of recommended amendments to flood related clauses within Council's LEP

- The review of flood related clauses of the LEP identified a number of additional items to include in the document. These are:
  - The most recent flood related clause agreed to by NSW Dept. of Planning and Dept. Environment Climate Change and Water.
  - The Flood Planning Area Mapping prepared as part the Griffith FRMS&P.
  - The floodway and flood storage extents defined in the Griffith FRMS&P.

Option P5 - Development of an On-site Stormwater Detention Policy that could control runoff from developed areas of the floodplain to the secondary drains within the Main Drain 'J' system

- Future growth strategies for the Griffith LGA have identified a number of areas for possible rezoning and future development. Future development within the floodplain has the potential to increase the percentage of impermeable surface and as a consequence, lead to an increase the volume and peak discharge of run-off from a particular area.
- Council prepared a draft On-site Stormwater Detention (OSD) Policy for areas north of the Main Branch Canal. The policy was reviewed as part of the Griffith FRMS&P and updated where required. On-site detention provisions for new development are aimed at mimicking existing hydrologic conditions to limit potential adverse impact of increased storm runoff.

Option P6 - Development of community flood awareness programs for the villages of Yenda and Yoogali, and for the Griffith CBD (Yambil Street Precinct).

- A Community Education Program was identified targeted towards educating communities within the study area at risk of flooding. The program includes the following tasks:
  - prepare a community information brochure for the Yenda, Yoogali and Griffith CBD precincts, referred to as a "FloodSafe" brochure. The brochure will contain details of predicted flood levels for the range of flood events investigated as part of the Griffith Flood Study (2006).
  - develop and install information posters at public locations such as libraries and community halls which provide flood related information for the community.
  - annual flood awareness meetings for at-risk communities.

6.5 Recommended Inclusions for Floodplain Management Plan

From the assessment of options noted above, the following recommendations were made for inclusion in the Griffith Floodplain Risk Management Plan. The prefix "PL" has been used signify a planning recommendation, while "ST" has been used to signify a structural recommendation. Further comment on the suitability of the Plan recommendation in light of the findings of the updated 2014 Flood Study is also provided hereunder.

__Flood Planning Options Included in the Plan__

PL1. *The Main Drain 'J' floodplain floodway extents and flood storage areas be adopted by Council and included in the Local Environment Plan (LEP).*

The planning recommendation remains appropriate; however, the floodway and flood storage classification mapping has been updated as a result of the 2014 Flood Study. The LEP mapping should be updated in accordance with the adopted 2014 Flood Study results.

The revised hydraulic categorisation mapping is shown in Figure A4 (Appendix A).

PL2. *The relevant clauses in Council's LEP should be updated to reflect the latest standard clauses for flood prone land, which has been agreed to by the relevant stage government agencies.*

The planning recommendation remains appropriate. No change required.

PL3. *The Flood Planning Area Map (refer Figures 26A – 26H) be adopted by Council and included within the draft LEP document.*

As per *PL1,* the mapping from the Griffith FRMS&P has been superseded. The Flood Planning Area Map should now reflect the outcomes of the 2014 Flood Study. The revised Flood Planning Area Map is shown in Figure A1 (Appendix A).

PL4. *The draft Flood Liable Lands Policy be considered for formal adoption as Council's flood policy.*

The Griffith Flood Liable Lands Policy (CS-CP-403) was originally adopted by Council on 11 October 2011 based on the recommendations in the Griffith FRMS&P. The most recent policy revision has been March 2013 following the completion of the Draft Review of Griffith Main Drain J

Catchment Floodplain Risk Management Plan inclusive of the impacts of flooding in Mirrool Creek (BMT WBM, 2013). This Draft flood study document has now been superseded by the adopted 2014 Flood Study. The Policy should be updated in accordance with the most recent flood study references.

No further changes to the body of the Policy are recommended.

PL5. *Council's draft On-site Stormwater Detention Policy, which has been updated for the Griffith Floodplain Risk Management Study, be considered for formal adoption by Council.*

The Griffith On-site Detention Policy (CS-CP-404) was originally adopted by Council on 11 October 2011 based on the recommendations in the Griffith FRMS&P and most recently updated March 2013.

The Policy references preliminary floodway lines for Main Drain 'J' and its tributaries established in the Griffith FRMS&P. As per *PL1* the floodway extents have been revised within the 2014 Flood Study. The Policy should be amended to make reference to the most current floodway definition and associated mapping.

No further changes to the body of the Policy are recommended.

PL6. *The Memorandum of Understanding, which has been developed to define Council's and Murrumbidgee Irrigation's responsibilities in regard to ownership, maintenance and upgrade of drainage channels be adopted by both organisations.*

No further changes to the MOU are recommended. However, it is noted that the options considered in the current study include major modifications to Murrumbidgee Irrigation infrastructure such as the Flood Escape structure at the East Mirrool Regulator. Accordingly, Murrumbidgee Irrigation is a key stakeholder in ongoing flood management in the region.

PL7. *Subsequent to PL6, Council and MI should modify their maintenance schedules to adhere with the MoU.*

No further changes to the MOU are recommended. Maintenance of the existing capacity of Main Drain 'J' is a crucial element of effective flood management in the study, particularly for providing flood immunity to parts of Yoogali, South Griffith, Hanwood and some of the rural areas west of Walla Avenue.

PL8. *A Community Education and Flood Awareness program be implemented for the emergency response precincts, including the preparation and distribution of a FloodSafe brochure, preparation and display of a flood information poster and convening an annual information sessions.*

No further changes to this planning option are recommended. Community Education and awareness programs require an ongoing commitment, with details of the program/community involvement being adapted and modified as needed. The lessons learnt from the 2012 flood event in concert with the improved knowledge of flood behaviour through the updated flood study, provides useful material to enhance the community's knowledge of flood risk in the study area and build resilience to future flood events.

PL9. *Flood evacuation centres be nominated for Yenda and Hanwood. The next amendment to the Griffith Local Flood Plan identify the new flood evacuation centres.*

No further changes to this planning option is recommended. The Griffith FRMS&P nominated the Yoogali Catholic and Yenda Diggers Club as potential evacuation centres. Hanwood was noted in the Griffith FRMS as largely subject to backwater inundation, as confirmed in the updated Flood Study. Nevertheless, there is some merit in identifying an appropriate centre in this location for residents located to the south of Main Drain 'J' in major flood events (i.e. > 100yr ARI design event) where access to the north (i.e. to Griffith CBD and Yoogali) is compromised.

PL10. *The next amendment to the Griffith Local Flood Plan incorporate the flood warning data for Yoogali relative to flood observations at Yenda and Beelbangera.*

This recommendation is largely superseded as a result the change in design flood conditions established in the updated Flood Study (BMT, 2014). There is considered to be little flood warning benefit afforded to Yoogali in establishing water level monitoring stations in these locations. Flood warning opportunities appropriate to the revised design flood conditions are considered further in Section 8.

PL11. *The potential to install an automatic water level recorder within DC 'TJ', in the area downstream of the Yenda Subway be investigated. If considered feasible, installation of the recorder should proceed.*

As for PL10 in regards to updated flood information from the 2014 Flood Study, a water level recorder in this location is not considered to provide any significant flood warning benefit for Yoogali. The flow in DC 'TJ' is already controlled by the siphon. The higher contributions to flow in Main Drain 'J' are well downstream of this point.

PL12. *The potential to record real time rainfall in the upper Main Drain 'J' catchment be investigated. If considered feasible, proceed with installation of the gauge.*

No change to this planning option is recommended. A gauge in this location would provide some benefit to the Main Drain 'J' catchment and also the neighbouring Lake Wyangan catchment.

PL13. *Existing Section 149 certification for flood prone properties in the study area be reviewed. Where necessary, Section 149 certificates be updated and re-issued to contain up-to date flood data and information.*

No change to this planning option is recommended. It is noted however that the most up-to-date flood data and information is now based on the current FRMS&P (BMT WBM, 2015) and corresponding Flood Study (BMT WBM, 2014).

PL14. *Update the estimate of damage caused by flooding for the reduced catchment area flood modelling results.*

This recommendation is largely superseded by the update of the property inundation and flood damages analysis undertaken as part of the current study (refer to Section 5). This updated analysis utilises the design flood conditions established in the updated 2014 Flood Study.

<u>Structural Options Included in the Plan</u>

ST1. *Option S6 should be implemented where dual purposes (e.g. flooding and maintenance requirements), or other construction cost savings can be realised to make the options economically viable.*

Option S6 involves widening of reaches of MD ‘J’ and DC 605J and upgrades to local culverts to increase flow capacity. The works are centred on reducing flood impacts in Yoogali. The option is further investigated in Section 7 considering the revised flood behaviour established in the 2014 Flood Study. The revised option also considers construction of levee similar to Option S1 investigated as part of the Griffith FRMS&P but not considered further due to adverse hydraulic impacts indicated by previous modelling. Changes in the modelled flood behaviour in the locality through the updated flood study indicate that the levee impacts may not be as significant as previously established and accordingly the levee option has been included in further assessments discussed in Section 7.

ST2. *Option S7 should be implemented where dual purposes (e.g. flooding and maintenance requirements), or other construction cost savings can be realised to make the options economically viable.*

Option S7 involves widening of MD ‘J’ in the reach between Irrigation Way and Walla Avenue to increase flow capacity. The works are centred on reducing flood impacts in Yoogali, South Griffith and Hanwood. The option is further investigated in Section 7 considering the revised flood behaviour established in the 2014 Flood Study.

ST3. *The work proposed by Council to implement Option S2 and Option S5 should proceed.*

These works are targeted towards improving the stormwater drainage infrastructure within the Griffith CBD incorporating a new subway, detention basin and drainage works. Some CDB drainage works have been constructed and incorporated into the modelling for the current study as required. Further review of CBD drainage options is not included in the current study and reference should be made to the Griffith CBD FRMS&P (WMAwater, 2013) for relevant options for the CBD area.

ST4. *Further studies should be completed for the CBD catchment to identify additional structural measures that will control run-off in the CBD catchment during larger floods.*

This option is expected to have been addressed through completion of the Griffith CBD Flood Study (WMAwater, 2012) and Griffith CBD Floodplain Risk Management Study and Plan (WMAwater, 2013).

ST5. *Further investigation of structural options around Yoogali is required. It is anticipated that the options may consist in combinations/variations on the options investigated as part of the Griffith FRMS. This would be carried out with the ultimate aim of reducing the floodway extent in the vicinity of Yoogali.*

The design flood conditions in the vicinity of Yoogali have been significantly modified as a result the updated 2014 Flood Study. This includes the definition of floodway areas throughout the Main Drain ‘J’ system. The revised flood conditions have warranted a re-assessment of potential structural options for Yoogali which is provided in Section 7 of this report.

ST6. *Review as appropriate, flood modelling and cost-benefit analyses undertaken for structural options for the reduced catchment investigations*.

As per ST5, the revised flood conditions have warranted a re-assessment of potential structural options.

6.6 Griffith CBD Floodplain Risk Management Study

The Griffith CBD Floodplain Risk Management Study and Plan (WMAwater, 2013) focuses on the overland flow flooding issues within the Griffith urban area. The FRMS&P follows on from the Griffith CBD Catchment Overland Flow Flood Study (WMAwater, 2012).

The findings of the studies and recommendations in the CBD Floodplain Risk Management Plan do not have major significance for the current study. Some of the structural options considered can potentially change some of the CBD flood behaviour. Already constructed measures have been incorporated into the flood modelling in the 2014 Flood Study update where appropriate. Given the relatively minor contribution of the CBD catchment area to the broader study area of the Main Drain J catchment, further changes in CBD flood behaviour through implementation of other measures would not be expected to have a major impact on the outcomes of the current study. However, as a general recommendation, any works throughout the study area that has a significant impact on flood behaviour should trigger a review of the flood studies and floodplain risk management studies. Moreover, the existing approvals process for such developments would require the appropriate consideration of flood related development controls.

7 Potential Floodplain Management Measures

Measures which can be employed to mitigate flooding and reduce flood damages can be separated into three broad categories:

- Flood modification measures: modify the flood's physical behaviour (depth, velocity) and includes flood control structures, mitigation basins, on-site detention, channel improvements, levees, floodways or catchment treatment;
- Property modification measures: modify property and land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase; and
- Response modification measures: modify the community's response to flood hazard by informing flood-affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

The Griffith FRMS&P (Worley Parsons, 2011) identified and investigated a number of potential flood management options. These options were reviewed with consideration of the updated flood study as presented in Section 6. Refinement of relevant options and assessment of additional potential options identified, particularly for Yenda in relation to Mirrool Creek flood contributions not previously considered, are assessed hereunder.

7.1 Structural Options Overview

In identifying potential flood modification measures for the Main Drain J and Mirrool Creek catchments, focus is given to the localised hotspot areas where potential flood impacts are concentrated. Accordingly these measures are focused on the communities of Yenda, Yoogali and Hanwood, although some of the flood modification options considered provide some flood mitigation benefit on a broader catchment scale to rural properties. However, it is important to recognise that changes to existing flood behaviour through implementation of measures can also provide for adverse impacts to some parts of the floodplain.

A summary of the structural options considered in the FRMS is provided in Table 7-1 including a brief description of the works and objective in terms of modifying flood behaviour. The following sections provide further detailed assessment of each option with consideration of the effective performance as a flood mitigation measure, and identification of other environmental, social and economic constraints/opportunities associated with each option.

Table 7-1 Summary of Potential Structural Flood Mitigation Options

Location / Option	Comments
Yoogali	
Yoogali Levee	Involves the construction of an earth embankment along the northern side of McCormack Road (along the alignment of DC605J/DC621J) and the western side of Yenda Road (along the alignment of Main Drain J). The embankment function is to contain waters within the existing drainage channels and prevent floodwaters exceeding the drain capacity and entering Yoogali during major floods.
DC 605J Structure Upgrades	Existing cross drainage structures at Yenda Road and Bosanquet Road provide flow capacity restrictions to DC 605J. Upgrade of these structures is considered to provide additional in-bank capacity along the drain alignment and further reduce opportunity for spills across McCormack Road and through to Yenda.
Main Drain J Structure Upgrades	The Griffith-Temora Railway bridge and Griffith Road bridge have been identified by the community as potential constraints on the capacity of Main Drain J. The study has investigated the merits of increasing capacity at these structures and potential reduction in spills from Main Drain J into Yoogali village.
Upstream Detention	Some parts of the community consider development within Collina and other local catchments upstream of Yoogali as contributing to local flooding. Flood detention basins providing additional temporary flood storage are identified by the community as a potential measure. The Main Canal embankment and siphon structure on DC Collina effectively provide a detention function by limiting flows through to Yoogali. Similarly, the broader storage of Myall Park and other siphons on drainage channels through the Main Canal also provide existing storage function. Accordingly, investigation of further detention would not provide any major benefit and therefore not considered further in the FRMS.
Yenda	
EMR Flood Gate Reinstatement	With the EMR flood escape decommissioned only the capacity of the existing siphon are available to transfer Mirrool Creek flows across the Main Canal. Reinstatement of the flood escape to fully operational status provides for an approximate 2% AEP (50-year ARI) capacity and flood immunity to the Yenda community.
EMR Flood Gate Upgrade	The EMR Flood Gate upgrade considers the construction of new flood escapes with increased discharge capacity. The upgrade works require new enhanced structures on both the right and left bank of the Main Canal to provide conveyance of the Mirrool Creek flows. The minimum design capacity to be considered would be the 1% AEP event plus appropriate freeboard, noting that the March 2012 event is representative of a design 0.5% AEP magnitude.

Location / Option	Comments
EMR "Lawson Siphon"	A "Lawson Siphon" arrangement (similar to Mulwala Canal across the Edward River floodplain at Deniliquin) would convey the Main Canal flows beneath the floodplain of Mirrool Creek. The siphon width would provide a clear floodplain opening for effective conveyance of Mirrool Creek flows. The option can be considered an alternative to the Flood Gate upgrade, with the siphon width providing similar flow capacity to provide the desired flood immunity for Yenda.
Northern Branch Canal Bank Raising	The discharge capacity of the EMR flood gates or siphon type arrangement is defined by the maximum flood level at the structure before overtopping of the NBC occurs at which point flows to Yenda are initiated. This allowable maximum water level is currently limited by the low points in the NBC bank level. Raising of the NBC bank levels will provide for additional flow capacity at the EMR structure before overtopping occurs, or alternatively be considered as additional freeboard above existing arrangements.
Main Canal Emergency Breaching	Significant breaching of the Main Canal occurred during the March 2012 event. These breaches conveyed a significant amount of flow and also served to reduce the flow towards Yenda. Given the potential for significant reductions to flows at the EMR, controlled breaching through formalised protocols/flood planning may be considered as a future emergency management measure.
Hanwood	
Local Drainage Works	Elevated Main Drain J levels reduce the effectiveness of the local drainage system in Hanwood. In major events, there is a backwater influence from Main Drain J through the connected drainage network. Local drainage enhancements such as minor bunding, one-directional drainage can provide for some local protection.
Main Drain J Capacity Increase	The existing capacity of Main Drain J is of the order of 1% AEP capacity. Accordingly, extensive works to increase capacity are not considered necessary. Localised spilling occurs at low points along the bank profiles providing for much of the overbank flooding downstream of Yoogali. Targeted bank raising/reinstatement at identified low points would provide for the local increase in capacity to prevent major spilling.

7.2 Yoogali Structural Options

7.2.1 Yoogali Levee and DC 605 Structure Upgrades

Flooding in Yoogali largely occurs when the capacity of DC 605 'J' is exceeded. Floodwater then spills over McCormack Road and inundates the village, backing up behind the railway embankment. Flooding may last for a few days, until the tailwater level in Main Drain 'J' lowers to enable drainage out of Yoogali.

The flows within DC 605 'J' are controlled by the capacity of the siphons beneath the Main Canal which convey the flows from the upper catchment. Accordingly, Yoogali is largely protected by the Main Canal embankment and siphons from uncontrolled overland flows.

Whilst flows through to Yoogali aren’t extensive, the majority of the village area sits within a low point behind the elevated Main Drain ‘J’ and the Griffith-Temora Railway embankment. In the event where flows escape DC 605 ‘J’, floodwaters within Yoogali fill up like a basin, resulting in inundation to property as experienced in March 2012.

Effective control of out of bank flows from DC 605 ‘J’ can be achieved through the construction of a “levee”. This option was investigated in the previous Griffith FRMS&P. The previous hydraulic assessment indicated typical reduction in peak flood level throughout Yoogali is between 0.5 and 0.6m confirming the options effectiveness in addressing the flood problem in Yoogali. However, the analysis also showed peak flood level increases of up 0.7m immediately upstream of the levee and about 200 metres north from the intersection McCormack and Yenda Roads. Accordingly, the option was not recommended due to adverse hydraulic impacts on adjoining lands.

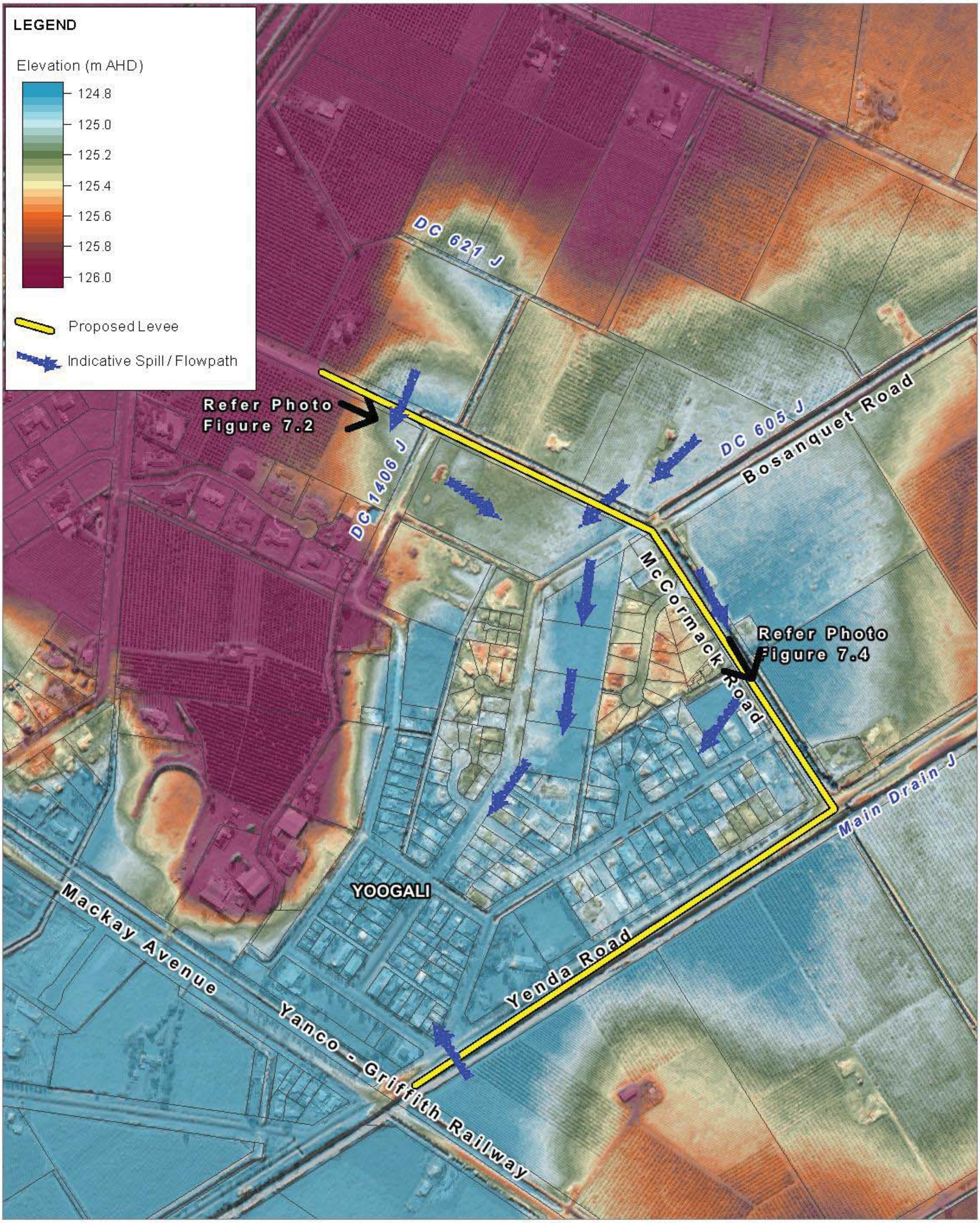
The Yoogali levee option has been re-assessed with the updated flood model. Changes in the model configuration and simulated design flood conditions through Yoogali were considered to provide a more favourable assessment of the performance and relative impact of the option.

The works proposed in the previous Griffith FRMS&P provided for a levee constructed to a nominal elevation of 126.4m AHD, providing for a 1% AEP (100-year ARI) protection with some 400mm freeboard. At this level, the proposed levee would be elevated some 1.5 to 2m above the natural surface. However, in reviewing the local flood conditions, a levee construction of this magnitude is not considered necessary. A less significant embankment would be sufficient to provide effective control of floodwater from spilling from DC 605J and other connecting drains such as DC 621J.

The proposed embankment alignment is shown in Figure 7-1 with respect to the local topography. Floodwaters can spill from a number of low points along the length of DC 605 ‘J’. Once out-of-bank, there is limited opportunity for flows to get back into the drain given the elevated banks. Flows can pass locally across Newman Road but generally flow towards Yoogali village area, ponding behind the railway and Main Drain ‘J’ embankments.

The embankment only effectively needs to be of sufficient height to remove the low points along the drainage channels adjacent to McCormack Road as the preferential overbank flow paths. One of these localised flow paths/spill points is shown in Figure 7-2, photographed during 4th March 2012. The photograph is looking east along McCormack Road from a location just to the west of Newman Road (refer to Figure 7-1 for photograph location). As evidenced in the photograph, this is a localised spilling at a low point in the drainage reserve with the broader length of McCormack Road visible in the photograph free from inundation.

To further appreciate the scale of the embankment works required, a long section along the alignment of the right bank of Main Drain J and DC 605 J is shown in Figure 7-3. The longsection shows the bank levels along the right bank of the drainage channels along with the simulated 0.5% AEP flood level profile (similar to March 2012 event) for existing conditions. There are numerous “low points” in the bank level profile which correspond to potential spill points along the length of the channel. In general the filling of these low points to provide a contiguous bank height to prevent spilling from the channel requires local bank raising typically less than 0.3m. Accordingly, the nature of works required is localised filling/bunding as opposed to a more formal levee type construction.



Title:
Yoogali Levee Option

Figure: 7-1

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Figure 7-2 Spills across McCormack Road March 2012

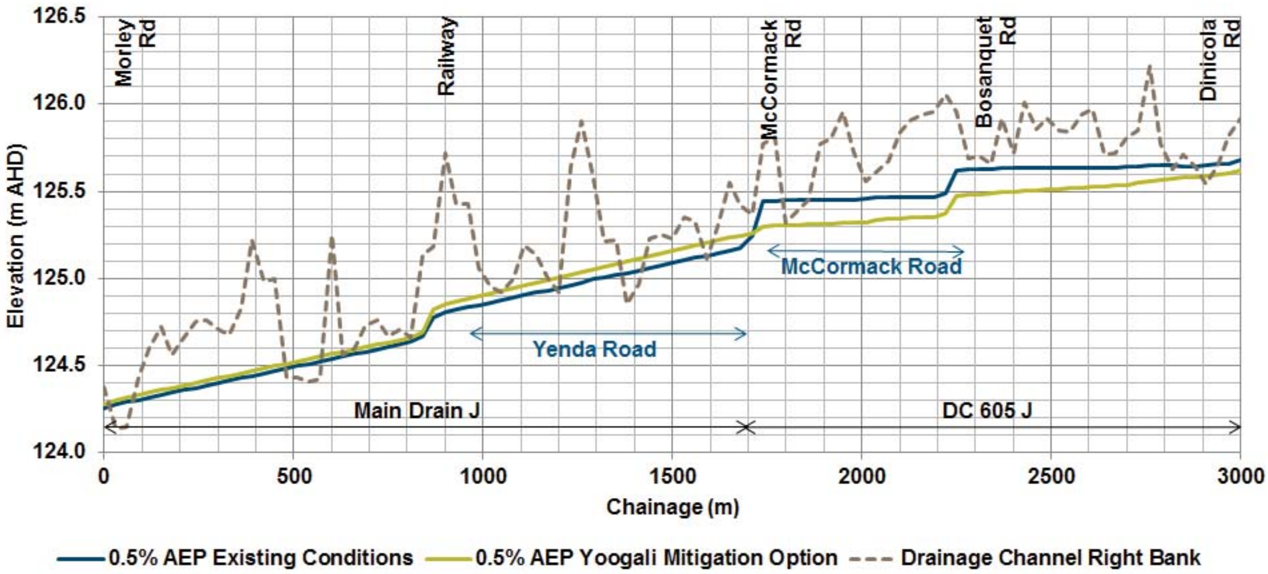


Figure 7-3 Yoogali Main Drain J and DC 605J Flood Level Profiles

The simulated flood level profile for existing conditions in Figure 7-3 show significant increases in water level along DC 605 J at chainages 1750m and 2250m. These locations corresponding to existing cross drainage structures on DC 605 J across Yenda Road and Bosanquet Road respectively. The head loss at these existing structures, which provide a substantial flow restriction, elevate peak flood levels upstream along DC 605 J and increase the propensity for spills from the channel. An upgrade of these culverts will provide for more effective conveyance within the channel and reduce the incidence of out-of-bank flooding and accordingly a reduction in spills across McCormack Road through to Yoogali.

An effective flood mitigation for Yoogali therefore comprises localised embankments along the existing drainage channels and an upgrade to structures on DC 605J. The simulated 0.5% AEP flood level profile for this option is also shown in Figure 7-3.

The key elements of the proposed works include:

- Approximately 1km of earthen levee constructed along right bank alignment of Main Drain 'J', DC 605 'J' and DC 621 'J'. The levee crest would vary along the length of the channels, however, at all locations a minimum a 0.5% AEP flood immunity with freeboard of approximately 0.3 is proposed. For example, along McCormack Road this would provide for a nominal embankment height of 125.7m AHD.
- Upgrade of the existing culvert structures (twin 1.65m diameter pipes) on DC 605 'J' at Yenda Road and Bosanquet Road to ensure flow capacity. The proposed culverts comprise twin cell 2.4m x 1.8m box culverts at each location.

There is the potential for drainage of DC 605 'J' to be impeded by elevated water levels in Main Drain 'J'. Similarly, there is potential for backwater flows from Main Drain 'J' such that a one-way flow system may be employed to prevent these backflows occurring.

The construction of a contiguous embankment along the drainage channels only requires filling up to the order of 0.3m at localised low points. As shown in Figure 7-3, the existing levels along majority of the drainage channel alignments provide the required flood immunity. Accordingly, it is envisaged these relatively local works can be constructed within the existing drainage corridors. Figure 7-4 shows the indicative nature of these works along the DC605 channel alignment adjacent McCormack Road. The works are unlikely to provide any significant impediment to access to the drainage corridor. Some minor modification of existing property access may need to be incorporated dependent on the relative scale of works at specific locations.

Flood mitigation measures for residential property are typically designed to a 1% AEP design standard with 0.5m freeboard. As noted above, the Yoogali mitigation option comprising the embankment and culvert upgrades provides for 0.5% AEP + 0.3m freeboard standard. Additional freeboard could be built into the design by increasing the relative embankment height, however, in this instance there is little benefit in doing so. With spilling over McCormack Road effectively controlled by the constructed embankment, alternative spill points provide for redistribution of flow to Main Drain 'J' at these higher levels, with McCormack Road no longer being the low point.

The Yoogali mitigation option has been simulated using the models developed for the Flood Study update. The objective of the analysis is to confirm the performance of the option in reducing the flood inundation within Yoogali, and also to identify any adverse potential impacts of the construction on design flood behaviour.

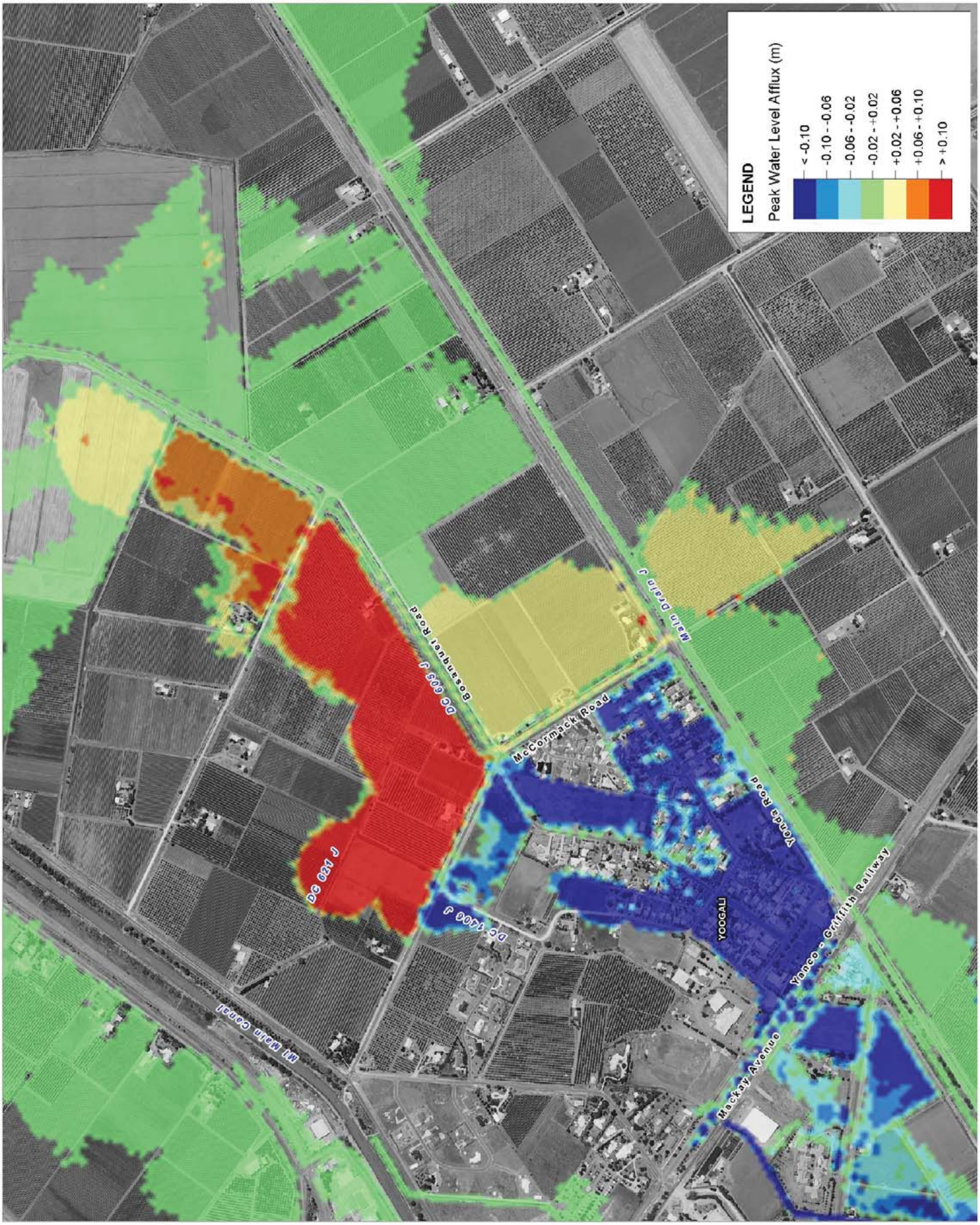
The impact of the proposed embankment (without the culvert upgrades) in terms of change in peak flood level from existing conditions for the 0.5% AEP event is shown in Figure 7-5. The 0.5% AEP event is shown as it is representative of the equivalent design flood conditions experienced in the March 2012 flood event. Evident is the performance of the embankment in reducing the flood inundation with Yoogali village through control of potential spills from DC 605 'J'. Some minor inundation is shown on the mapping to remain for the Yoogali village area, however, this is only minor local drainage with upgrades to the local drainage system incorporating pumping capacity expected to easily manage these locally derived flows.

Figure 7-4 Indicative Embankment along DC 605 J

Some increases in flood levels are noted upstream of the proposed embankment alignment on McCormack Road. The impacts are not extensive in area and affect only a few existing properties. However, peak flood level increases of the order of 0.2-0.3m are simulated. The flood level impacts arise from flows spilling from DC 605 'J upstream backing up behind the levee alignment. The volume of flow previously conveyed through to Yoogali is now stored in the upstream rural property areas.

In order to reduce these impacts, upgrades to the culvert structures along DC 605 'J' were modelled to increase the conveyance of the drainage system and the subsequent discharge to Main Drain 'J'. The simulated impacts for the combined embankment with upgraded culverts are shown Figure 7-6. The culvert upgrades in association with the embankment construction is effective in reducing peak flood levels upstream of McCormack Road. Some minor increases in flooding of 5-10cm are noted on the left bank of Main Drain 'J' due to the increase in discharge from the improved conveyance within DC 605 'J'. The scale and extent of these minor changes are not expected to have significant adverse impact on existing property.

The peak design flood inundation depth and extent for the mitigation option is shown in Figure A-6 in Appendix A for the 0.5% AEP design event (similar to March 2012 magnitude). The minor residual flooding shown in Yoogali is due to the local catchment rainfall and may be expected to be managed effectively by the local drainage system, including the recent pump installations.



Title:

Yoogali Mitigation Options - Change in Peak Flood Level 0.5% AEP Event McCormack Road Levee

Figure: 7-5

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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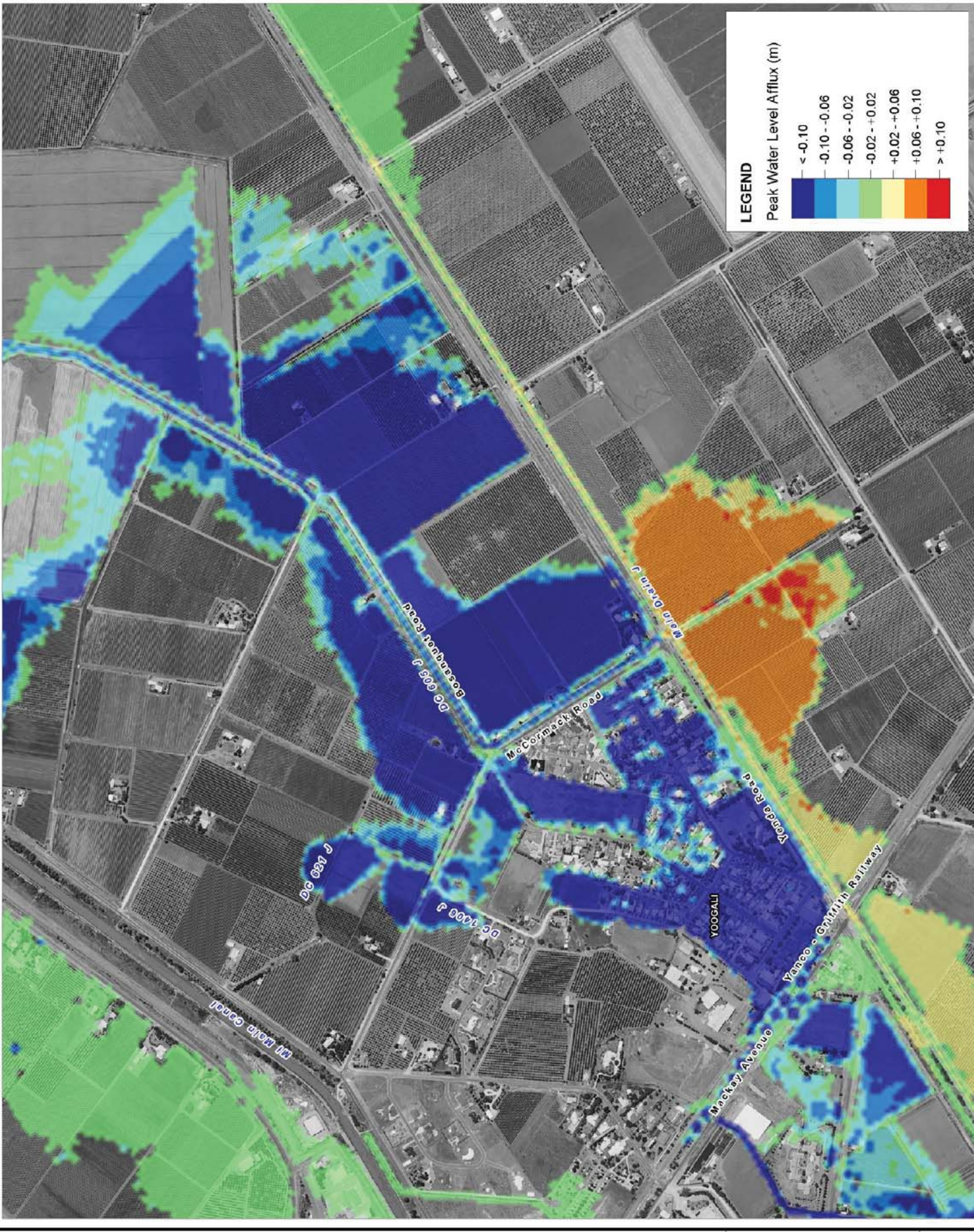

Title:

Yoogali Mitigation Options - Change in Peak Flood Level 0.5% AEP Event McCormack Road Levee + Culvert Upgrade

Figure: **7-6**

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7.2.2 Main Drain J Structure Upgrades

The Griffith-Temora Railway bridge and Griffith Road bridge have been identified by the community as potential constraints on the capacity of Main Drain J. Given the location of structures, any significant backwater influence from these structures may unduly raise peak flood levels within Main Drain 'J' and increase the potential for spills into Yoogali village.

The structures have been represented in the hydraulic models to enable assessment of their relative impact on peak flood conditions. Figure 7-7 shows the simulated peak flood level profile along Main Drain 'J' for the 0.5% AEP event (representative of March 2012 flood conditions). The location of the Railway and Griffith Road structures is circled for reference from which can be seen the relative head loss through the structures. The peak water level profile for existing conditions shows a combined head loss across the structures of the order of 0.1 to 0.15m. Accordingly, the structures only have a minor influence on peak flood level conditions. Peak flood levels in the vicinity of the structures are more so driven by the capacity of the Main Drain 'J' channel. This is reflected in the photographs of the structures during the March 2012 event as shown in Figure 7-8.

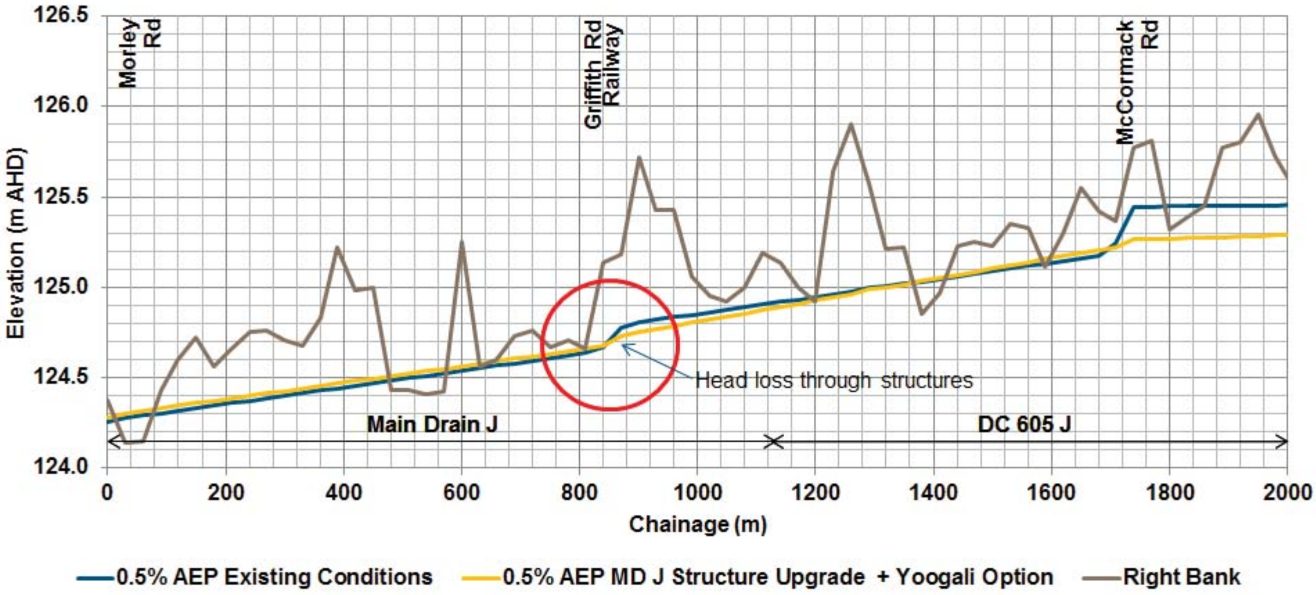


Figure 7-7 Flood Level Impact of Main Drain 'J' Railway and Griffith Road Structure Upgrade

A further model simulation for the 0.5% AEP design event was undertaken for a potential upgrade of the Railway and Griffith Road structures. These structure upgrades provide for approximately a clear span opening across Main Drain 'J' limiting the encroachment of the deck levels into the waterway area. This upgrade option was simulated in concert with the proposed Yoogali option comprising the Main Drain 'J' / DC605 'J' embankment and culvert upgrades. The peak 0.5% AEP flood level profile along Main Drain 'J' is shown in Figure 7-7. Whilst head loss through the structures is reduced, there is little benefit more broadly along Main Drain 'J' in terms of flood level reductions.

Figure 7-8 Main Drain 'J' Railway and Griffith Road Structures March 2012

7.3 Yenda Structural Options

7.3.1 East Mirrool Regulator Works Overview

The objective of upgrade options for the flood relief structures at the EMR is to increase the flow capacity to prevent Mirrool Creek floodwaters bypassing the structure through overtopping of the Northern Branch Canal. There are numerous options available to increase the flow capacity at the EMR such as additional siphons, additional gates, new regulating structures etc. Given the scale of works, the detail of the most appropriate structure will not be determined in the Floodplain Risk Management Study. Appropriate feasibility assessments, including environmental impact assessments, would need to be undertaken to identify the preferred option and progress a preliminary design. A major consideration of any works is the implications for Murrumbidgee Irrigation's water supply operations, both in terms of infrastructure design and long term operations, but also short term construction impacts. Accordingly, the assessment of potential upgrade works within the current study is limited to identifying an appropriate design capacity and assessing potential impacts of changes in design flood behaviour.

The 2014 Flood Study determined the design flows approaching the EMR as summarised in Table 7-2. With consideration of the existing capacity of the EMR flood relief structures, the following is noted:

- The current status of the EMR flood relief structures with the flood gates decommissioned and only the siphons functioning provides for approximately a 5% AEP design capacity.
- Reinstatement of the decommissioned flood gates provides for a total design capacity of the order of a 2% AEP design event.
- Design 1% AEP event flows are ~1.5 times the 2% AEP flows such that a similar scale up of the EMR flood relief structures would be required to provide 1% AEP capacity.
- The estimated March 2012 event flow approaching the EMR is representative of the 0.5% AEP design flood condition.

Table 7-2 Adopted Design Peak Flood Flows for Mirrool Creek at the Main Canal

Design Event Magnitude	Peak Flow U/S of Main Canal
5% AEP	20m^3/s (~1,700 ML/day)
2% AEP	100m^3/s (~8,600 ML/day)
1% AEP	160m^3/s (~14,000 ML/day)
0.5% AEP	220m^3/s (~19,000 ML/day)
0.2% AEP	290m^3/s (~25,000 ML/day)

Given the elevated embankment of the Main Canal, there is considerable attenuation of the Mirrool Creek approach flows as floodwaters back up behind the embankment. Figure 7-9 shows the simulated hydrographs for the March 2012 event including the approach flow to the EMR, the representative outflow at the EMR, and the flow further downstream at McNamara Road. The peak approach flow to the EMR is of the order of 220m^3/s with some 140m^3/s discharged downstream of the EMR.

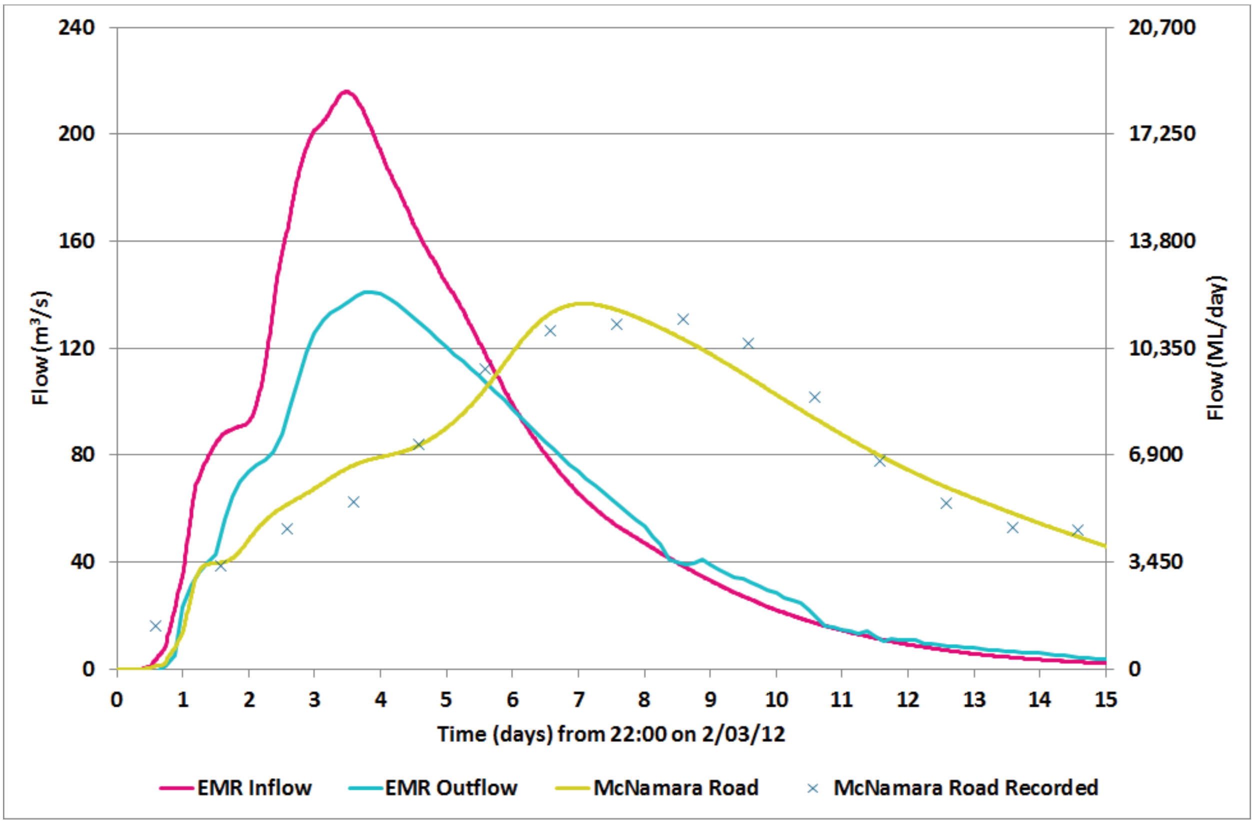


Figure 7-9 March 2012 Modelled Flow Hydrographs for Mirrool Creek

The report entitled *"MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works Options on Floodway Lands"* (Dept. Water Resources, 1994) identified a number of potential options for upgrading of the EMR in order to better convey flood discharges from the Mirrool Creek. The options were summarised as:

1) **Retain Existing Regulator** – passes Mirrool Creek flows by means of subway and a five bay and eight bay flood check in the northern and southern bank of the Main Canal respectively.

2) **Option 2A –** retains the existing subway and eight bay flood check in the southern bank. The flood check in the northern bank is extended from five to eight bays.

3) **Option 4A** – passes Mirrool Creek flows by way of a natural waterway opening through the Main Canal. The Main Canal flows are siphoned under the Main Canal for a 48m width.

4) **Option 4A Amended** – As for Option 4A except the width of the natural opening increased by approximately 20m. The Main Canal flows by means of a 68m siphon.

The option to "Retain Existing Regulator" is equivalent to reinstatement of the currently decommissioned flood gates (i.e. eight bay southern bank check structure) as discussed above. "Option 2A" provides for an upgrade of the existing northern bank structure. The northern bank structure is the key limiting control for passing Mirrool Creek flood flows being of lesser width/flow capacity in comparison to the southern bank structure. Whilst some increase in overall design capacity would be achieved, the upgraded capacity would again be limited by current capacity of the southern bank structure.

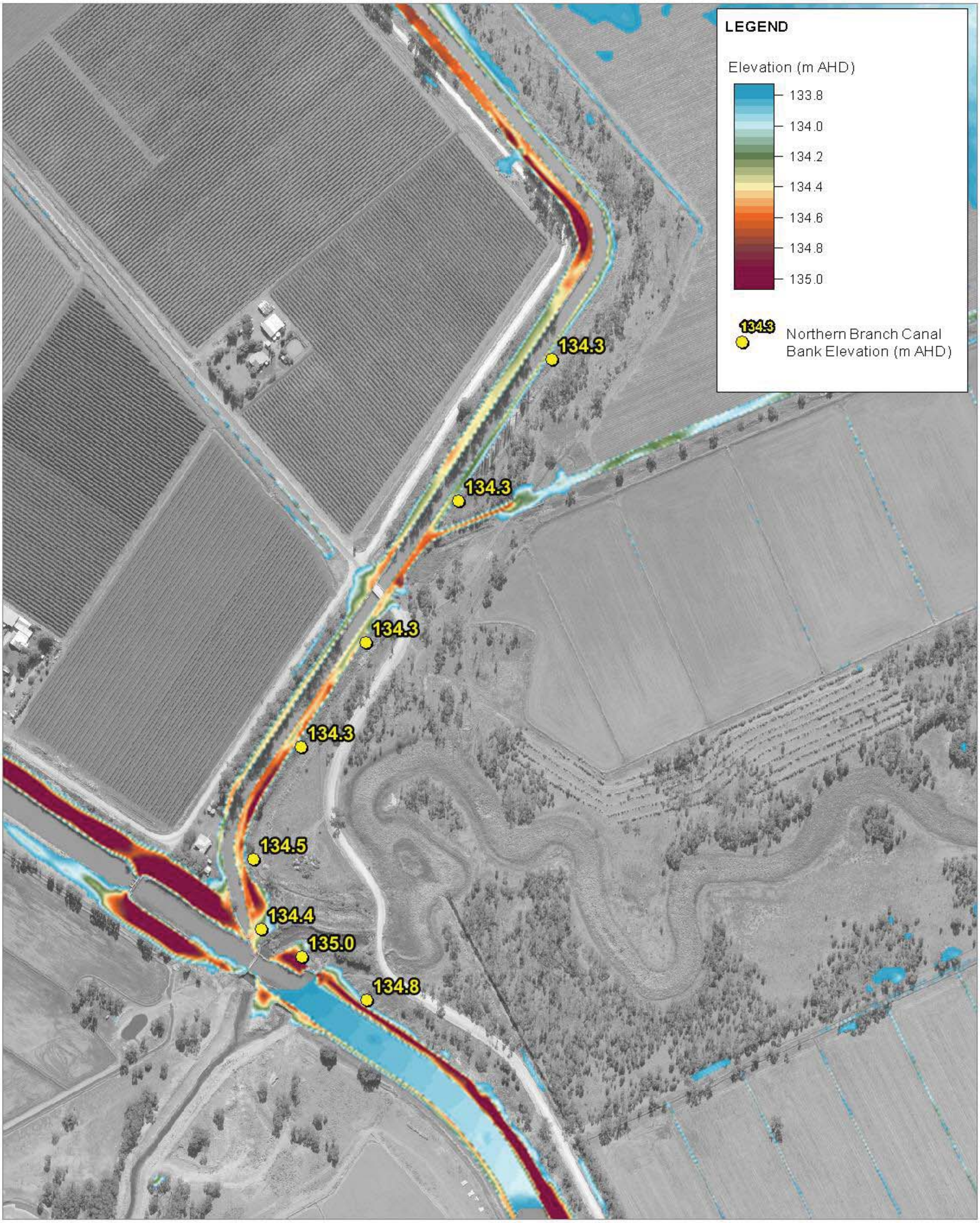
Both "Option 4A" and "Option 4A Amended" provide for a removal of the Main Canal embankments across a nominal width of the Mirrool Creek floodplain with the Main Canal flows siphoned beneath the natural floodplain section. This is similar to the "Lawson Siphon" arrangement for the Mulwala Canal across the Edward River floodplain at Deniliquin. The "Option 4A Amended" provided the greater waterway area for the passage of floods and was considered the most appropriate option moving forward.

Overtopping of the flood gates on the right bank of the Main Canal was noted as occurring at a water level of 134.9m AHD which was estimated to correspond to an estimated inflow of 140m^3/s. The nominal 68m siphon width provided for a design 1% AEP discharge (EMR outflow) of some 200m^3/s thereby providing a significant increase in design capacity. The increase in peak flows for the Option 4A Amended configuration from existing conditions was found to result in only minor increases in peak flood level of the order of 0.1m for downstream reference points including the Whitton Stock Route, Darlington Point Road and McNamara's Bridge.

7.3.2 Northern Branch Canal Bank Raising

The design capacity of the EMR upgrade options is linked to the maximum upstream water level able to be developed before overtopping of the Main Canal right bank. As noted, the Dept. Water Resources (1994) identified this critical headwater level to be 134.9m AHD. However, in undertaking the 2014 Flood Study and reviewing available detailed topographical data, flood flows towards Yenda are initiated at a level of only 134.3m AHD. This level represents the low points along the Northern Branch Canal at which overtopping are initiated. Figure 7-10 shows a detail of the elevations along the NBC with numerous low points identified. It can be seen that the NBC levels are generally below the Main Canal right bank levels at the EMR flood gates.

In investigating options for possible upgrades to the EMR flood relief structures, limiting the flow across the NBC and through to Yenda is a key objective. These flows are initiated as water levels increase upstream of the EMR, eventually overtopping the crest levels of the NBC. These threshold water levels that initiate overtopping of the NBC are an important design factor in assessing EMR upgrade options. It is these levels effectively provide a limit to the allowable head levels able to be built at the EMR flood relief structures, and accordingly define the structure capacity limits.



Title:

Northern Branch Canal Bank Height Elevations

Figure: 7-10

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The EMR upgrade options in the Dept. Water Resources (1994) assessment are therefore expected to have a lower design capacity. The nominal 68m siphon width for Option 4A Amendment would need to be increased in order to provide a similar design flow capacity at the lower maximum upstream water level threshold of 134.3m AHD.

Given the flows through Yenda are largely via overtopping of the NBC, and this level of overtopping provides a limit on the effective discharge capacity to the EMR flood relief structures, raising and strengthening of the bank levels is considered an integral component of any Yenda works option, including EMR upgrades.

Similar to the Yoogali embankment works considered in Section 7.2, the NBC works largely also represent localised bank raising to remove the relative low points alignment the existing top of bank alignment. The nominal minimum design level of 134.8m AHD is proposed which corresponds to the existing bank levels of the Main Canal at the EMR Flood Escape. As noted, the existing low points along the NBC are around 134.3m AHD such that an increase in bank height of 0.5m would be required at these lowest points. Typically lower depths of fill are required more broadly along the NBC alignment to provide the proposed design level.

Upgrades to the EMR flood relief structures discussed in the following sections have adopted a design 1% AEP peak flood level of 134.3m AHD. Accordingly, provision of a contiguous NBC bank elevation of 134.8m AHD would provide for an additional 0.5m freeboard above the design flood level.

7.3.3 Reinstatement of Decommissioned EMR Flood Escape

The significant flood impact at Yenda experienced in the March 2012 event drew much attention to performance of the EMR flood escape. Following flooding of Yenda in June 1931 a set of flood gates were installed that allow flow to be released from the Main Canal to Mirrool Creek on the downstream side of the canal. With the exception of March 2012, during flood events since 1931 the escape doors and flood gates have been opened to allow flood waters from Mirrool Creek to flow through the Main Canal to the downstream floodplain. This was the case for the March 1939 event and March 1989 event which were both significant events on the Mirrool Creek system. Whilst major flooding of Yenda was avoided in 1939 and 1989, the structure was close to capacity with original gates operational.

The left bank flood gates (southern bank check structure) were decommissioned in the early 1990s and were unable to be operated during the March 2012 event. Figure 7-11 shows a photograph of the decommissioned gates with bulk spoil placed in from of the gates The March 2012 event was the first event since the flood gate installation in which the design capacity has been exceeded. Given the magnitude of the flows approaching the EMR for the March 2012, the capacity of the EMR would have been well exceeded even with full design operational capacity of both the siphon and flood gates.

The observed flood conditions for Mirrool Creek for the March 2012 event are estimated to be in excess of the 1% AEP (1 in 100-year) design conditions. The flood risk to Yenda from Mirrool Creek floodwaters emanates as the EMR capacity is exceeded, resulting in flow from the Mirrool Creek floodplain spilling over the Northern Branch Canal and progressing to Yenda. With both existing siphon and flood gates fully operational, this flow capacity may be expected to be exceeded for events in excess of the 2% AEP (1 in 50-year probability event). The current decommissioned status of the EMR flood gates structures significantly reduces the capacity to transfer Mirrool Creek flood flows across the Canal to the order of a 5% AEP (1 in 50-year probability) design standard. Accordingly, substantial flood mitigation measures may be required to provide increased flood immunity to the Yenda township.

Figure 7-11 March 2012 Photograph of Decommissioned EMR Flood Escape

A 5% AEP flood protection standard is not considered appropriate for Yenda, with some 500 properties at potential risk. Further, as experienced in March 2012, such widespread inundation across the township provided significant hardships in the flood recovery.

The reinstatement of the decommissioned flood gates is considered as a standalone option as an interim measure. Whilst the reinstatement would provide additional discharge capacity to convey Mirrool Creek floodwaters, the combined siphon and reinstated flood gate capacity still only provides a 2% AEP design flood capacity. The generally accepted standard of protection considered for residential property is typically the 1% AEP design event. Accordingly, reinstatement of the flood gates in the current configuration is considered as an interim measure, with further options for augmentation considered separately.

The reinstatement of the existing structure may not be straight forward. Although recommended as an interim measure, there is some key constraints that require further consideration as part of the works assessment. These include:

- Structural integrity - this refers to both the existing structure and also the bed/banks of the Main Canal. Given the age of the structure, a full condition assessment (structural and geotechnical) would be required to inform the opportunity for reinstatement and the economic viability of an existing structure refurbishment in comparison to a replacement structure.

- Gate arrangements – refurbishment requires work on both flood escape structures, including gate modifications to provide the function of transferring Mirrool Creek floodwaters across the Canal and not close under headwater pressure from the upstream side.
- Siphon operation – part of the function of the existing northern bank structure is to provide maintenance flows to scour the siphons and remove siltation that may impact on siphon capacity. This function will need to be retained in any flood gate refurbishment.

7.3.4 EMR Flood Gate Upgrade

It is not the intention of the current study to determine the preferred configuration for providing the recommended capacity upgrades to the EMR flood relief structures. The solution involves major engineering design with potentially a number of design solutions. For example, this may incorporate a major upgrade to the existing structure through expansion of current flood gates, or alternative solutions such as siphoning Main Canal flows underneath the Mirrool Creek floodplain (similar to the Lawson Siphon at Deniliquin).

Various upgrade options to the existing flood relief structures were simulated using the existing flood models. Iterations were undertaking gradually increasing design capacity of the flood relief structures.

Some key indicators were identified to assess the relative performance of the upgrades options:

- Peak discharge through the EMR flood relief structures – this considered the combined discharge of the siphons and existing or upgraded gate structures.
- Peak water level U/S of the EMR flood relief structures – a critical level of approximately ~134.3m AHD has been identified as the initiation of significant overtopping of the NBC.
- Peak flow through Yenda – this is obviously the key indicator of effective performance of the management option
- Yenda flood depth – a reference location in Leaver Street, Yenda, was selected representing a location potentially subject to significant inundation.
- Myall Park flows – these represent combined flows moving through to Myall Park via Yenda and North Yenda.

The relative performance of a combination of upgrades to the EMR flood relief structures and a NBC levee is summarised in Table 7-3. The options represent:

a) Reinstatement of the decommissioned flood gates - this option provides for no major augmentation but a return to full function of the existing configuration.

b) Upgrade of the flood gates – this option provides for an approximate duplication of the capacity of the existing flood gates.

c) Reinstatement of the decommissioned flood gates plus construction of a NBC levee.

d) Upgrade of the flood gate plus construction of a NBC levee – as per above in provision of approximate duplication of existing flood gate capacity.

Results are provided in Table 7-3 for the 1% AEP and 0.5% AEP design flood events. Whilst the 1% AEP event would typically be considered an appropriate design flood standard for flood mitigation options, the 0.5% AEP is more representative of the conditions experienced in the March 2012 flood event.

Table 7-3 Peak Flow and Water Level for Yenda Mitigation Works

Reference Location	Reinstate Flood Gates	Upgrade Flood Gates	Reinstate Gates & Levee	Upgrade Gates & Levee
1% AEP Event				
Flow through EMR Flood Structures (m^3/s)	84	114	92	114
Peak Level U/S Flood Structure (m AHD)	134.43	134.32	134.51	134.32
Flow through Yenda (m^3/s)	32	7	0	0
Leaver Street Yenda Flood Depth (m)	0.6	0.5	0.1	0
Myall Park Flow (m^3/s)	30	26	58	38
0.5% AEP Event				
Flow through EMR Flood Structures (m^3/s)	92	132	99	135
Peak Level U/S Flood Structure (m AHD)	134.49	134.43	134.64	134.45
Flow through Yenda (m^3/s)	60	24	1	1
Leaver Street Yenda Flood Depth (m)	0.7	0.6	0.3	0.1
Myall Park Flow (m^3/s)	44	41	103	74

Ultimately the key indicator of performance of each option is in the reduction in flooding in Yenda as represented by the “Flow through Yenda” and “Leaver Street flood depth” in the above table.

Although increasing the flood protection to Yenda, the reinstatement of the flood gates does not provide sufficient capacity to manage events of the order of the 1% AEP. Significant discharges of the order of $30m^3/s$ and $60m^3/s$ for the 1% AEP and 0.5% AEP events respectively would spill through to Yenda providing for significant inundation in the township, similar to conditions experienced in March 2012.

In conjunction with a NBC levee, reinstatement of the flood gates would provide suitable flood protection to Yenda. However, this protection is at the detriment to North Yenda properties in that the flow exceeding the EMR flood gate capacity is pushed north around the levee to North Yenda and through to Myall Park as indicated by the increased flows in the table.

The upgraded flood gate option (approximate duplication in flow capacity at the EMR flood relief structures) provides for almost a 1% AEP discharge capacity with a reduced flow through Yenda as shown in Table 7-3. The peak water level U/S of the EMR structure is just over the critical threshold value of 134.3m AHD. Under the greater flood magnitude of the 0.5% AEP event, this capacity would be insufficient to protect Yenda form significant inundation. A further increase in structure capacity of 20-$30m^3/s$ however would appear sufficient to provide the higher flood immunity.

The combination of the flood gate upgrades and NBC levee effectively provide a 0.5% AEP flood immunity standard to Yenda. There is some increase flows through North Yenda to Myall Park as the levee pushes to the north the flow that would have previously inundated Yenda township.

7.3.5 EMR "Lawson Siphon" Type Structure

The Floodplain Risk Management Study has identified a required flood relief structure capacity of the order 120m^3/s to provide a 1% AEP design flood standard. This represents approximately a 50% increase in the current capacity of the combined siphon/flood gate arrangement if fully operable. This arrangement however would not provide full protection to Yenda for a similar to the March 2012 event conditions. This event has been estimated as representative of a 0.5% AEP event. Accordingly, an upgraded flow capacity of the order of 140 - 150m^3/s would be required to provide an equivalent flood standard protection to Yenda.

A siphon type structure was previously identified in the Dept. Water Resources (1994) options study. This study presented options for siphon widths of 48m and 68m providing for nominal flow capacities of approximately 140m^3/s and 200m^3/s respectively. However, in determining these arrangements a maximum allowable water level at the structure was assumed to be 134.9m AHD. As noted in Section 7.3.2, the current maximum water level prior to overtopping the NBC is only is approximately 134.3m AHD. Accordingly, to provide for a similar flow capacity at a lower operating water level, significantly larger siphon widths than the Dept. Water Resources (1994) options would be required.

Similar targets to the flood gate upgrade option are adopted in defining a design flow capacity for the siphon type structure. With consideration of the minimum level of the NBC embankment elevated to 134.8m AHD, the target design capacity provides for:

- 1% AEP discharge of 120m^3/s at operating water level of 134.3m AHD (0.5m freeboard to NBC overtopping); and
- 0.5% AEP discharge of 140m^3/s at operating water level of 134.5m AHD (0.3m freeboard to NBC overtopping)

The width of the siphon structure required to provide the nominal design discharge capacity is somewhat dependent on the channel and floodplain topography through the structure opening. Depending on design constraints, particularly in relation to integrating a siphon arrangement with the existing major regulating structures of the Main Canal and NBC offtake, the alignment of the floodway opening may not coincide with the location of the Mirrool Creek main channel. With general floodplain levels typically higher than the normal channel geometry, the flow capacity of the floodway opening section can vary considerably depending on location.

It is envisaged that a siphon type arrangement may require some realignment of the main Mirrool Creek channel section. The extent of Creek realignment and excavation works may be limited by environmental constraints. Accordingly, in determining a nominal width of floodway opening, consideration has been given to the potential variability of the design floodway section through the opening.

Figure 7-12 presents stage-discharge relationship for two siphon floodway arrangements, one with a nominal floodway opening of 100m width at existing floodplain levels (no Creek excavation), and a 70m width incorporating a realigned Mirrool Creek channel (excavated channel) of some 20m. The excavated Creek channel provides for some additional flow conveyance compared to the higher typical floodplain levels. Shown for reference is the indicative design window with the targeted 1% AEP and 0.5% AEP peak design flows and upstream water levels.

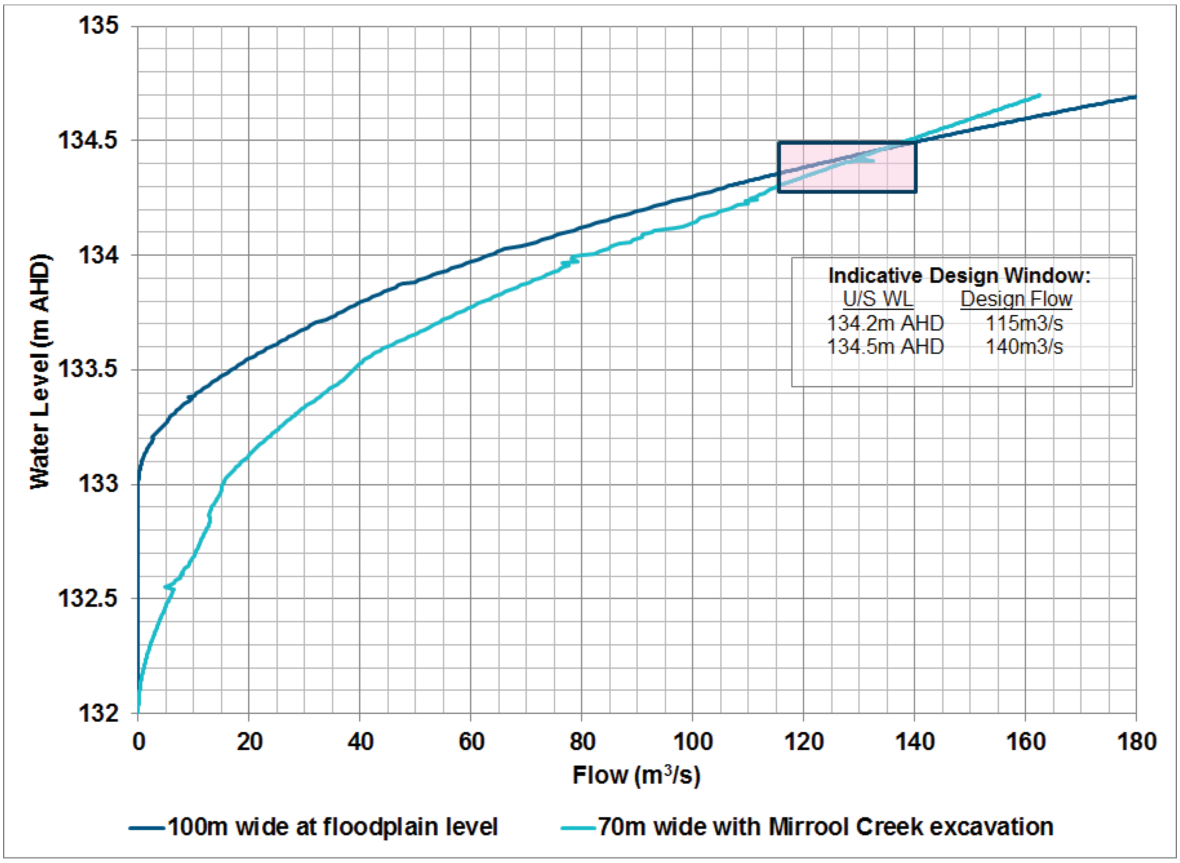


Figure 7-12 "Lawson Siphon" Type Structure Design Stage-Discharge

Concept design details for a gate upgrade arrangement and an alternative "Lawson Siphon" type arrangement are presented in Appendix C. To provide the nominal 1% AEP design protection to Yenda, the gate upgrade option provides for a structure consisting of 9 bays of 2.4m x 1.8m gate openings. The corresponding design for the siphon type structure provides for a floodplain opening of some 70-100m. Any additional capacity provided at the structures would increase the design flood immunity for the Yenda and North Yenda localities.

Murrumbidgee Irrigation is one of the major stakeholders in any future upgrade works. MI's ongoing operations represent one of the major constraints within design of upgrade options with consideration of:

- Integrating works within the existing operational supply system;
- Maintenance and operational responsibilities; and
- Construction phase impacts and potential disruption to MI business and impacts to customers.

Accordingly, in the context of the Floodplain Risk Management Plan, the recommendation is to progress concept design for the upgrade of the EMR flood relief structures. It is envisaged this works would identify a preferred option (e.g. gate upgrade configuration or Lawson Siphon type arrangement), undertake a review of environmental factors, confirm planning and approvals process and progress the preliminary design.

7.3.6 Impacts of EMR Works

Whilst the EMR upgrade options specifically aim to reduce the flood impact on the Yenda community, the changes in flow distribution through increasing discharge through the EMR flood relief structures and the NBC levee directing flow to the north, provide some changes in peak flood levels throughout the system.

Figure 7-13 to Figure 7-24 show the change in peak flood levels for three representative mitigation options; 1) upgrade of the flood gates (approximate duplication of existing capacity); 2) NBC levee; and 3) combined upgrade of flood gates with levee. Note that when referencing “upgrade of the flood gates”, this condition is also representative of the siphon type structure which has been designed for the same flow capacity. Accordingly, the potential impacts of the different options are effectively the same.

The plots show the relative change in peak flood levels compared with conditions assuming only the reinstatement of the decommissioned flood gates. This has been used as the base case as represents the scenario upon which previous floodway definition and land use management have been based. It is noted it doesn’t represent existing conditions given the decommissioned status of the flood gates, however, the reinstatement of the gates has been recommended as an interim measure. For each of the three upgrade options, the change in peak flood level for the 1% AEP and 0.5% AEP is presented for both the Yenda township locality and the broader Mirrool Creek floodplain. A summary of the key observations from the figures is provided below.

EMR Flood Relief Structure Upgrade 1% AEP Impact (Figure 7-13 and Figure 7-14)

- Option provides for limited reduction in flood inundation in Yenda. Whilst there are flood level reductions of the order of 0.1-0.2m, the majority of the township remains inundated.
- Areas in North Yenda and Myall Park show modest peak flood level reductions (0.1–0.2m).The larger capacity of upgraded EMR flood relief structures conveys greater flow down the Mirrool Creek with less flow spilling through Yenda and North Yenda in Myall Park.
- The higher flows discharged into Mirrool Creek provide for general increases in peak level of around 0.1-0.2m throughout the floodplain downstream of the Main Canal. A smaller percentage of floodplain area show flood level increases of 0.1-0.2m
- Downstream of the confluence with Main Drain ‘J’, the impacts of increased Mirrool Creek discharges are less significant.

EMR Flood Relief Structure Upgrade 0.5% AEP Impact (Figure 7-15 and Figure 7-16)

- Option provides for reduction in flood depths in Yenda with levels reduced by around 0.2m in general. However, the township is still subject to significant inundation at this flood magnitude.
- Areas in North Yenda and Myall Park again show modest peak flood level reductions (0.1–0.2m, although the benefit is not as extensive as for the 1% AEP event.
- The higher flows discharged into Mirrool Creek provide for general increases in peak level of around 0.05-0.1m throughout the floodplain downstream of the Main Canal. A smaller percentage of floodplain area show flood level increases of 0.1-0.2m.
- Impacts for areas downstream of the confluence with Main Drain ‘J’ remain less significant.

Northern Branch Canal Levee 1% AEP Impact (Figure 7-17 and Figure 7-18)

- Option provides for effective reduction in flood inundation in Yenda. Areas of previous flooding with depths of the order of 0.5-0.6m within the Yenda township now free from flooding. However, in the western corner of the town bounded by the Main Canal and the railway, some inundation is still evident. This inundation results from floodwater spilling over the railway embankment due to the higher flows forced around the levee through North Yenda, without any additional capacity provided at the EMR.
- Areas in North Yenda show peak flood level increases generally around 0.2m as flow is redirected by the levee alignment over the railway line in the vicinity of the Whitton Stock Route.
- With no additional capacity provide at the EMR flood relief structures, there is no significant impacts for the Mirrool Creek floodplain downstream of the Main Canal.

Northern Branch Canal Levee 0.5% AEP Impact (Figure 7-19 and Figure 7-20)

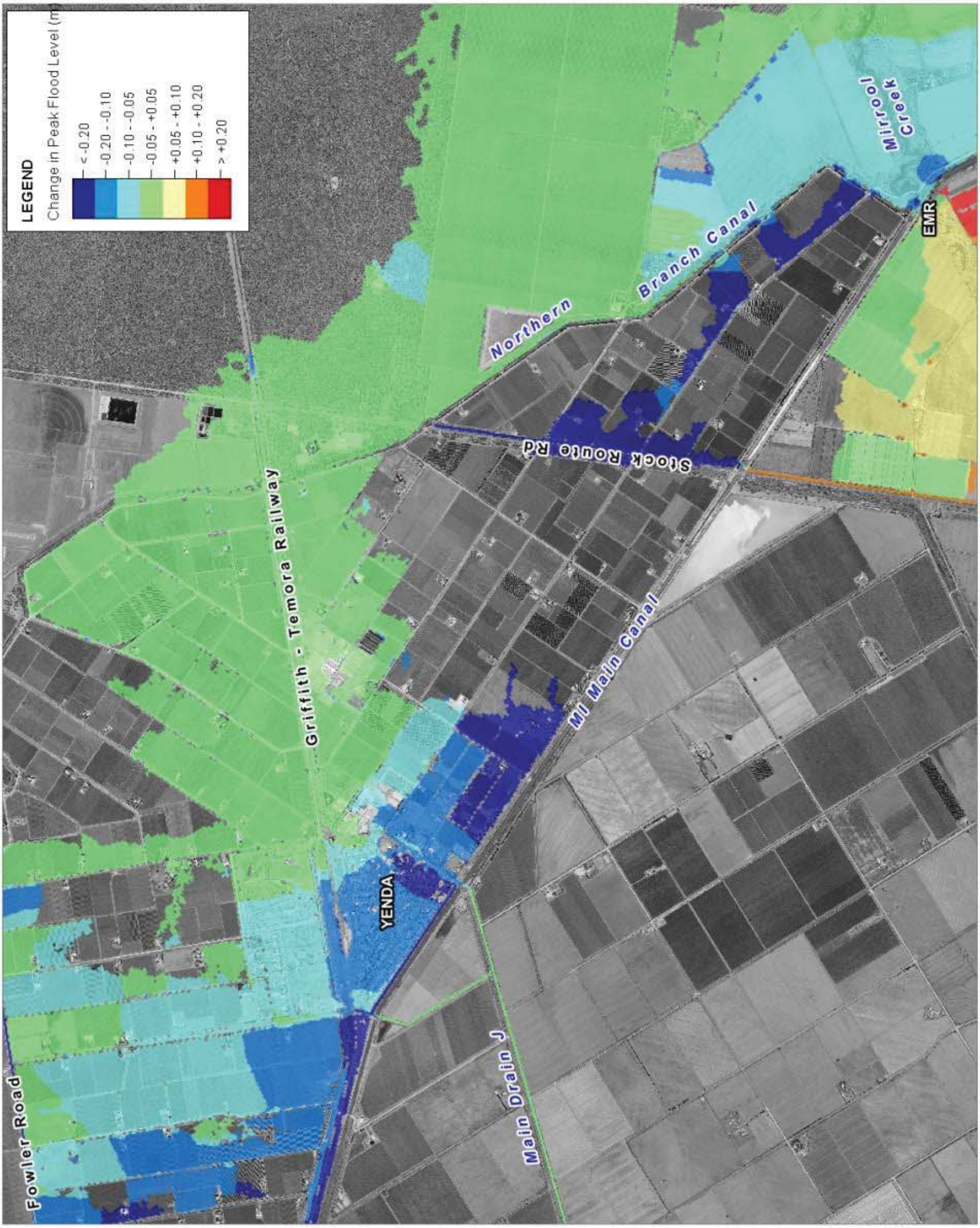
- Similar impacts as for the Option under the 1% AEP design flood condition. There is an increase in inundated are within Yenda from floodwater spilling over the railway embankment.
- The extent and magnitude of water level increases for areas upstream of the NBC and North Yenda are more significant. Peak flood level increases across broader areas in North Yenda are of the order of 0.2m.
- With no additional capacity provide at the EMR flood relief structures, there are no significant impacts for the Mirrool Creek floodplain downstream of the Main Canal.

EMR Flood Relief Structure Upgrade and NBC Levee 1% AEP Impact (Figure 7-21 and Figure 7-22)

- Option provides for effective reduction in flood inundation in Yenda. Areas of previous flooding with depths of the order of 0.5-0.6m within the Yenda township now free from flooding.
- Areas in North Yenda and Myall Park show modest peak flood level reductions (0.1–0.2m).The larger capacity of upgraded EMR flood relief structures conveys greater flow down the Mirrool Creek with less flow spilling through Yenda and North Yenda in Myall Park.
- The higher flows discharged into Mirrool Creek provide for general increases in peak level of around 0.1-0.2m throughout the floodplain downstream of the Main Canal. A smaller percentage of floodplain area show flood level increases of 0.1-0.2m
- Downstream of the confluence with Main Drain ‘J’, the impacts of increased Mirrool Creek discharges are less significant.

EMR Flood Relief Structure Upgrade and NBC Levee 0.5% AEP Impact (Figure 7-23 and Figure 7-24)

- Option provides for reduction in flood depths in Yenda with levels reduced by around 0.2m in general. However, the township is still subject to significant inundation at this flood magnitude.
- Areas in North Yenda and Myall Park again show modest peak flood level reductions (0.1–0.2m, although the benefit is not as extensive as for the 1% AEP event.



Title:

Yenda Mitigation Options - Change in Peak Flood Level 1% AEP Event EMR Structure Upgrade

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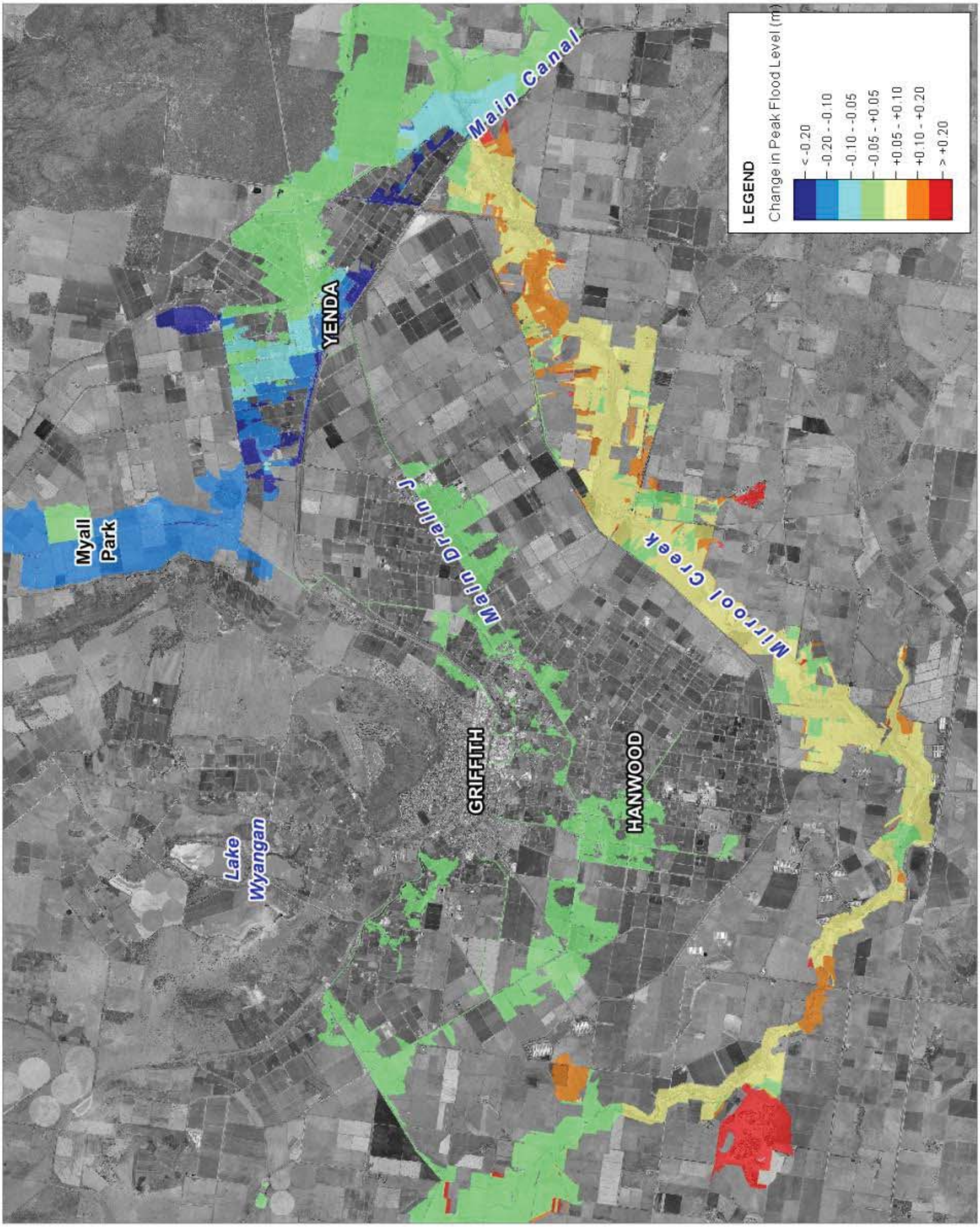

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Yenda Mitigation Options - Change in Peak Flood Level 1% AEP Event EMR Structure Upgrade

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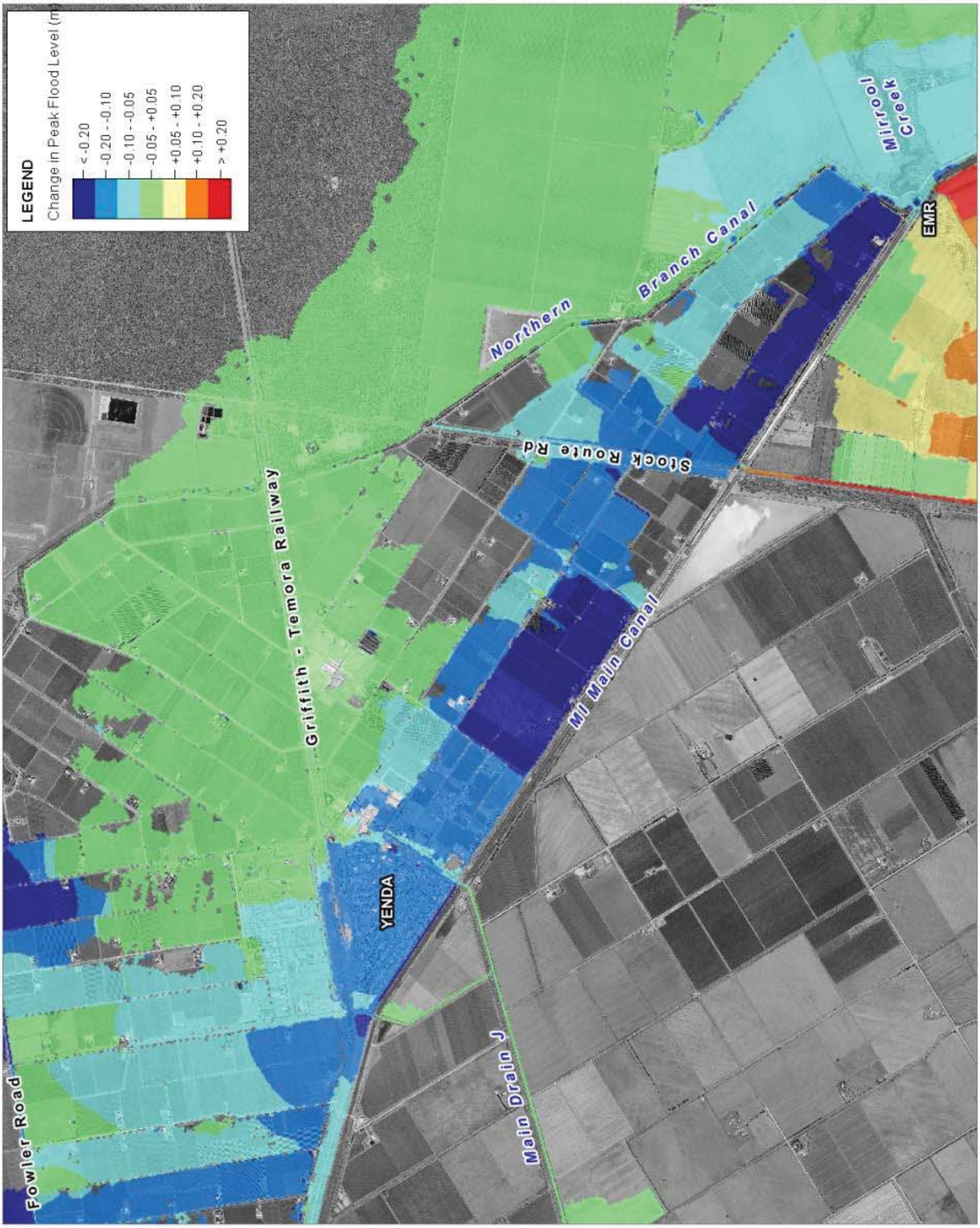

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Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event EMR Structure Upgrade

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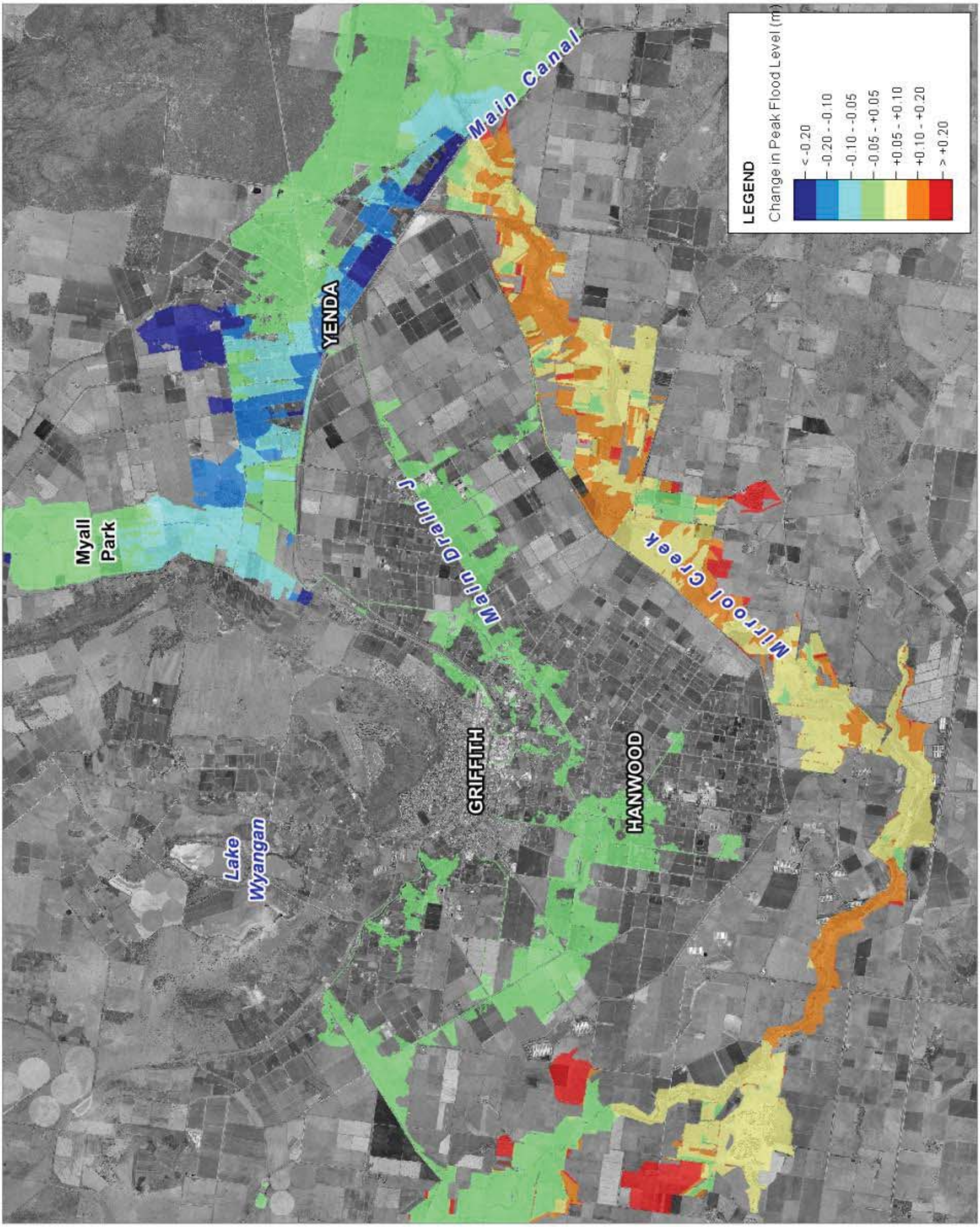

Title:
Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event EMR Structure Upgrade

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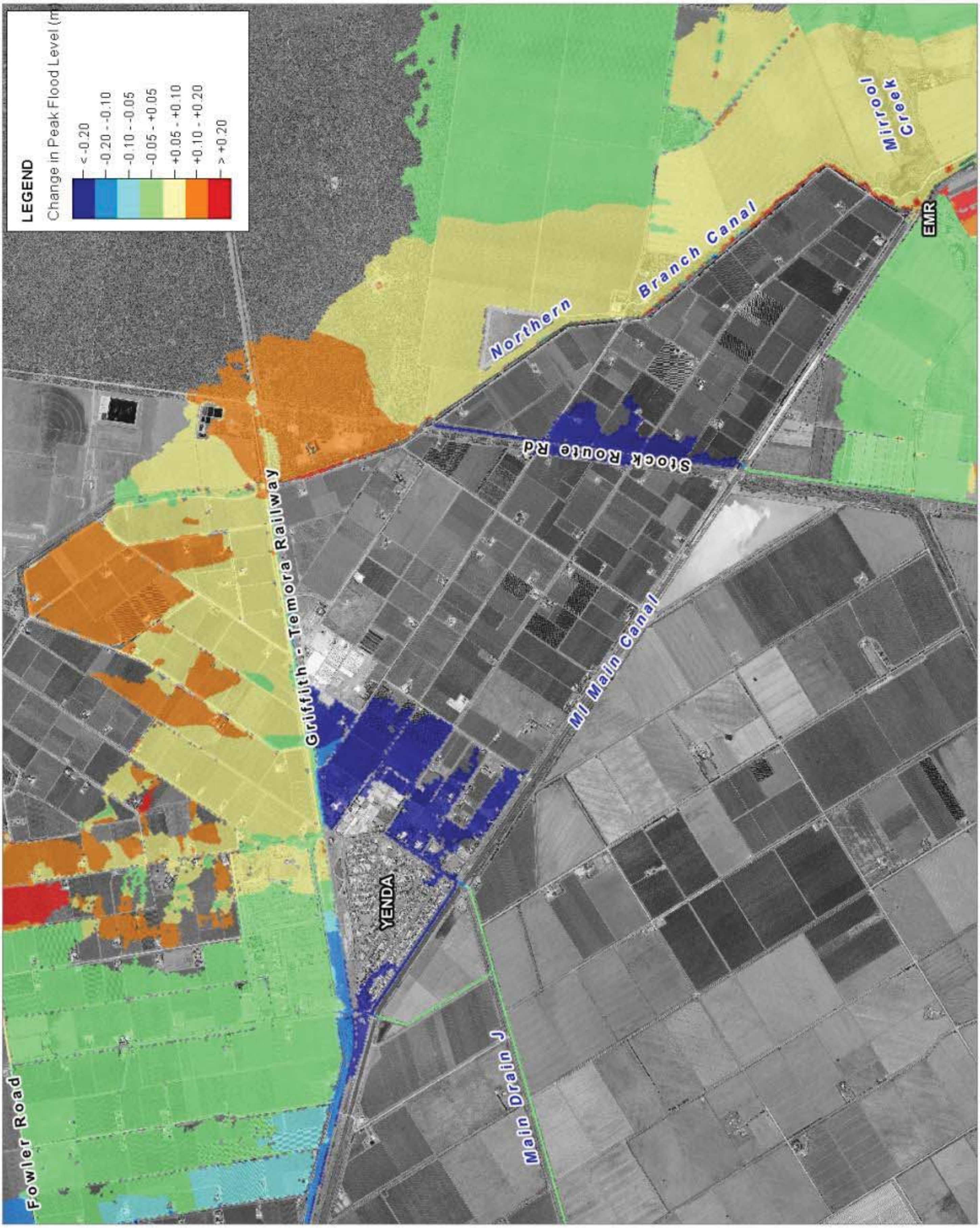

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Yenda Mitigation Options - Change in Peak Flood Level 1% AEP Event Northern Branch Canal Levee

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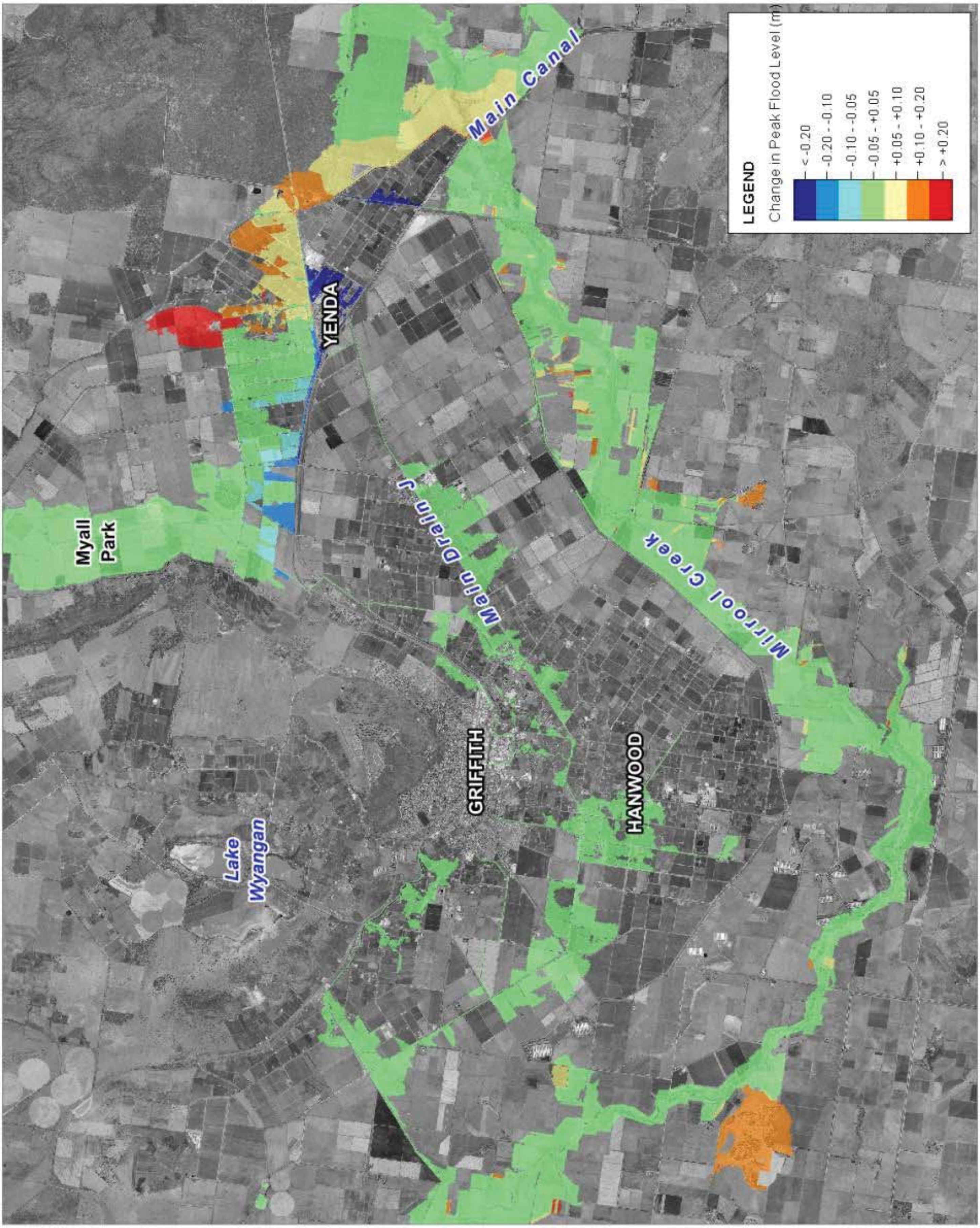

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Yenda Mitigation Options - Change in Peak Flood Level 1% AEP Event Northern Branch Canal Levee

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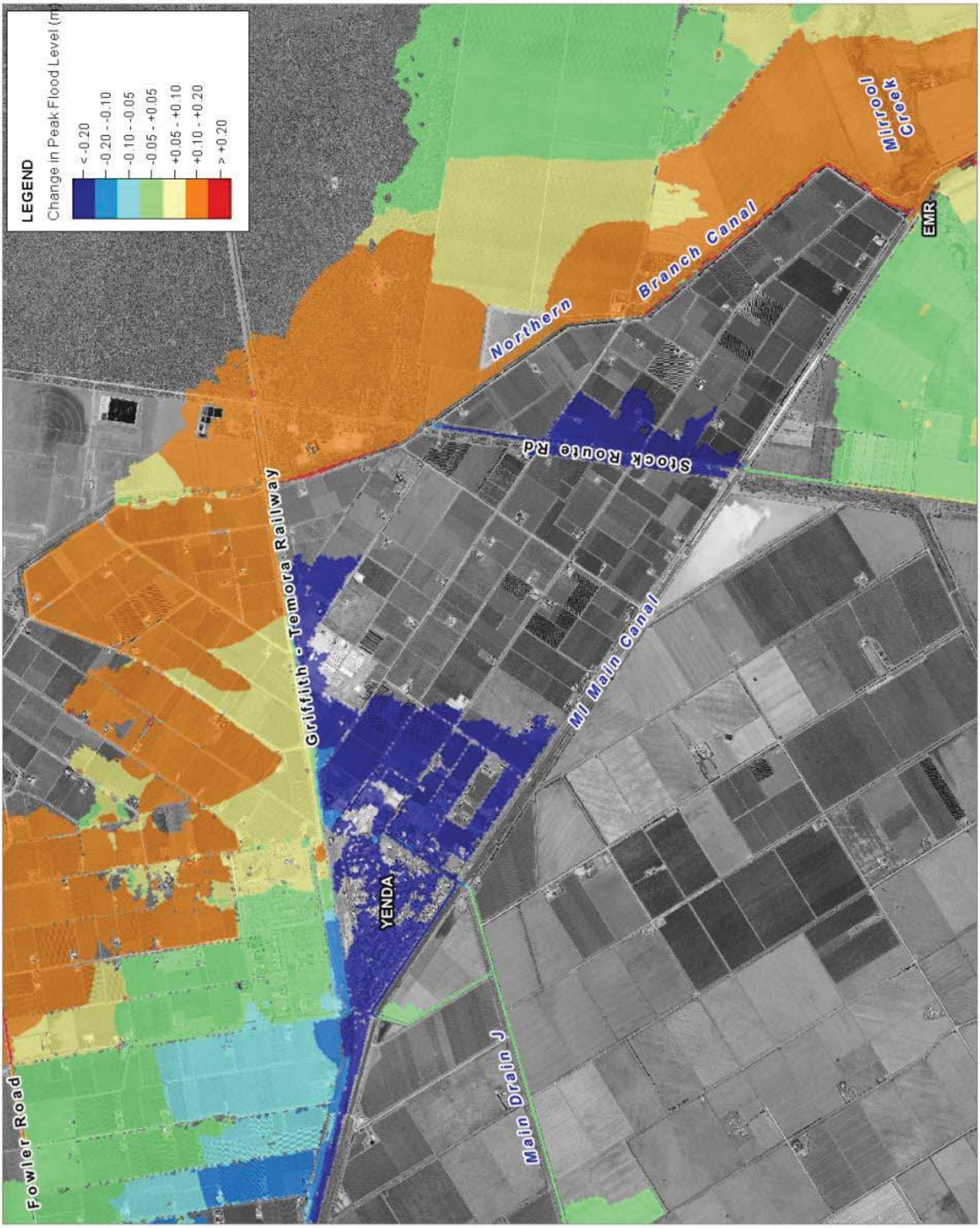

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Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event Northern Branch Canal Levee

Figure: 7-19

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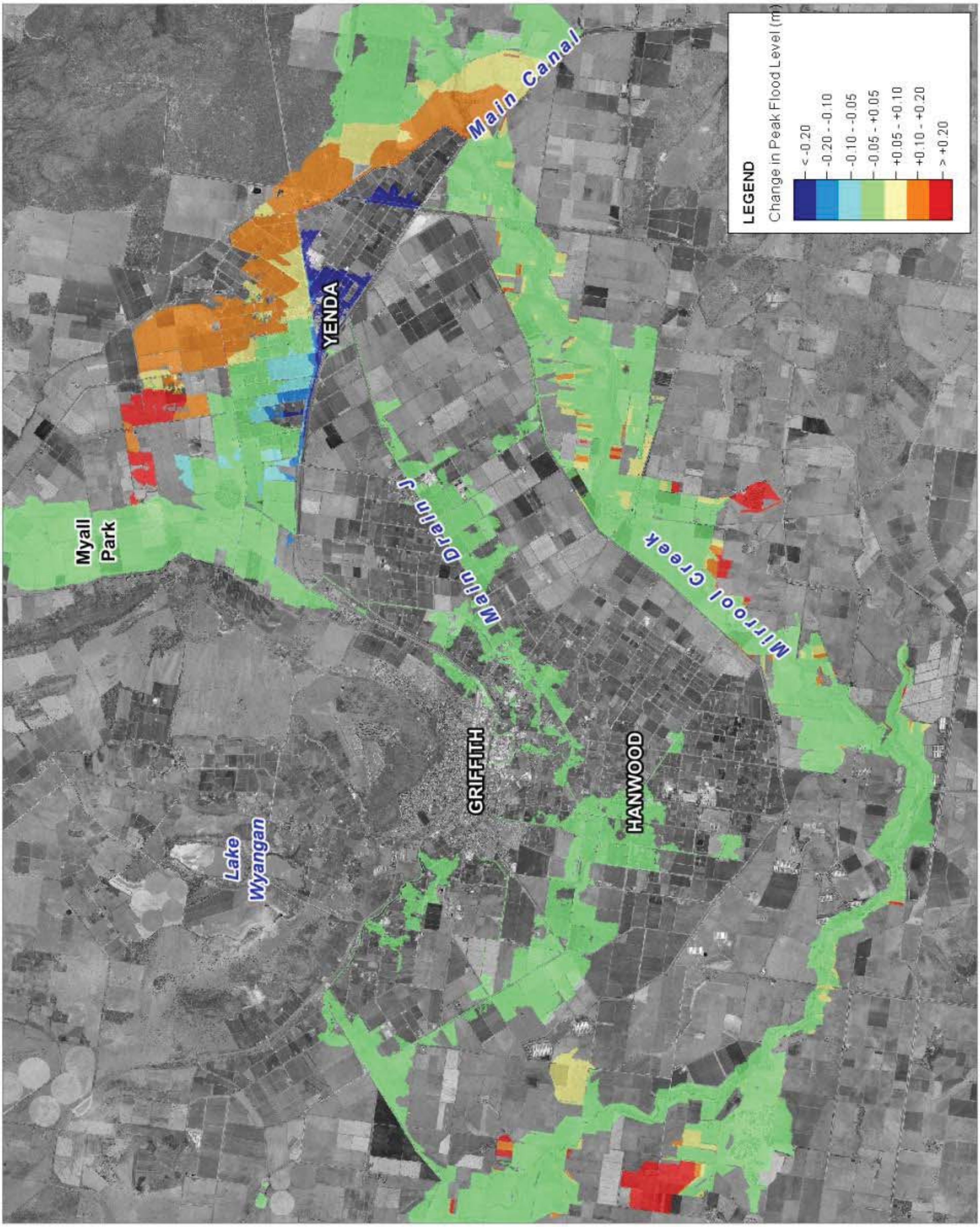

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Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event Northern Branch Canal Levee

Figure: 7-20

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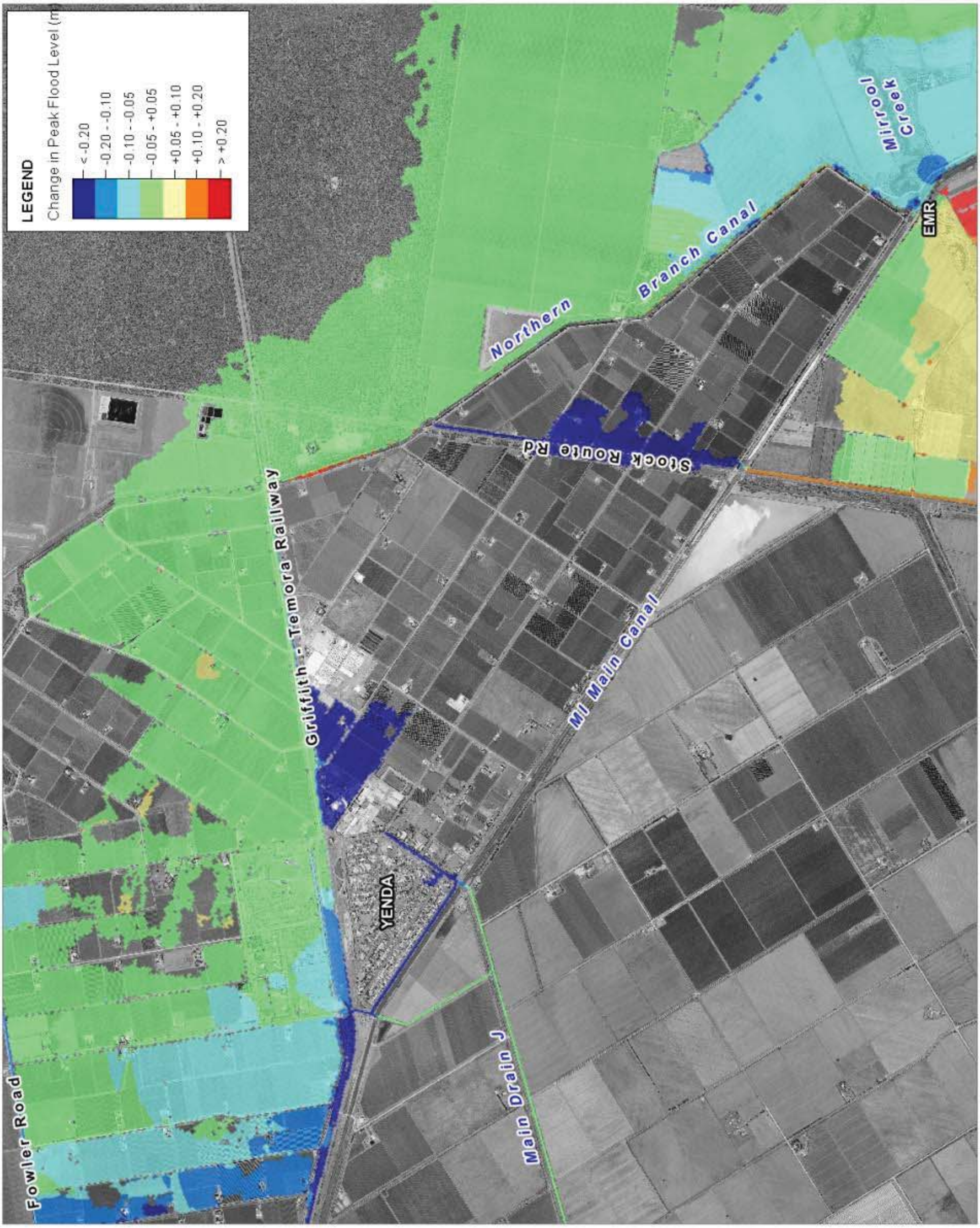

Title:
Yenda Mitigation Options - Change in Peak Flood Level 1% AEP Event EMR Structure Upgrade & NBC Levee

Figure: 7-21

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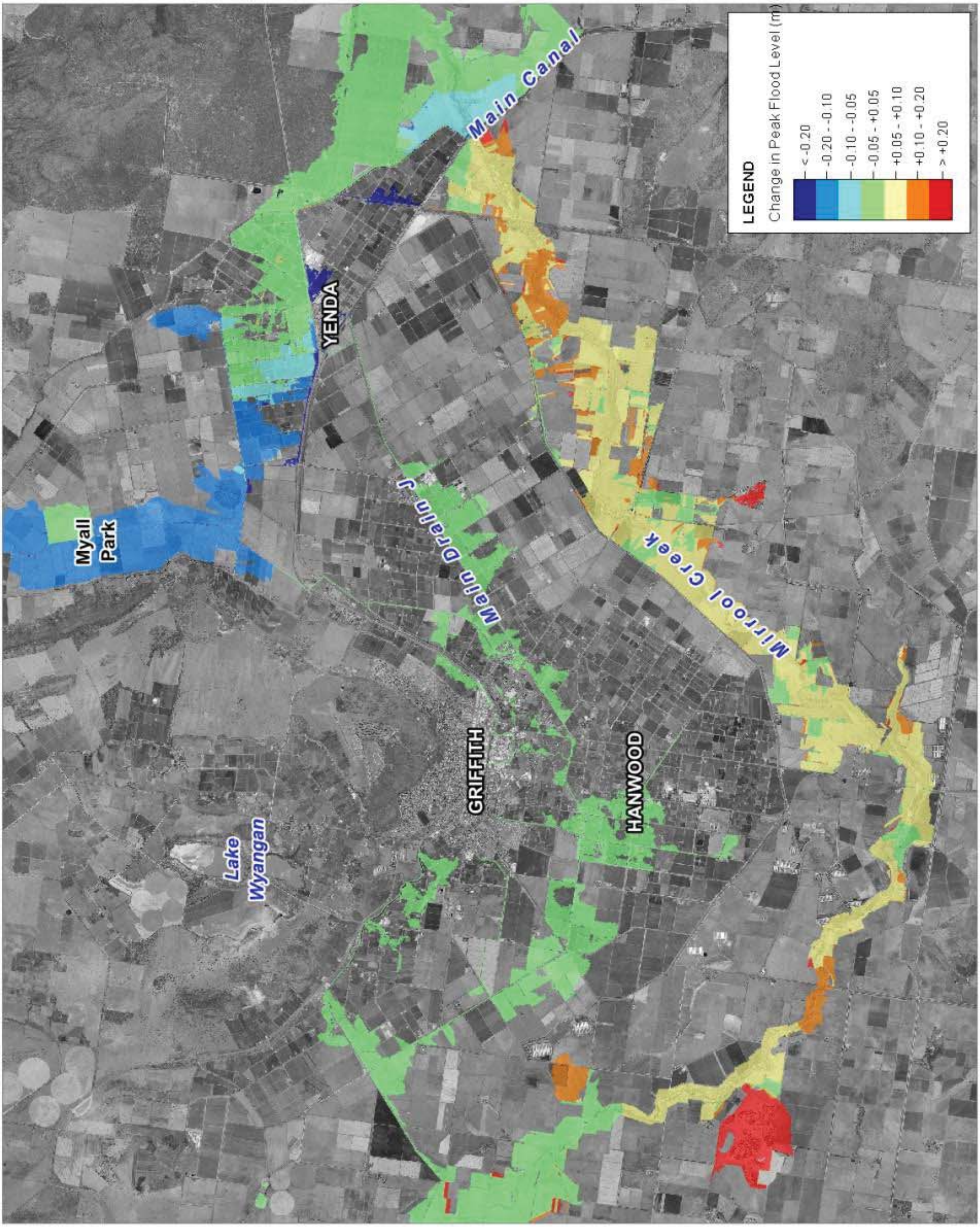

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Yenda Mitigation Options - Change in Peak Flood Level
1% AEP Event EMR Structure Upgrade & NBC Levee

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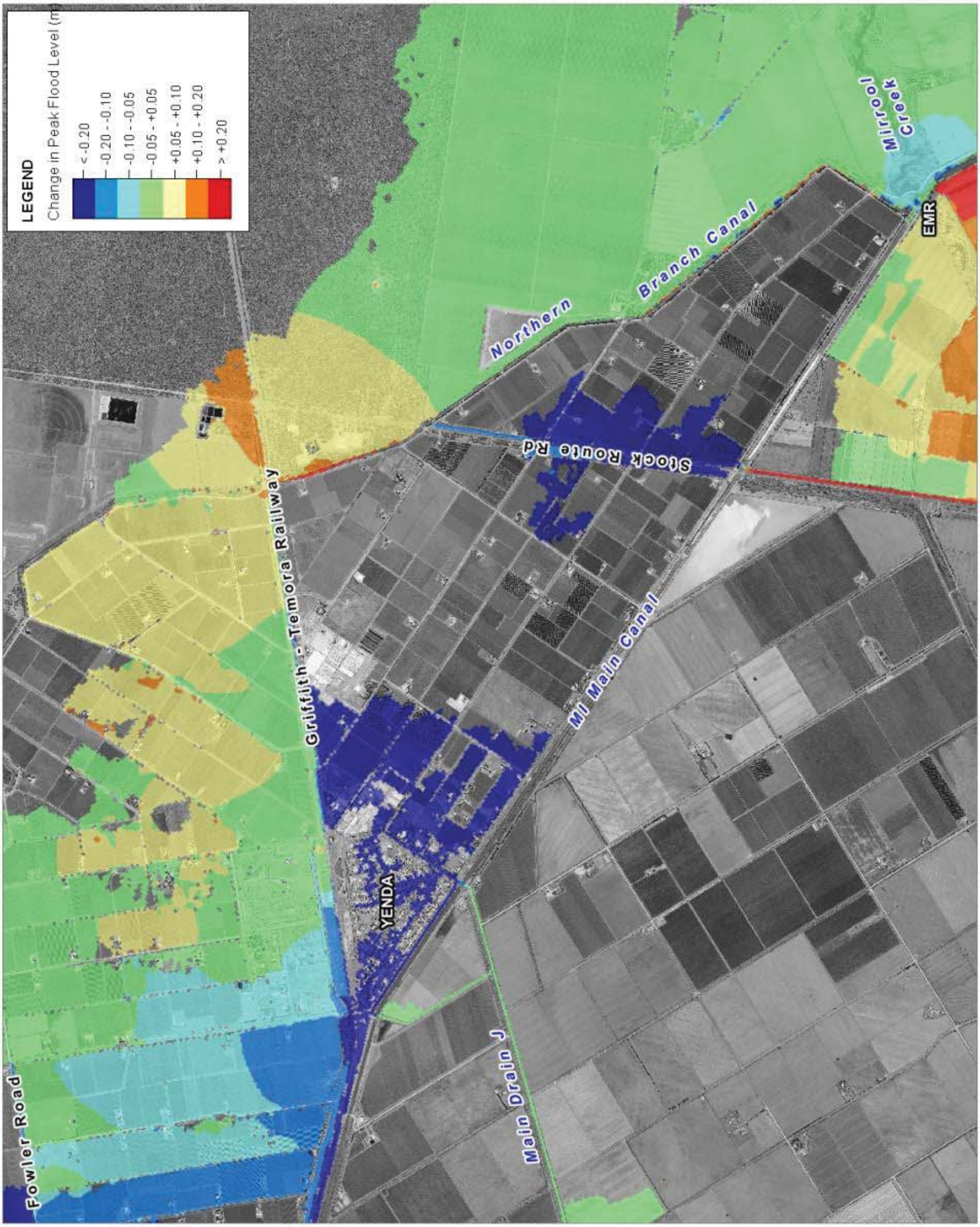

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Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event EMR Structure Upgrade & NBC Levee

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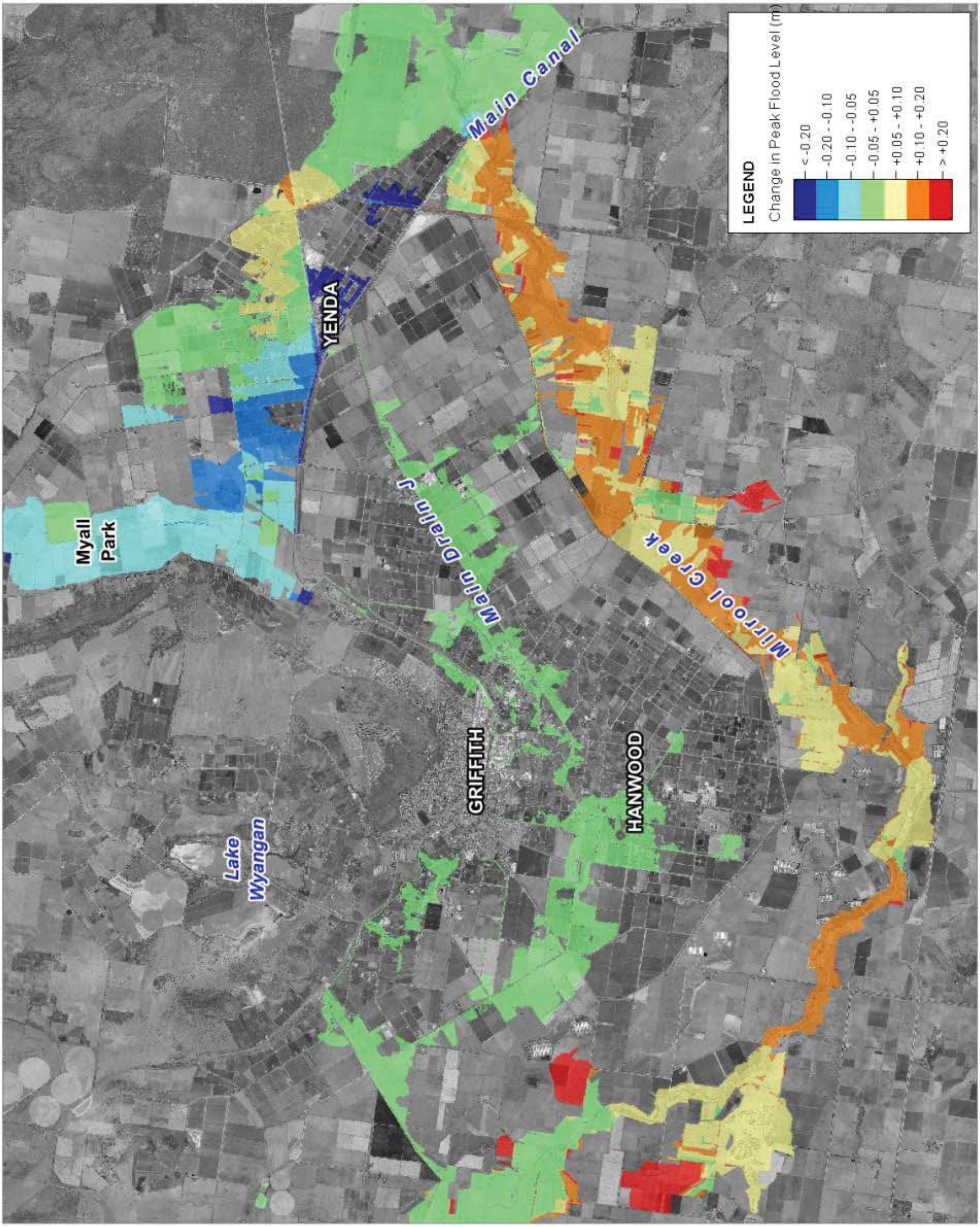

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Yenda Mitigation Options - Change in Peak Flood Level 0.5% AEP Event EMR Structure Upgrade & NBC Levee

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The combined option of upgrades to the EMR flood relief structures and NBC levee provides for an effective solution to the Yenda flood problem. The peak design flood inundation depth and extent for the mitigation option is shown in Figure A-7 in Appendix A for the 0.5% AEP design event (similar to March 2012 magnitude). The minor residual flooding shown in Yenda is due to a combination of local catchment rainfall and some backflow across the railway from the North Yenda side. The majority of this flow may be expected to be managed effectively by the local drainage system, including the recent pump installations.

Whilst providing effective mitigation to the Yenda township, it is noted that changes in the flow distribution arising from the works provide for adverse impacts to other parts of the floodplain. Specifically the two key areas of potential adverse impact are North Yenda and the broader Mirrool Creek floodplain downstream of the Main Canal.

The impacts to North Yenda only come into effect for the 0.5% AEP flood event with relatively minor increases of the order of 0.05-0.1m in a relatively localised area. Impacts of this scale and magnitude are not considered a significant increase in overall flood risk and may be considered acceptable. Nevertheless, further reductions in peak flood impact in this area may be achieved by providing even more flow capacity at the EMR flood relief structures.

The most significant of the impacts of the proposed mitigation option is the extensive area of increased flood levels throughout the Mirrool Creek floodplain downstream of the Main Canal. Whilst this area largely represents the natural floodplain of the Mirrool Creek system, it has to be recognised that significant agricultural development has taken place, such that increases in flow has the potential to adversely impact existing landholders.

Nevertheless, typical increases in peak flood levels are only of the order 0.1m for the 1% AEP event and 0.2m for the 0.5% AEP. This magnitude of impact was similar to that documented in the Dept. of Water Resources (1994) options study. Considering the nature of flooding within this existing floodplain area, peak flood level increases of this magnitude are not considered to major implications. There is limited opportunity to offset these impacts within the natural floodplain areas with alternative measures.

In terms of changes in the peak flood extents these increases in flood levels translate into significant changes in the extent of floodplain inundation, as presented in Table 7-4. This shows reasonably consistent changes in the area of modelled floodplain inundation, with the EMR upgrade works indicating around a 20% reduction in flood extents in the Yenda and Myall Park locality corresponding to a 20% increase in flood extents along the Mirrool Creek floodplain. In reality these changes in flood extent may not always be evident, as the interface between flood waters emanating from Mirrool Creek and those from local rainfall and drainage can be difficult to discern. However, it indicates that increased flood extents are likely to be experienced along the Mirrool Creek floodplain with reduced flood extents being experienced in and around Yenda.

Another important consideration for the increased flooding conditions along Mirrool Creek is the potential impact on road inundation depth and duration, particularly for the principal transport link of Kidman Way. Figure 7-25 shows the modelled water level hydrographs on Mirrool Creek upstream of Kidman Way. The road is overtopped at an elevation of approximately 123.6m AHD and so the modelled indicates that overtopping of the road may be expected to occur for around 12 hours longer over a total period of several days under the upgraded EMR condition, with upstream flood levels increased by around 0.05m to 0.1m.

Table 7-4 Summary of Floodplain Inundation Extents for the EMR Upgrade Works

	Area of Modelled Flood Extent (ha)		
Design Flood	**Reinstated EMR**	**Upgraded EMR**	**% Change**
Yenda and Myall Park			
1% AEP	689	536	-22%
0.5% AEP	838	705	-16%
Mirrool Creek from the Main Canal to Barren Box Swamp			
1% AEP	821	993	+21%
0.5% AEP	970	1,160	+20%

The peak flow rate along Mirrool Creek during the March 2012 event was larger than that of the modelled 0.5% AEP upgraded EMR condition (due to the Main Canal breaching) and Kidman Way was still trafficable throughout the event. Therefore the modelling suggests that the upgrade of the EMR is unlikely to impact on the trafficability of Kidman Way for events up to the 0.5% AEP.

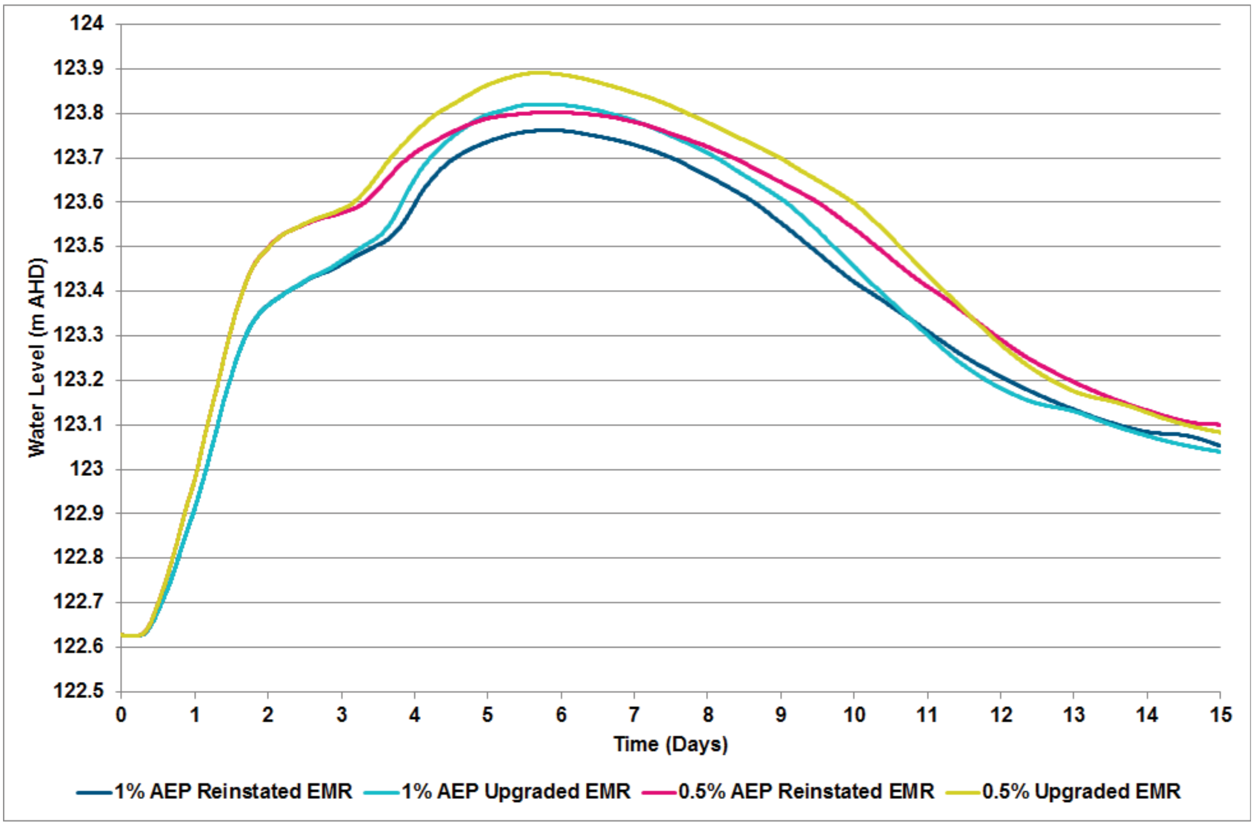


Figure 7-25 Impact of EMR Upgrade on Modelled Water Level Hydrographs at Kidman Way

The relative changes in flood level response shown at Kidman Way in Figure 7-25 is also indicative of the changes at other locations in the Mirrool Creek floodplain downstream of the Main Canal, such as Irrigation Way and the Railway at Widgelli. Increasing the capacity of the EMR flood relief structures to a 0.5% AEP design standard typically provides for peak water level increases of the order 0.1m. The 0.5% AEP discharge capacity is similar to the peak flow conditions experienced in March 2012 that included significant breaching of the Main Canal. Accordingly, the EMR upgrades provide no significant additional flood impact to the main transport routes relative to the March 2012 conditions.

There was also some concern in March 2012 in regard to potential flooding of the electricity substation along Irrigation Way. Some localised earthworks was undertaken to prevent any significant spilling from the Mirrool Creek floodplain and provide additional protection to the substation. As with the general water levels in the vicinity of Irrigation Way, the magnitude of changes resulting from potential upgrade works provides no further significant increase in flood risk to the substation. Events in excess of the 0.5% AEP event may require some localised protection as undertaken for March 2012.

The changing of Mirrool Creek flow distributions can also potentially impact on the flood volumes being discharged through the Mirrool Creek floodplain. This is of most concern for Barren Box Swamp, where flood conditions are driven by the volume of floodwaters being discharged to the swamp rather than the peak discharge rate of the inflows.

Table 7-5 shows the modelled discharge volumes within Mirrool Creek over a 15 day duration. It can be seen that the modelling indicates an increase in discharge volumes of around 10% at Kidman Way under the upgraded EMR scenario. However, at McNamara Road the discharge volumes are similar as the total flood volume of the system is being accounted for once downstream of Main Drain J. Under the reinstated EMR scenario a greater volume of water is discharged to Myall Park, which is then drained back to Mirrool Creek via Main Drain J.

The overall change in flood volumes entering Barren Box Swamp will approach zero when considering volumes over periods longer than 15 days. As the flood waters being discharged along Mirrool Creek or into Myall Park both ultimately drain to Barren Box Swamp the total volume being discharged under different flow distributions between the two flow paths should be similar, given a long enough period of time. However, as more flow is directed along the Mirrool Creek alignment, the timing of flood volumes entering Barren Box Swamp will change. Flows along the Mirrool Creek floodplain will arrive at the swamp sooner than those being conveyed via Myall Park.

Despite the magnitude of the March 2012 flood event, significant flooding problems were not experienced within Barren Box Swamp. MI manages Barren Box as one of its key storages including for flood risk management within the system, with controlled storage/releases dependent on forecast hydrological conditions. The March 1989 flood event produced far more serious flooding conditions at Barren Box Swamp and subsequently land situated further downstream. Although a much smaller event in terms of magnitude of peak flows, the March 1989 event was of much greater volume than that of March 2012. This is because the March 1989 flood event was actually a series of flood events occurring over a period of several weeks. The cumulative discharge volume of these flood events exceeded that of the single event experienced in March 2012. Given the long periods of time over which the critical flood conditions of Barren Box Swamp occur it is not expected that alterations to the Mirrool Creek flow distribution would significantly impact on the flood immunity of the Barren Box Swamp storage capacity.

A key driver for the current study was to find solutions to the significant problems at Yenda as experienced in March 2012. On balance, the increase in flood discharges to the natural floodplain of Mirrool Creek as opposed to the redistribution of the flow to Yenda by irrigation infrastructure would appear the most appropriate scenario. Whilst it is recognised there are some adverse impacts to properties through the Mirrool Creek floodplain, the EMR upgrade works would effectively restore the flow distributions to more like natural conditions. The formal floodways adopted through the floodplain downstream of the Main Canal were based on Mirrool Creek flood flows being conveyed across the structure in a relatively natural distribution (i.e. no diversion of flow to Yenda).

Table 7-5 Summary of Mirrool Creek Flood Volumes for the EMR Upgrade Works

	15 day Discharge Volume (GL)		
Design Flood	**Reinstated EMR**	**Upgraded EMR**	**% Change**
Kidman Way			
1% AEP	754	810	+7%
0.5% AEP	878	970	+10%
McNamara Road			
1% AEP	1,116	1,122	+1%
0.5% AEP	1,260	1,301	+3%

In the context of flood events of the 1% AEP magnitude and above, the incremental increase in flood affectation as a result of mitigation works at the EMR over and above the existing 1% AEP and higher flood condition is not particularly severe and largely affects agricultural property as opposed to significant residential property in the case of Yenda.

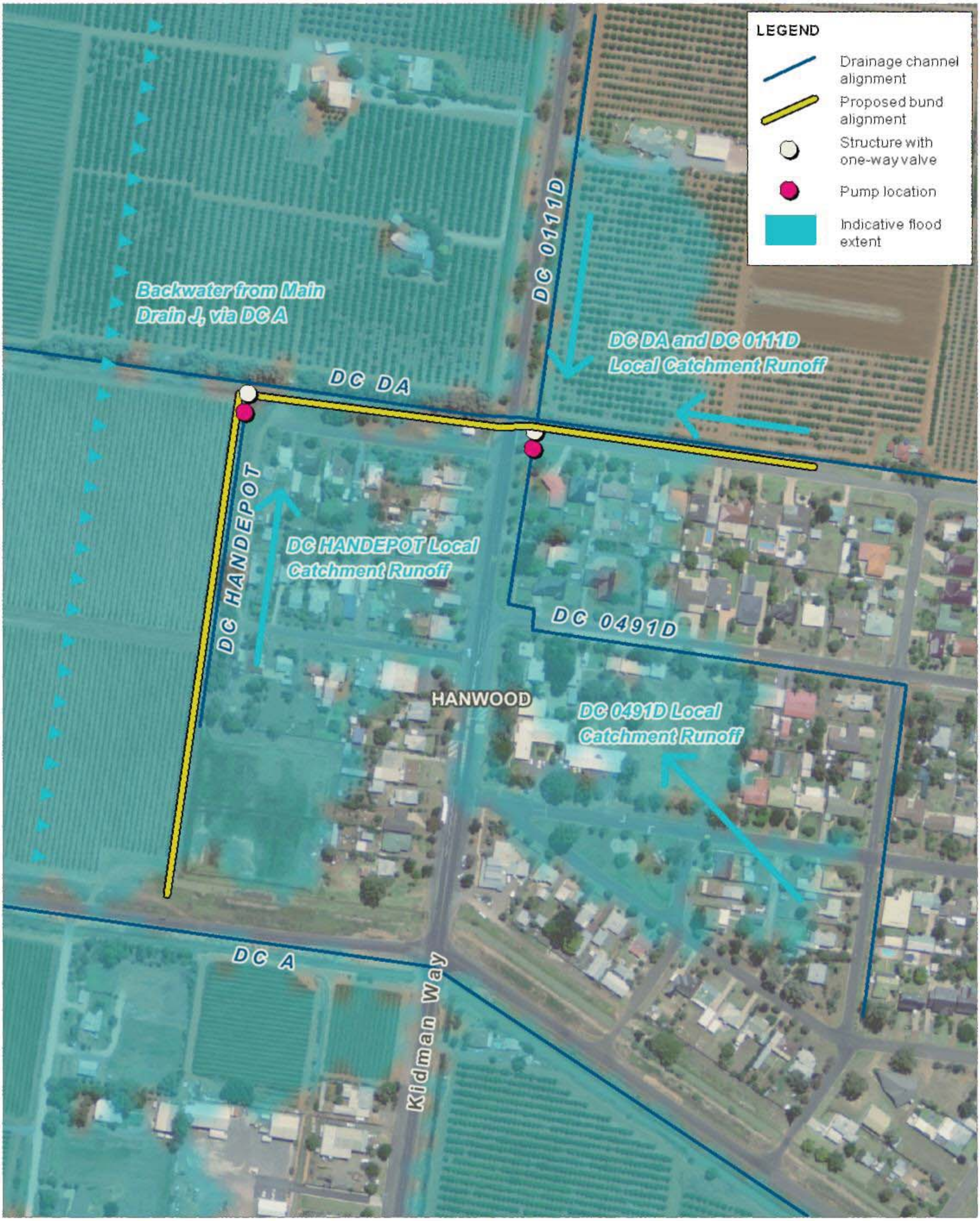
7.4 Hanwood Structural Options

7.4.1 Hanwood Local Drainage Works

Flooding in Hanwood largely occurs when Main Drain ‘J’ is running at capacity. The elevated water levels in Main Drain ‘J’ extend a backwater influence along DC ‘A’. This (together with a hydraulic gradient to drain DC ‘A’ and its contributing catchments) initiates extensive out of bank flooding, including within Hanwood. Flooding may last for a few days, until the tailwater level in Main Drain ‘J’ lowers to enable drainage out of Hanwood.

The flows draining through Hanwood are relatively small due to the size and flat nature of the upstream catchment, which is drained via DC ‘DA’. It is principally the backwater influence of flooding from Main Drain ‘J’ that causes flooding within Hanwood, rather than a lack of capacity within the drainage channels to convey the local catchment runoff.

The extent of the backwater flooding into Hanwood can be limited through the construction of a bund. The proposed bund alignment is shown in Figure 7-26 with respect to the local flooding and drainage. The bund height is limited to that of the surrounding topography with which the ends of the embankment can be tied into. The nature of earthworks required is similar to those presented for Yoogali.



Title:

Hanwood Local Drainage

Figure: 7-26

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant guarantee or make representations regarding the currency and accuracy of information contained in this map.

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0 75 150m

Approx. Scale

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The key elements of the proposed works include:

- Approximately 700m of earthen bund constructed along left bank alignment of DC 'DA' and DC 'HANDEPOT'. The bund crest is at a nominal height of 122.1m AHD (typical height of 0.4m) providing for a 1% AEP flood immunity with freeboard of approximately 0.25m.
- Provision of one-way flow structures on DC '0491D' and DC 'HANDEPOT' (and any other drainage connections that might be present) to prevent elevated water levels in DC 'DA' flowing into the area behind the bund; and
- The installation of pumps or suitable alternative means on DC '0491D' and DC 'HANDEPOT' to discharge local catchment runoff from behind the bund into DC 'DA' during periods when the one-way flow structures are 'locked'.

The Main Drain 'J' catchment model has not been configured to precisely represent local drainage at this scale and so the impacts of such works and the appropriate capacity of the discharge structures cannot be determined.

The impact on peak flood levels within the land areas outside of the bund is expected to be negligible, given that the area being protected is relatively small compared to the extensive floodplain storage that surrounds it. Appropriate sizing of the discharge structures through a local catchment assessment will ensure that the flood levels within the bunded area can be regulated to prevent flooding during periods when the one-way flow structures are 'locked'.

7.4.2 Increasing Main Drain 'J' Channel Capacity

Option S7 of the Griffith FRMS&P (2011) assessed widening of MD 'J' in the reach between Irrigation Way and Walla Avenue to increase flow capacity. The works were centred on reducing flood impacts in Yoogali, South Griffith, Hanwood and the rural properties west of Kidman Way. Between Walla Avenue and the intersection of Main Drain 'J' with DC 'A' (near Kidman Way), the option considered widening the existing channel which has a top-of-bank width of about 20 metres to a top width of 40 metres, occupying the full width of the drainage reserve. Typical decreases in flood levels of 0.15-0.2m on the floodplain areas between Kidman Way and Walla Avenue were predicted.

The revised flood modelling for the 2014 Flood Study updated design flood behaviour throughout the Main Drain 'J' system. In general, it was found that the existing Main Drain 'J' channel capacity was sufficient to convey the design 1% AEP design discharge and in most parts the 0.5% AEP discharge also.

Downstream of Kidman Way however, model simulations provided for relatively extensive out-of-bank flooding with significant areas of floodplain inundated. This indeed was experienced in the March 2012. Review of model results indicate that rather than a broad scale exceedance of flow capacity of Main Drain 'J', out-of-bank inundation was largely a result of localised spills from the channel at low point in the channel banks.

Figure 7-27 shows a long section profile along Main Drain 'J' downstream of Kidman Way. Shown for reference are the general elevations of the bed, top of left bank and top of right bank. The simulated flood profile for March 2012 event is also shown. Comparison of the relative bank levels and simulated water surface profile indicate some likely spill locations. The right bank of the Main

Drain 'J' channel appears to be consistently lower than the left bank for a significant length of channel between Kidman Way and Walla Avenue. It is anticipated that there would significant pressure on bank overtopping at a number of locations within this reach which may account for the overbank flooding. Even at isolated locations along the left bank, there are low points that afford the opportunity for flows to spill from the channel to the floodplain.

The reason for the inconsistency in bank elevations within this reach is unknown. However it is understood that some areas may have been subject to bank scraping in order to access clay material for channel maintenance.

It is considered that major channel widening works to increase the channel flow capacity is not required within this reach. A more targeted program of bank reinstatement or heightening is expected to provide the relatively minor increase in flow capacity required in order to prevent major spilling for events up to the 1% AEP and 0.5% AEP (representative of March 2012 flood conditions). In most instances, increases in bank heights of 0.2-0.3m are all that may be required. Furthermore, Murrumbidgee Irrigation would be advised to avoid accessing channel bank material that may result in a reduction in bank full capacity of the channel.

Recommendation – raising bank elevations in identified low point areas in the reach of Main Drain 'J between Kidman Way and Walla Avenue.

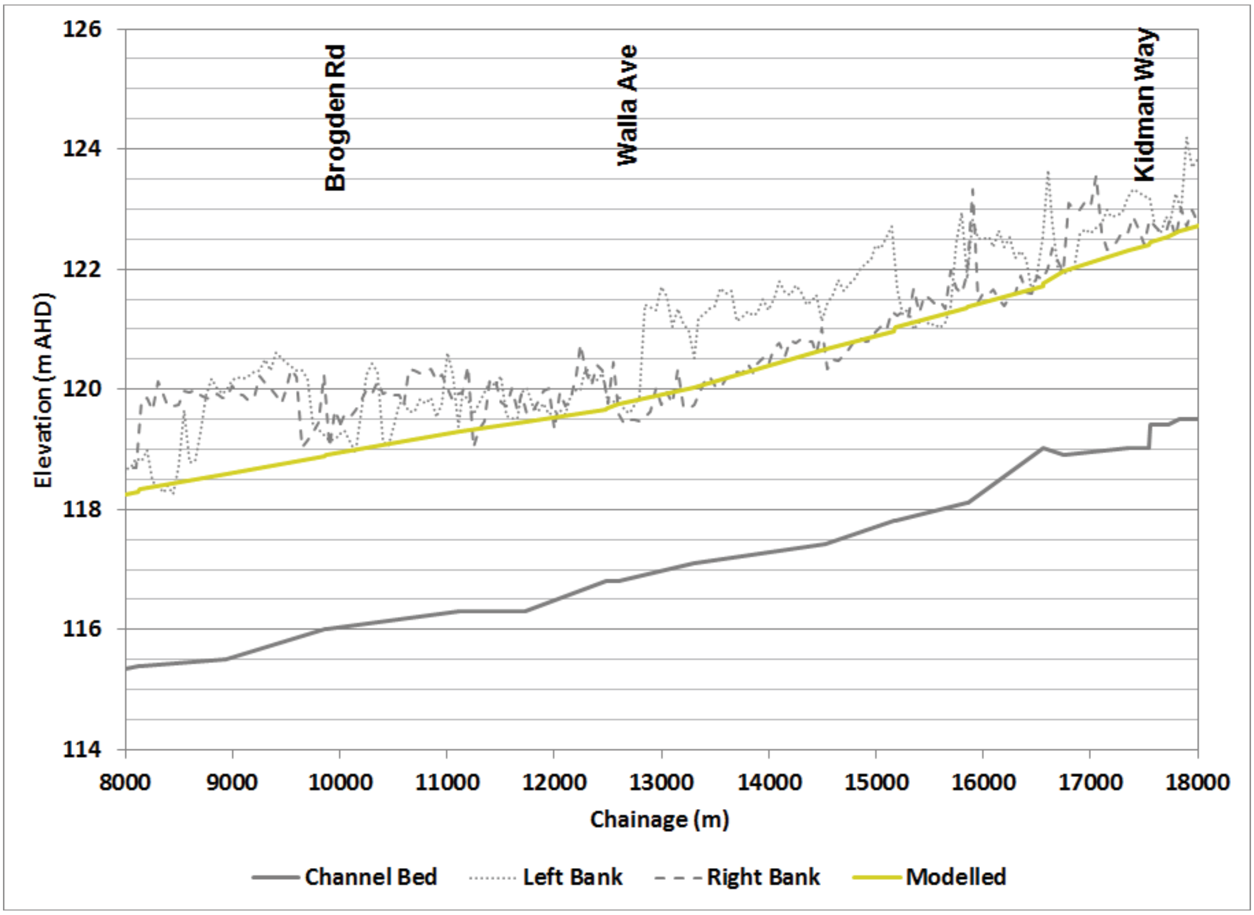


Figure 7-27 Main Drain 'J' Longsection Downstream of Kidman Way

7.5 Preliminary Benefit-Cost Analysis of Structural Options

A preliminary benefit-cost analysis has been undertaken to assess the relative merit of the major structural options with consideration of the capital costs and associated reduction in flood damages.

The baseline flood damages and the calculation methods were presented in Section 5.3. Updated damages have been calculated using the modelled flood results assuming implementation of the proposed works as discussed above. Table 7-6 and Table 7-7 show the estimated reductions in flood damages for the Yenda levee works (including culvert upgrades) and the EMR Flood Relief Structure Upgrade (include NBC levee work).

Table 7-6 Flood Damages Reductions for Yoogali Levee Option

Damage Sector	Reduction in Flood Damages ($,000)				AAD Reduction ($,000)
	5% AEP	2% AEP	1% AEP	0.5% AEP	
Direct Residential	0	0	115	783	6
Indirect Residential	0	0	6	40	0
Direct Commercial	0	0	29	609	3
Indirect Commercial	0	0	14	305	1
Infrastructure and Public Sector	0	0	50	521	3
Total	0	0	214	2258	13

Table 7-7 Flood Damages Reductions for EMR Upgrade and NBC Levee Option

Damage Sector	Reduction in Flood Damages ($,000)				AAD Reduction ($,000)
	5% AEP	2% AEP	1% AEP	0.5% AEP	
Direct Residential	0	0	14164	21359	212
Indirect Residential	0	0	708	1068	10
Direct Commercial	0	0	988	1349	14
Indirect Commercial	0	0	494	675	7
Infrastructure and Public Sector	0	0	4906	7335	73
Total	0	0	21260	31786	316

The Yoogali levee and EMR structure upgrades provide for Annual Average Damage savings of $13,000 and $316,000 respectively. The damages savings can be used in a benefit-cost analysis to assess the economic viability of implementing the flood management options. The “benefit” defined by the AAD was reduced to a net present value assuming a design life of 50-years and discount rate of 4%, 7% and 11%. The “cost” for each option is estimated capital construction costs for each of the measures. (Note: the cost of the major EMR upgrade works could vary considerably dependent upon configuration/design).

The benefit-cost ratios (BCR) for each option are summarised by:

Yoogali Levee and Culvert Upgrade

Cost to Implement: ~$500,000, Flood Damages Benefit: ~$279,000, ~$179,000, ~$117,000 for discount rates 4%, 7% and 11% respectively

Benefit-Cost Ratio: 4% discount rate- 0.56, 7% discount rate – 0.36, 11% discount rate 0.24

EMR Upgrade and NBC Levee

Cost to Implement: ~$10M, Flood Damages Benefit: ~$6.8M, ~$4.4M, ~$2.9M for discount rates 4%, 7% and 11% respectively

Benefit-Cost Ratio: 4% discount rate- 0.68, 7% discount rate – 0.44, 11% discount rate 0.29

Both options provide cost-benefit ratios of less than 1. The cost of the EMR upgrade may vary considerably between alternative options. For example, a $5M construction cost would increase the BCR to 0.88, with a $20M construction reducing the BCR to 0.22 for a 7% discount rate. Similarly however, a structure of this type may have a design life more like 70-100-years in which case the greater accrued flood damages reduction benefit and provide for an improved BCR.

Both the Yoogali and Yenda options provide solutions to flooding inundation of almost the entire townships. There are considerable intangible damages associated with the trauma and ongoing difficulties in recovery of the communities from such an event. Indeed, the viability of some parts of the township may be at risk if similar events to these experienced in March 2012 occurred again in the near future. Accordingly, the BCR based on the simplified economic analysis as above may understate the value of implementing these measures.

7.6 Land Use Planning and Development Controls

A comprehensive review of land use planning and development controls was undertaken in the Griffith FRMS&P. This review provided for the number of planning control recommendations incorporated in the Plan. The key changes to existing Policy incorporated recommendations for:

- Flood Clause to be incorporated in updated LEP;
- Council adopt draft Flood Liable Lands Policy as its Flood Policy;
- Council adopt draft On-site Stormwater Detention Policy; and
- Council and MI adopt drainage channel ownership, maintenance and upgrade Memorandum of Understanding.

No formal changes to these recommendations are considered warranted as part of the Plan review. However, as an outcome of the Flood Study update, it is necessary to update corresponding mapping included in the planning documents. The design flood conditions established in Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) is now used as the basis for flood planning. Accordingly the following recommendations are made in regards to updated mapping:

Recommendation – Updated Hydraulic Category map and Flood Planning Area map to be incorporated in updated LEP.

7.7 Flood Warning

The BoM Flood Warning Service provides different types of information to inform the community of type of flooding and the level of flood risk. The range of information may include (BoM, 2013):

- **An Alert, Watch or Advice** of possible flooding, if flood producing rain is expected to happen in the near future. The general weather forecasts can also refer to flood producing rain.
- **A Generalised Flood Warning** that flooding is occurring or is expected to occur in a particular region. No information on the severity of flooding or the particular location of the flooding is provided. These types of warnings are issued for areas where no specialised warnings systems have been installed. As part of its Severe Weather Warning Service, the Bureau also provides warnings for severe storm situations that may cause flash flooding. In some areas, the Bureau is working with local councils to install systems to provide improved warnings for flash flood situations.
- **Warnings of 'Minor', 'Moderate' or 'Major' flooding** in areas where the Bureau has installed specialised warning systems. In these areas, the flood warning message will identify the river valley, the locations expected to be flooded, the likely severity of the flooding and when it is likely to occur.
- P**redictions of the expected height of a river** at a town or other important locations along a river, and the time that this height is expected to be reached. This type of warning is normally the most useful in that it allows local emergency authorities and people in the flood threatened area to more precisely determine the area and likely depth of the flooding. This type of warning can only be provided where there are specialised flood warning systems and where flood forecasting models have been developed.

There is currently no formal flood warning service for Main Drain 'J' and Mirrool Creek provided by the BoM. Local advice is provided SES.

Flood classifications in the form of locally-defined flood levels are used in flood warnings to give an indication of the severity of flooding (minor, moderate or major) expected. These levels are used by the NSW State Emergency Service (SES) and the Bureau of Meteorology (BoM) in flood bulletins and flood warnings were formal systems and reference gauge locations exist for a catchment. To date, no formal warning systems have been developed Main Drain 'J' and Mirrool Creek catchments.

There is potential opportunity to develop a more formal system for the study catchments utilising both existing gauge networks and potential new gauges at key sites. Appendix C provides a background review of flood warning opportunities for the Main Drain 'J' and Mirrool Creek catchments with respect to modelled design flood behaviour and experiences born out of the recent March 2012 event.

Recommendation – Investigation of formal a flood warning system for the Main Drain 'J' and Mirrool Creek catchments.

7.8 Emergency Response

The State Emergency Service (SES) has formal responsibility for emergency management operations in response to flooding. Other organisations normally provide assistance, including the Bureau of Meteorology, Council, Police, Fire Brigade, Ambulance and community groups. Emergency management operations are usually outlined in a Local Flood Plan.

The March 2012 flood event highlighted the significant work undertaken by the SES to provide support both during and post event. For such a major event as March 2012, significant pressures on implementing effective emergency response were provided by , the isolation of the community through road closures, and the stretched resourcing of the SES in dealing with a region-wide event. Consideration therefore needs to be given to developing community based action plans that have less reliance on external support, at least in the early stages of a major flood event.

The key improvements to emergency response considered in the current study is the update of Local Flood Plans to incorporate the flood intelligence data borne out of the revised understanding of catchment flooding conditions. This data includes the updated flood modelling, property inundation and flood damages analysis, and the collation of flood data form the March 2012 event.

It is important that the SES Plan incorporates all relevant technical data and specific community vulnerabilities (including addresses of areas at highest risk) that have been determined through the Floodplain Risk Management process. Updates to the Local Flood Plan would be expected to build upon the following flood intelligence data:

- Update of linkage to flood warning/gauge sites and local property database
- Key levels at gauge locations with references to design and historical events
- Updated flood mapping showing flood depth and inundation extents and flood hazard categories for a range of events.
- Property database and inundation statistics
- Potential evacuation requirements
- Post flood recovery services

On the basis of the flood intelligence from March 2012, it is envisaged that some changes to emergency response plans will be undertaken from lessons learnt. Some specific changes are likely to be:

- Changes to evacuation procedures – having now a better understanding of the catchment flood response and nature of potential flooding across the region, the timing and methods of evacuations are now better informed;
- Property protection - for locations such as Yenda, there may be opportunities for increased property protection through sandbagging, or property removal, given the likely advance

warning of potential flooding and available response time with due consideration of the actual nature of flooding and associated risk.

The March 2012 event saw significant breaching of the Main Canal in numerous locations. These breaches considerably reduced the flows moving towards the EMR and without the breaching, the extent of flooding around Yenda is likely to have been more extensive. During the March 2012 flood response, emergency services were considering controlled breaching of the Main Canal. Given the potential for significant reductions to flows at the EMR, controlled breaching through formalised protocols/flood planning may be considered as a future flood management measure.

The structural options considered for the EMR upgrade aim to provide effective conveyance of Mirrool Creek floodwaters up to the 0.5% AEP design event (similar flows to March 2012). An emergency breaching operation could be considered as interim measure should an event of a similar nature be experience prior to construction of any EMR upgrade works, and also as an ongoing emergency measure for events in excess of the 0.5% AEP event where the EMR upgrade capacity may be exceeded.

Recommendation – Review of flood emergency planning and update of Local Flood Plan utilising updated flood intelligence.

7.9 Community Education and Awareness

Raising and maintaining flood awareness provides residents with an appreciation of the flood problem and what measures can be taken to reduce potential flood damage and to minimise personal risk during future floods.

The basic objectives of the community awareness program are to:

- Make people aware they are living / working in a flood zone
- Receiving, understanding and reacting to flood warnings
- Appropriate actions - e.g. where to evacuate to, what to do if caught in car

Community awareness is an on-going process and there is also the inherent danger of complacency between events. The Griffith FRMS&P (2011) provided for estimated cost of about $3,000 every 2 years, which is in addition to the work-hours required by SES and Council staff. This estimate incorporates an allowance for any materials and distribution costs associated with information brochures and also for the hire of a suitable venue for an annual community meeting.

Community education can be given a high priority in this Floodplain Risk Management Plan for several reasons:

- Education is required to build a flood-resilient community who is prepared for flooding and able to respond to and recover from actual flooding;
- This Plan is underpinned by the concept of shared responsibility where government, business, community groups and individuals all have a role to play in building resilience, preparedness, response and recovery. Community education will be important in helping people understand the risks and how they can be managed and equipping themselves to fulfil their role;

- Without community education, other elements of the plan such as flood warning, evacuation and emergency response planning would be less effective;
- Because of their dependence on technology and human action, flood warnings and emergency response cannot be considered as failsafe, so it is critical that the community knows how to self-respond to an actual flood without assistance from combat agencies such as SES or Police.
- It will take time for many elements of the plan to be implemented, particularly those associated with major capital works. In the interim, community flood response can be an effective way to manage risks to life and property in these areas;
- Even if all other elements of the plan are fully implemented, there will still be a residual or continuing risk that needs to be managed by appropriate community flood responses; and
- There are few planning or administrative barriers that would delay the development and implementation of a community education plan. Education and flood awareness should be a key role for combat agencies such as the SES. Community-specific education is also required to maximise effectiveness, and as such, Council has a key supporting role to play in assisting SES with the technical elements of flood characteristics of the Main Drain ‘J’ and Mirrool Creek catchments.

7.10 Analysis of Recommended Actions

A simple matrix has been developed to assess the positive and negative benefits and costs of the recommended actions. The criteria are based on a “traffic light” colour system to clearly display if an aspect of an option should be cause to “stop” and reconsider, “slow” to proceed with caution or “go” with few trade-offs expected.

The aim of the rapid analysis is to provide a straightforward overview of the various actions applicable for the Main Drain ‘J’ / Mirrool Creek catchment, presenting quickly and clearly to community the benefits and trade-offs of a particular action, to assist in the prioritising and ordering of works within the immediate, medium and longer terms.

The criteria used for the rapid analysis is described below and summarised in Table 7-8.

Performance

The performance criterion considers how well the action would actually address the risks it is specifically targeting. The performance criterion also factors whether the action provides a long term solution, or is just a short term fix.

The criterion for Performance is based on a scale from high to low, where high performance represents effectiveness of the action in addressing flood risks, and low performance represents low performance or uncertainty in the outcomes.

Practicality / Technical Feasibility

The practicality criterion considers how easy and practical the action will be to implement. If the action can be considered standard process for Council or other agencies with minimal delays and hurdles, then the practicality would be high. If there are some barriers or delays to the option being implemented, then the practicality would be lower. With reducing practicality, it is expected that the effort (and costs) required to implement the action would increase.

Table 7-8 Rapid Analysis Assessment Criteria

	LOW (STOP / reassess)	MEDIUM (SLOW)	HIGH (GO)
Performance	Action is not particularly effective over the short or longer terms	Action provides only a short-term fix, or is only partly effective over the long term	Action provides an effective long term solution to the risks identified
Practicality	Acton would be difficult to implement through existing constraints, approvals required etc. Would be very demanding to successfully implement	Action would have some hurdles for implementation, which may take longer and demand more effort to overcome.	Action is straightforward to implement with few barriers or uncertainties
Community Acceptability	Unlikely to be acceptable to the majority of the community and politically unpalatable. Significant championing required by Council and State.	Would be palatable to some, not to others. Briefing by Councillors, GM and community education required.	Is very politically palatable, acceptable to community. Minimal education required
Environmental Impacts	Likely to have significant adverse environmental impacts unable to be effectively managed	Likely to manageable environmental impacts through appropriate assessment and planning	No significant environmental impact identified. Environmental / ecological benefit through measure implementation
Costs / Resources	Very Expensive (more than $1,000,000) and/or very high (unmanageable) resource demands on authorities	Moderately expensive (e.g. $100,000 - $1,000,000) and/or high resource demands on authorities	Manageable costs (< $100,000) and manageable resource demands on authorities

Community Acceptance

The community acceptance criterion aims to reflect the general support for the action by the community as a whole. It is recognised that some actions may have a small section of the community that is most affected, however, it is the expected opinions of community at large that have been captured by this criterion.

Environmental Impacts

The environmental criterion aims to reflect the scale of potential impacts on the environment. Measures with major impacts are likely to trigger a requirement for formal environmental assessments (REF or EIS). Some measures may have a positive environmental effect (e.g. pollution prevention, habitat creation)

Costs / Resource Needs

Floodplain Risk Management actions can be inherently costly, especially when dealing with engineered works or property modifications. Planning controls are the exception to this, although these can still require significant effort from Council and others.

The Costs / Resource Needs criterion represents a rating wherein a High Rating reflects the lowest costs, while a Low Rating reflects the highest costs. This has been adopted for consistency with the other criteria.

The results of the Rapid Analysis are presented in Table 7-9. This table also gives a Total Score for each action. The score is calculated based on the following points system:

- All HIGH (go) criteria have a score of +1
- All MEDIUM (slow) criteria have a score of 0
- All LOW (stop and reassess) criteria have a score of -1.

The scoring in the rapid analysis provides some indication on the recommended prioritisation of the recommended measures. The higher scoring options typically have few barriers to implementation whilst providing effective floodplain risk management benefit.

Of note in the table are the lowest scoring options associated with the major works at the EMR. This is reflective of the relative scale and costs associated with the works and the considerable planning required for implementation of the options. Nevertheless, the performance of the measures in reducing flood risk to the Yenda community is unquestioned and accordingly is recommended to be pursued as a priority in association with the other measures.

Table 7-9 Assessment of Management Options

Performance	Performance	Practicality	Community Acceptability	Environmental	Costs/ Resources	Total Score
Structural Measures						
Yoogali Embankment and Structure Upgrades	HIGH	HIGH	HIGH	HIGH	MED	4
Main Drain J Structure Upgrades	LOW	MED	HIGH	HIGH	MED	1
Northern Branch Canal Raising	HIGH	MED	HIGH	HIGH	MED	3
Reinstatement of Decommissioned EMR	MED	LOW	HIGH	MED	MED	0
EMR Flood Gate Upgrade	HIGH	LOW	HIGH	MED	LOW	0
EMR Lawson Siphon	HIGH	LOW	HIGH	MED	LOW	0
Hanwood Local Drainage	MED	HIGH	HIGH	HIGH	MED	3
Main Drain 'J' Capacity Increase	MED	HIGH	HIGH	HIGH	MED	3
Planning and Development Controls						
Update Hydraulic Category Mapping	HIGH	HIGH	HIGH	HIGH	HIGH	5
Adopt Flood Planning Area Mapping	HIGH	HIGH	MED	HIGH	HIGH	4
Flood Warning and Emergency Response						
Investigate Flood Warning System	LOW	MED	HIGH	HIGH	MED	1
Update to Local Flood Plan and Emergency Response	HIGH	HIGH	HIGH	HIGH	HIGH	5
Investigate Emergency Breaching Protocols	MED	LOW	MED	MED	HIGH	0
Ongoing Community Education and Awareness	MED	HIGH	HIGH	HIGH	HIGH	4

8 Recommended Floodplain Management Plan

The Floodplain Risk Management Study and Plan (Flood Plan) has been developed to direct and co-ordinate the future management of flood prone lands across the Main Drain 'J' and Mirrool Creek catchment. It also aims to educate the community about flood risks across the study area, so that they can make more appropriate and informed decisions regarding their individual exposure and responses to flood risks. The Flood Plan sets out a strategy of short term and long term actions and initiatives that are to be pursued by agencies and the community in order to adequately address the risks posed by flooding.

Statutory responsibility for land use planning and management under the EP&A Act rests with Council. As part of their normal planning responsibilities, Council need to plan and manage flood prone land in accordance with its flood exposure. The State Emergency Service (SES) has formal responsibility for emergency management operations in response to flooding. Other organisations normally provide assistance, including the Bureau of Meteorology, Office of Environment and Heritage, Council, police, fire brigade, ambulance and community groups. Emergency management operations are usually outlined in a Local Flood Plan. Murrumbidgee Irrigation is also noted as a major stakeholder in on-going floodplain risk management in regards to infrastructure for both water supply and potential flood management.

Accordingly there are some shared responsibilities across a number of agencies in a Plan of this nature, requiring for an integrated and collaborative engagement of stakeholders.

8.1 Changes to Adopted Griffith Floodplain Management Plan

A key outcome of the current study is the review of the adopted Griffith Floodplain Management Plan in the context of changes in design flood behaviour established as part of the 2014 Flood Study. The summary table below replicates the measures in the Griffith FMP and the recommendation to retain, update or exclude the measure. Section 6 of the Floodplain Risk Management Study described the previous proposed measures and assessed the applicability of the option in view of updates to the Flood Study. Details of the updated measures are presented in Section 8.2.

Table 8-1 Summary of Reviewed Griffith Floodplain Management Plan (2011) Recommendations

No.	Description of Measure	Action for Plan Update
Floodplain Management Planning Recommendations		
PL1	Hydraulic Categories to be incorporated in updated LEP	update
PL2	Flood Clause to be incorporated in updated LEP	retain
PL3	Flood Planning Area map to be incorporated in updated LEP	update
PL4	Council adopt draft Flood Liable Lands Policy as its Flood Policy.	retain

No.	Description of Measure	Action for Plan Update
PL5	Council adopt draft On-site Stormwater Detention Policy.	retain
PL6	Council and MI adopt drainage channel ownership, maintenance and upgrade Memorandum of Understanding.	retain
PL7	Council & MI implement outcomes from the MoU	retain
PL8	Community Education and Flood Awareness Program for emergency response precincts	retain
PL9	Update Griffith Local Flood Plan to include evacuation centres for Yenda and Hanwood.	retain
PL10	Include flood warning data for Yoogali relative to Beelbangera and Yenda.	exclude
PL11	Investigate installation of automatic water level recorder in DC 'TJ'.	exclude
PL12	Investigate installation of real time rainfall gauge in the upper catchment.	retain
PL13	Review and update flood related information on Section 149 certificates as required	retain
PL14	Review the estimate of flood damages for the Main Drain 'J' floodplain	retain
Floodplain Management Structural Recommendations		
ST1	Implement Option S6 where the opportunity to share costs is available	update
ST2	Implement Option S7 where the opportunity to share costs is available	exclude
ST3	Implement works associated with Option S2 and Option S5 to reduce nuisance flooding in the Griffith CBD	retain
ST4	Undertake further studies of overland flow in the Griffith CBD aimed at managing run-off on a catchment wide basis	retain
ST5	Investigate additional structural options aim at reducing floodway extents within Yoogali	exclude
ST6	Review structural options for reduced catchment area	exclude

8.2 Recommended Measures

8.2.1 Yoogali Structural Works

The Yoogali structural works incorporate the construction of earth embankment/bund along Main Drain 'J', DC 605 'J' and DC 621 'J' to elevate existing bank levels. The bunding, which may be incorporating into channel bank profile, is designed to prevent spilling of floodwater form the channel which otherwise results in extensive flooding to Yoogali as experienced in March 2012. The proposed bunds have considered providing at least 1% AEP flow capacity in order to limit out of bank flows and provide greater flood immunity to the Yenda community. With appropriate freeboard provisions, the design flood immunity may be expected to be in excess of the 0.5% AEP design standard. Whilst having a relatively high capital cost, the corresponding reduction in flood damages provides a significant financial and social benefit.

A key component of the works includes the upgrade of existing cross drainage structures on DC 605 'J' at Yenda Road and Bosanquet Road. These structures are MI assets and currently adequately serve their design drainage function. It is recognised that upgrade of these structures for flood mitigation purposes are likely to be outside of current maintenance/replacement schedules. A shared responsibility has been noted between Council and Murrumbidgee Irrigation given the potential changes to the drainage channel. Reference can be made to the MoU developed to define Council's and Murrumbidgee Irrigation's responsibilities in regard to ownership, maintenance and upgrade of drainage channels.

Estimated Cost – **High ($0.5M)** Priority - **High**

8.2.2 Yenda Structural Works

The recommended structural works at Yenda consist of a staged upgrade of the existing capacity of the EMR flood relief structures supplemented with the raising and strengthening of the Northern Branch Canal as a formal levee protection.

An initial recommendation is made as an interim measure to reinstate the EMR flood gate structures to be fully operational. The decommissioning of the gates is considered to have reduced the relative flood protection afforded to the Yenda community from approximately a 2% AEP (1 in 50-year) flood standard to a 5% AEP (1 in 20-year flood) standard. The gates were in a decommissioned state during the March 2012 event, however, given the magnitude of this event estimated in the order of a 0.5% AEP (1 in 200-year), similar flood conditions would have been experienced in Yenda irrespective of the flood gate operation.

The reinstatement of the flood gates is subject to the stability and condition of the overall structure. A detailed condition assessment is required initially to determine the full scale of works required to reinstate the gates as an operable flood relief structure. Accordingly, the scale and costs of required works cannot be confirmed at this stage.

A longer term solution for the management of flooding in Yenda incorporates the upgrade of the existing EMR flood relief structure configuration to provide additional flow capacity, in association with the NBC bank raising. The structure upgrade is expected to provide for 50 to 100% increase in existing structure capacity, to accommodate the design discharges for up to the 1 % AEP to 0.5% AEP. There are potentially a number of suitable structural configurations including gate upgrades or a Lawson Siphon type arrangement. Murrumbidgee Irrigation is a major stakeholder in this regard and solutions will need to integrate into MI's ongoing operations. Recommendation is to progress preliminary design of preferred option including appropriate approvals and environmental assessments.

The recommended Yenda Structural Works is presented as a package of measures to be progressively implemented. This package of works includes:

- Northern Branch Canal Works – localised bank raising along the NBC to provide required design flood immunity relative to design standard of recommended EMR upgrades.

Estimated Cost – **Moderate ($500K)** Priority - **High**

- Reinstatement of Decommissioned Flood Gates – initially incorporates appropriate structural/condition assessments to establish the viability of a refurbished structure. A potential outcome of this investigation may be to proceed directly to a preliminary design of a full structure replacement as per the subsequent components of the proposed works package

  Note that this option initially only provides for feasibility assessment. Detailed design and construction costs, subject to option feasibility, are estimated to be in excess of $2M.

Estimated Cost – **Moderate ($200K)** Priority - **High**

- Preliminary Design of EMR Upgrade – progression through pre-feasibility design and identification of preferred configuration of EMR upgrade to preliminary design.
  - Technical support studies - e.g. survey, geotechnical, economic appraisal
  - Concept design and options assessment leading to preferred option
  - Environmental impact assessment
  - Planning Approvals

Estimated Cost – **Moderate ($600K)** Priority - **Medium**

- Detailed Design and Construction - progression of the preferred option through to detailed design and construction

Estimated Cost – **High ($10M+)** Priority - **Medium**

8.2.3 Hanwood Structural Works

Flooding in Hanwood largely occurs when Main Drain ‘J’ is running at capacity. The elevated water levels in Main Drain ‘J’ extend a backwater influence along DC ‘A’. The extent of the backwater flooding into Hanwood can be limited through the construction of a bund. The nature of earthworks required is similar to those presented for Yoogali.

The key elements of the proposed works include construction of earthen bund along the left bank alignment of DC ‘DA’ and DC ‘HANDEPOT’, provision of one-way flow structures on DC ‘0491D’ and DC ‘HANDEPOT’ (and any other drainage connections that might be present) to prevent Main Drain ‘J backflow, and installation of pumps or suitable alternative means on DC ‘0491D’ and DC ‘HANDEPOT’ to discharge local catchment runoff from behind the bund into DC ‘DA’.

Estimated Cost – **Moderate ($250K)** Priority - **Medium**

8.2.4 Main Drain ‘J’ Works

Channel works are proposed along the reach of Main Drain ‘J’ between Kidman Way and Walla Avenue to increase bank heights. Some low points in the bank profiles, particularly on the right bank, have been identified which result in spilling from the channel and inundation of floodplain areas. The bank works will increase the bank full capacity of Main Drain ‘J’ locally without need for extensive channel widening.

Estimated Cost – **Moderate ($250K)** Priority - **Medium**

8.2.5 Flood Warning

Whilst there are some existing rainfall stations and water level recorders in the catchment areas, there is currently no flood forecasting or warning system for water levels in flood conditions. This Plan recommends further investigation of the existing gauging network and strategic locations for new gauges in order to provide a more formal flood warning system. This would provide local reference points for the Griffith community as well as the SES to gauge the imminent flood risk, and respond accordingly.

An accurate, prompt warning system ensures that residents are given the best opportunity to remove their possessions and themselves from the dangers of floodwaters. The ultimate success of flood warning and emergency planning is closely linked to the effectiveness of issued warnings and the level of flood awareness throughout the community.

Flood warnings to residents can be issued by a variety of measures, from automated messaging to door knocking. The community would benefit from new and emerging means of mass communication of flood warnings and general improvement in access to flood information. The use of social media to enhance other warning dissemination channels should be considered further to supplement traditional methods such as media broadcasts, internet postings and door knocking.

Estimated Cost – **Low ($50K)** Priority - **Low**

8.2.6 Emergency Response

Information from the current floodplain management study and flood damages database will provide valuable data to enable specific catchment detail to be incorporated into the Local Flood Plan (LFP). Some flood intelligence data has been acquired through the experiences of the March 2012 event. The information provided by the FRMS will enable flood mapping to be updated and aid the SES in prioritising the areas in the Griffith LGA with the highest flood risk under Main Drain 'J' and Mirrool Creek catchment flooding. Whilst this is normally the responsibility of the SES, assistance could be offered through the floodplain management committee to assist in a review of the LFP.

The flood mapping and property database including property locations, floor levels will be provided to the SES for incorporation into existing systems and emergency management procedures.

Estimated Cost – **Low (staff costs)** Priority - **High**

8.3 Funding and Implementation

The timing of the implementation of recommended measures will depend on the available resources, overall budgetary commitments of Council and the availability of funds and support from other sources. It is envisaged that the FRM Plan would be implemented progressively over a 2 to 5 year time frame.

There are a variety of sources of potential funding that could be considered to implement the Plan. These include:

(1) Council funds;

(2) Murrumbidgee Irrigation funds;

(2) Section 94 contributions;

(3) State funding for flood risk management measures through the Office of Environment and Heritage; and

(4) State Emergency Service, either through volunteered time or funding assistance for emergency management measures.

State funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is likely to be available on a 2:1 (State:Council) basis. Although much of the FRM Plan may be eligible for Government assistance, funding cannot be guaranteed. Government funds are allocated on an annual basis to competing projects throughout the State. Measures that receive Government funding must be of significant benefit to the community. Funding is usually available for the investigation, design and construction of flood mitigation works included in the floodplain management plan.

As noted, a number of proposed measures incorporate works to MI infrastructure. Many of these works are likely to be outside of MI maintenance / replacement strategies given remaining design life of existing structures and current adequate condition and performance. Accordingly, it would be unreasonable that upgrade costs be borne by MI and funding arrangements as discussed above would be expected to be pursued.

8.4 Plan Review

The FRM Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include new flood events and experiences, legislative change, alterations in the availability of funding, or changes to the area’s planning strategies.

A thorough review every 5 years is warranted to ensure the ongoing relevance of the FRM Plan.

9 References

BMT WBM (2014) *Griffith Main Drain J and Mirrool Creek Flood Study*

Department of Water Resources River Management Branch (1994) *MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works Options on Floodway Lands*

Griffith City Council (2000) *Griffith Growth Strategy GS2030.*

NSW Government (2005) *Floodplain Development Manual.*

Patterson Britton and Partners (2006) *Griffith Flood Study*

Water Resources Commission (1978) *Guidelines for Mirrool Creek Floodplain Development Barellan to Yenda*

Water Studies (1992) *Griffith Flood Study*

WMA Water (2012) *Griffith CBD Overland Flow Study*

WMA Water (2013) *Griffith CBD Floodplain Risk Management Study and Plan*

WMA Water (2014) *SES Flood Intelligence Report, 2012*

Worley Parsons (2011) *Griffith Floodplain Risk Management Study and Plan*

Appendix A Design Flood Mapping

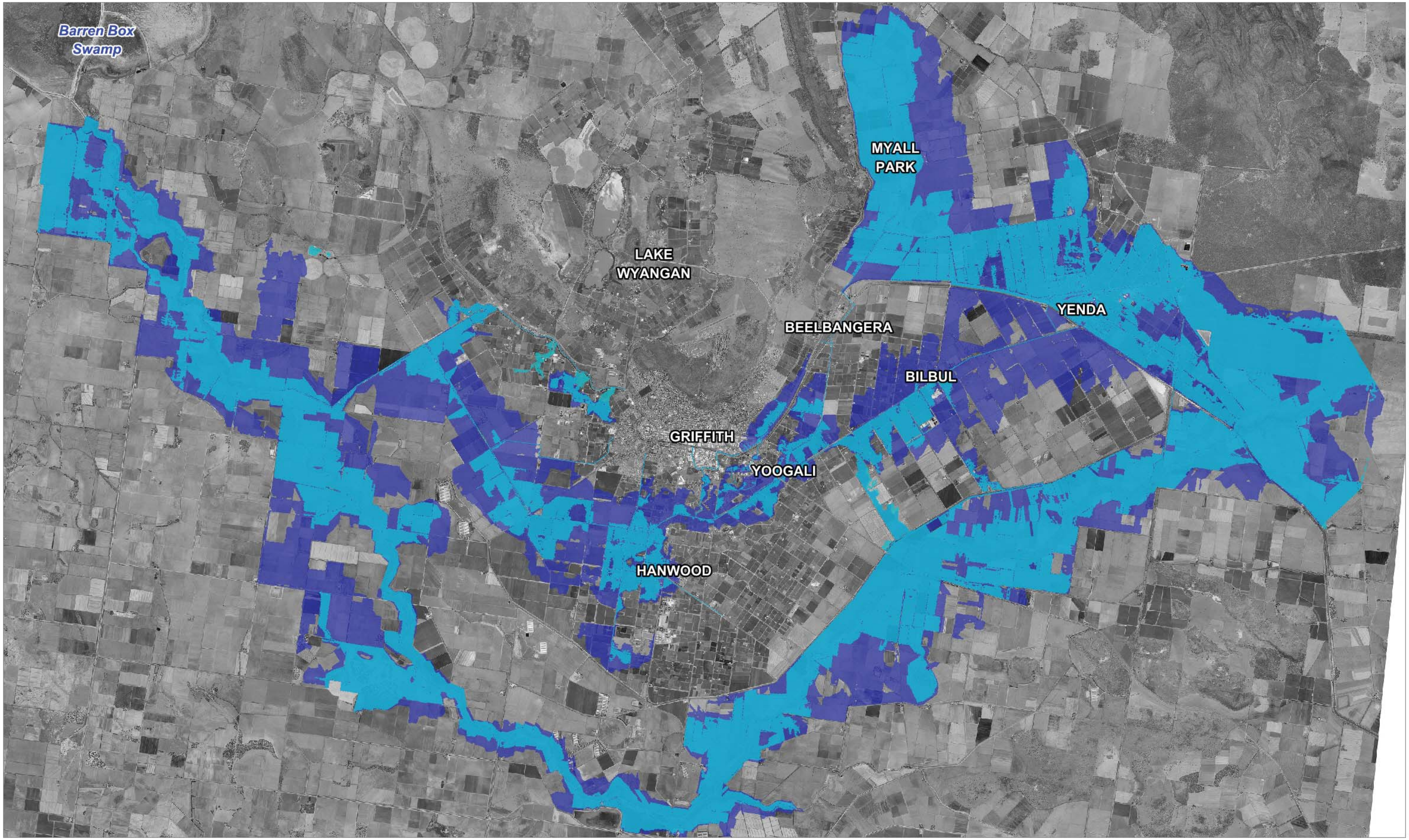
Existing Flood Conditions

- Flood Planning Area
- 1% AEP Flood Inundation Extent and Peak Flood Depth
- PMF Flood Inundation Extent and Peak Flood Depth
- 1% AEP Hydraulic Category
- 1% AEP Flood Hazard Category

Note: A single map coverage is provided for the study areas. Detailed mapping of localities is provided in Mapping Compendium of the Griffith Main Drain J and Mirrool Creek Flood Study, BMT WBM (2014).

Mitigated Flood Conditions for Yoogali and Yenda

- 0.5% AEP Flood Inundation Extent and Peak Flood Depth (Yoogali)
- 0.5% AEP Flood Inundation Extent and Peak Flood Depth (Yenda)



LEGEND

- 1% AEP Flood Extent
- Flood Planning Area

Title:
Griffith Main Drain J Catchment Flood Study
Flood Planning Area

Figure: **A-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 2.5 5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

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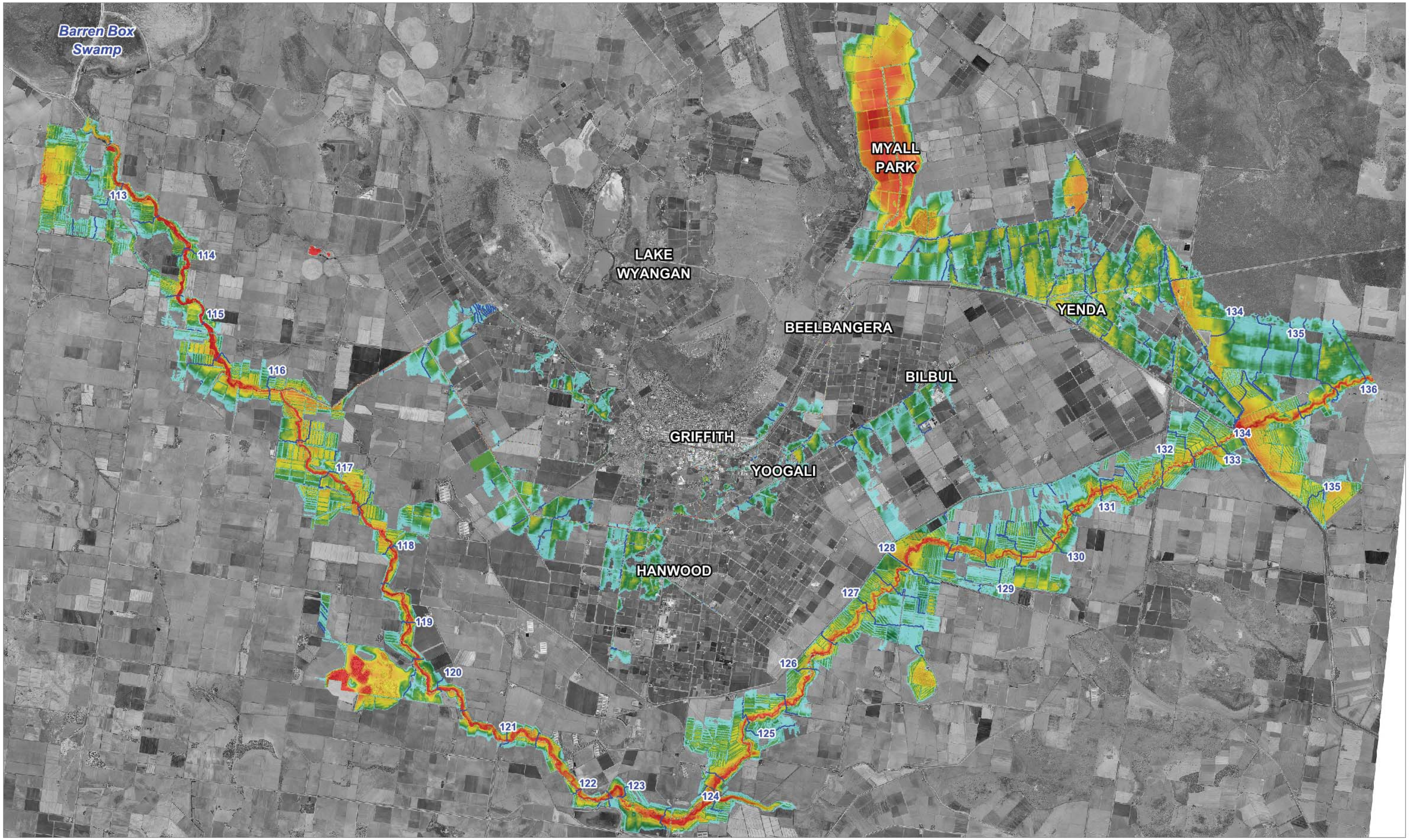

LEGEND

Peak Flood Depth (m)
- 0.10 lower depths mapped as same colour
- 0.25
- 0.50
- 1.00
- 1.50 higher depths mapped as same colour

20 Peak Flood Level Contours (m AHD)

Title:
Griffith Main Drain J Catchment Flood Study 1% AEP Modelled Peak Flood Conditions

Figure: A-2

Rev: A

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Approx. Scale

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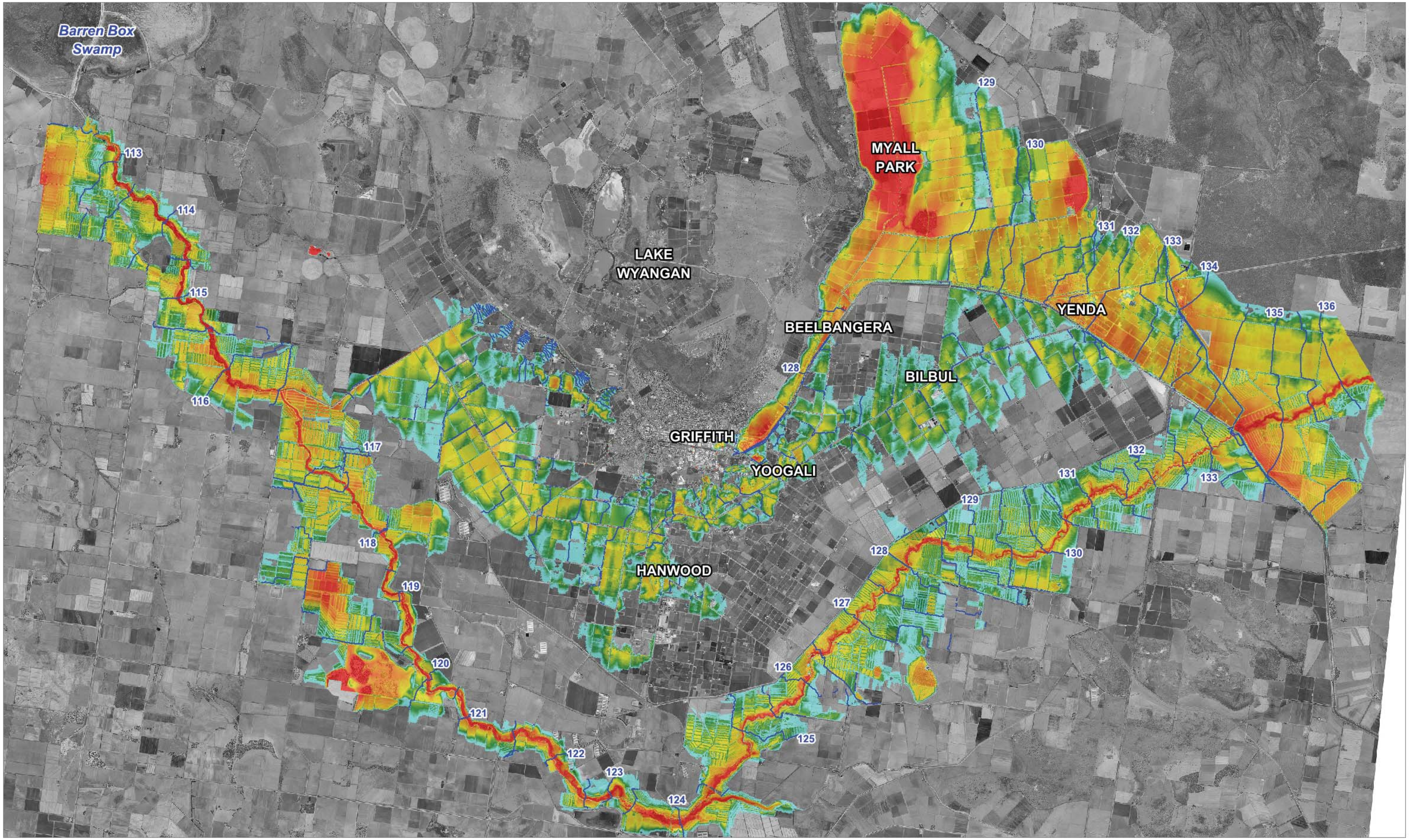

LEGEND

Peak Flood Depth (m)

- 0.10 lower depths mapped as same colour
- 0.25
- 0.50
- 1.00
- 1.50 higher depths mapped as same colour

20 Peak Flood Level Contours (m AHD)

Title:

Griffith Main Drain J Catchment Flood Study PMF Modelled Peak Flood Conditions

Figure: **A-3**

Rev: **A**

N

0 2.5 5km

Approx. Scale

BMT WBM

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Filepath : K:\N20024_Main_Drain_J_Mirrool_Ck_FRMS\MapInfo\Workspaces\DRG_803_150331_PMF_Results.WOR

LEGEND

Flood Categorisation

- Flood Fringe
- Flood Storage
- Floodway

Title:

Griffith Main Drain J Catchment Flood Study 1% AEP Provisional Flood Categorisation

Figure: **A-4**

Rev: **A**

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Approx. Scale

BMT WBM

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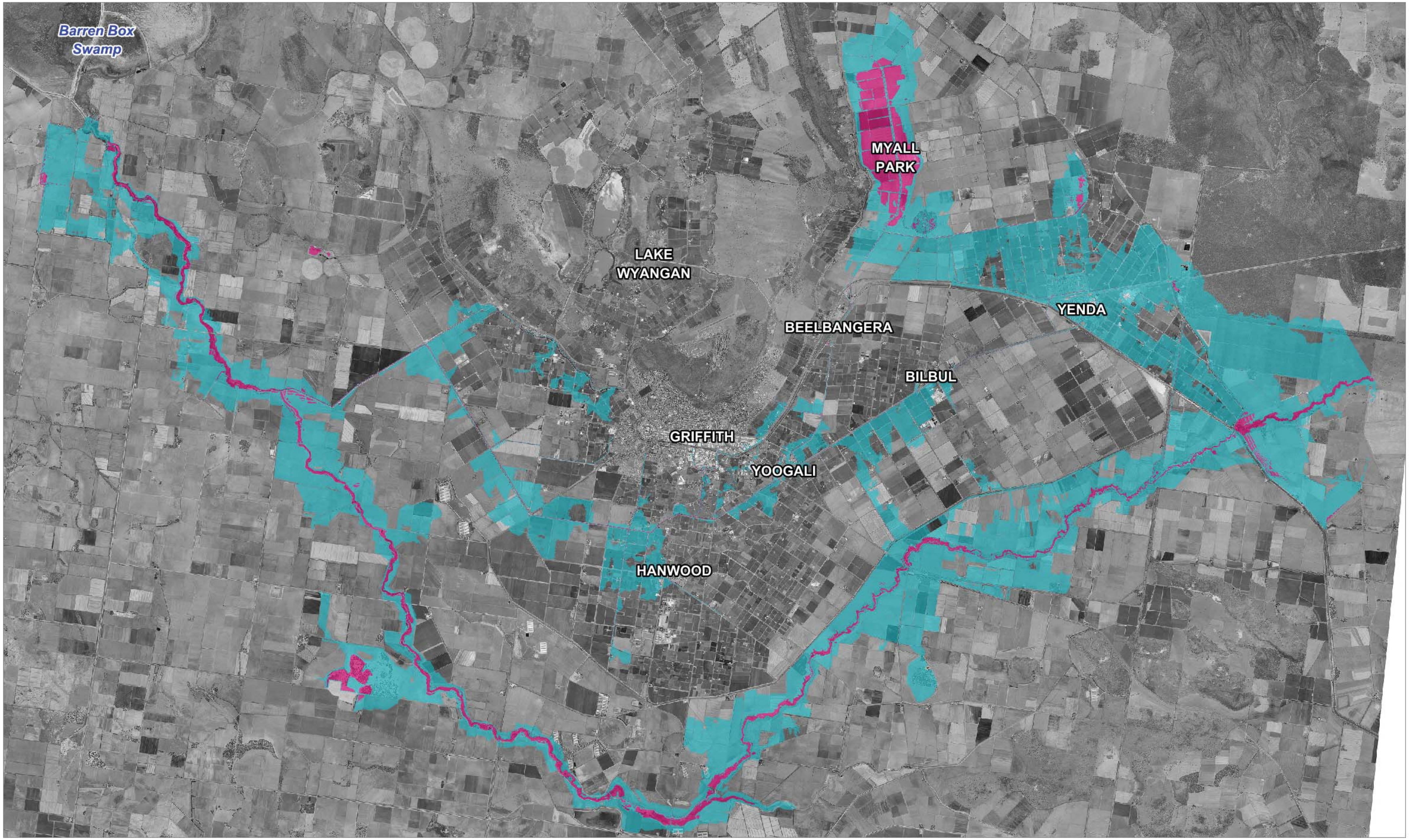

LEGEND

Flood Hazard Classification

- Low Hazard
- High Hazard

Title:

Griffith Main Drain J Catchment Flood Study 1% AEP Provisional Flood Hazard - Overview

Figure: **A-5**

Rev: **A**

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N

0 2.5 5km

Approx. Scale

BMT WBM

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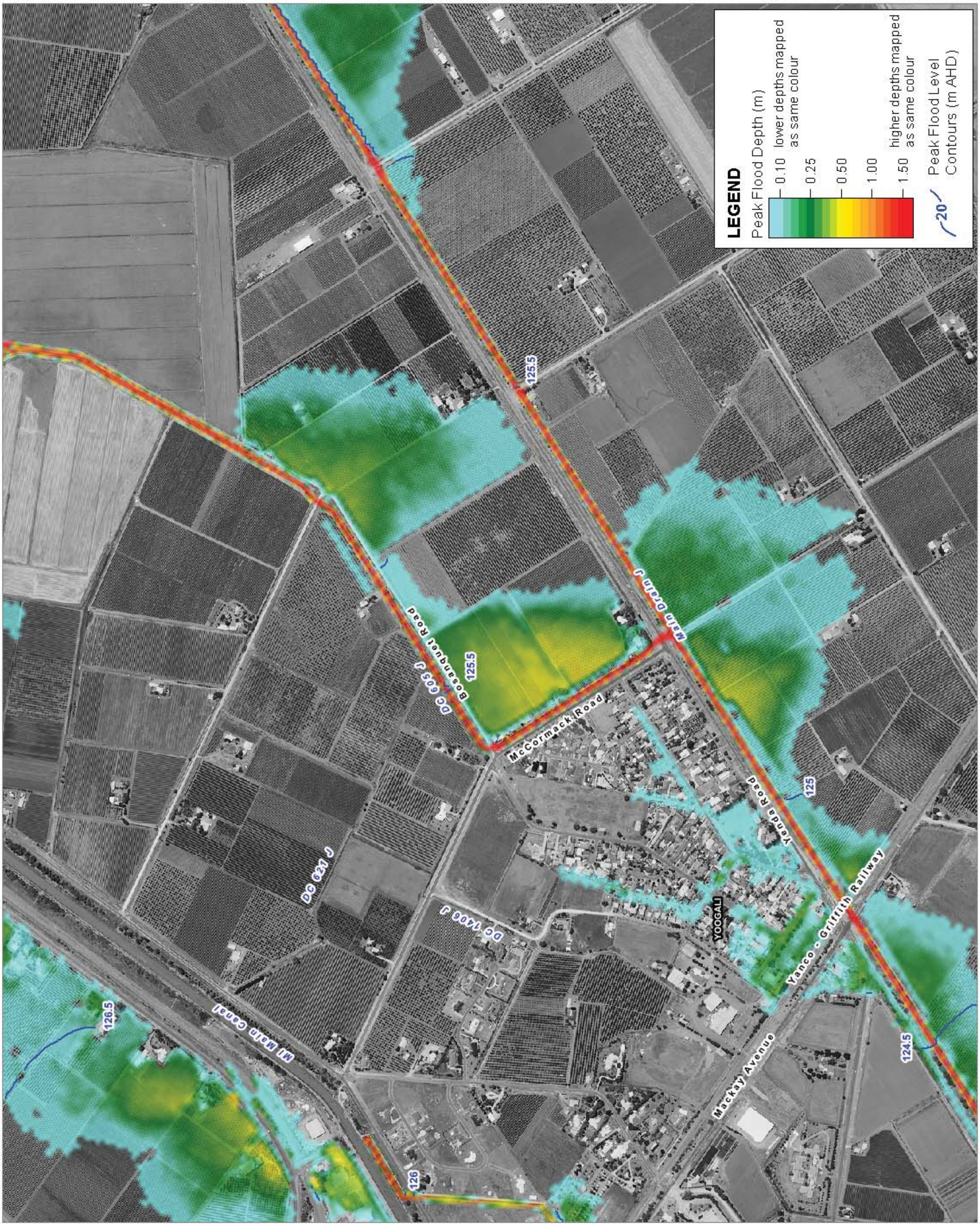

Title:

Yoogali Mitigation Options - Mitigated Flood Conditions 0.5% AEP Event McCormack Road Levee + Culvert Upgrade

Figure: **A-6**

Rev: **A**

N

0 200 400m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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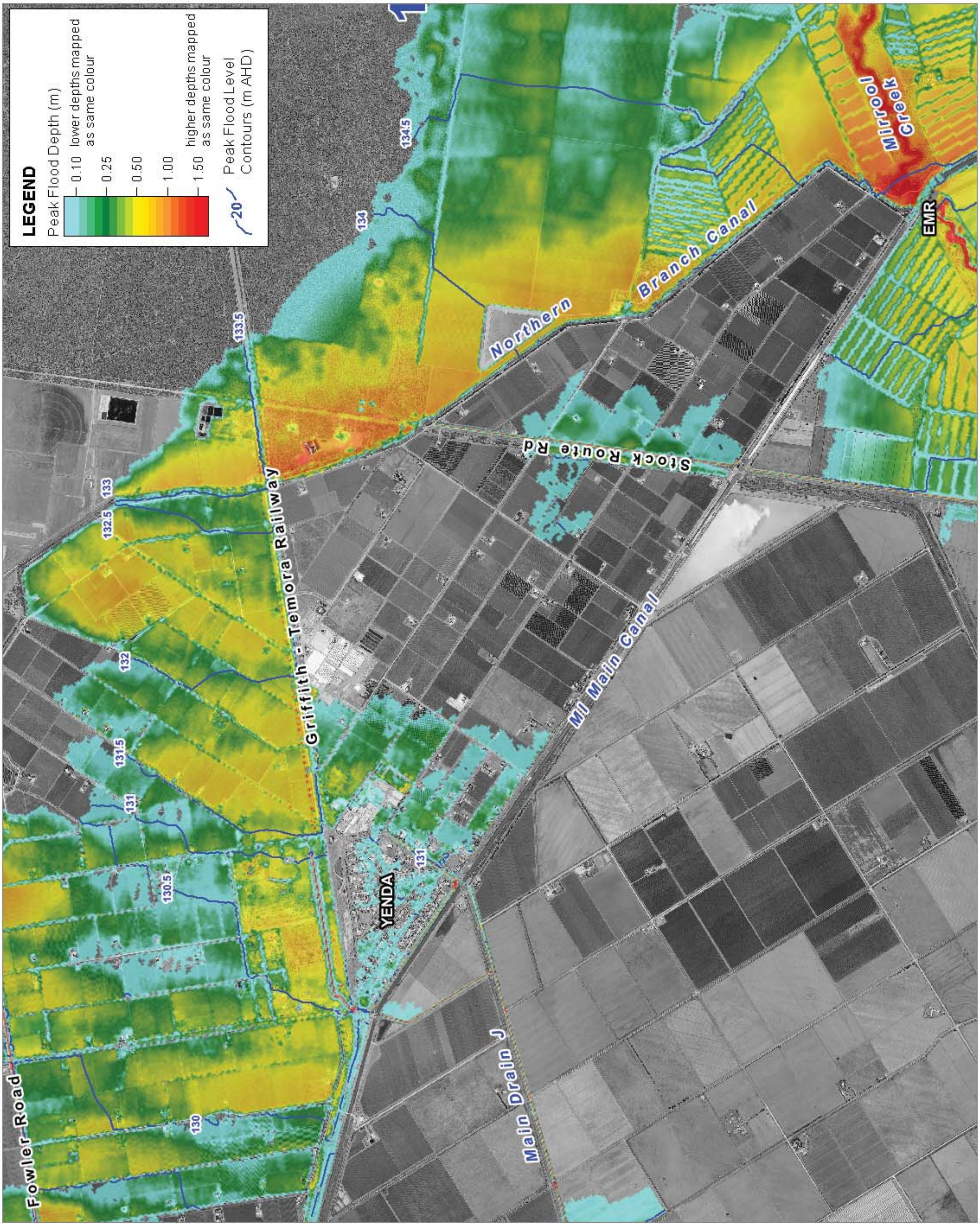


Title:
Yenda Mitigation Options - Mitigated Flood Conditions 0.5% AEP Event Northern Branch Canal Levee

Figure: A-7

Rev: A

N

0 0.75 1.5 km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath :K:\N20024_Main_Drain_J_Mirrool_Ck_FRMS\MapInfo\Workspaces\DRG_059_150518_0.5%AEP_Yenda_Mitigation.WOR

Appendix B Flood Damages Assessment Inputs

Residential Property Damage Curves

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT						
Version 1.00			Queries to duncan.mcluckie@dipnr.nsw.gov.au			
PROJECT	DETAILS			DATE	JOB No.	
BUILDINGS						
Regional Cost Variation Factor	1.00	From Rawlinsons				
Post late 2001 adjustments	1.66	Changes in Avge Weekly Earnings - www.abs.gov.au				
Post Flood Inflation Factor	1.40	1.0	to	1.5		
Multiply overall structural costs by this factor		Judgement to be used. Some suggestions below				
	Regional City			Regional Town		
	Houses Affected		Factor	Houses Affected		Factor
Small scale impact	<	50	1.00	<	10	1.00
Medium scale impacts in Regional City		100	1.20		30	1.30
Large scale impacts in Regional City	>	150	1.40	>	50	1.50
Typical Duration of Immersion	48	hours				
Building Damage Repair Limitation Factor	0.85	due to no insurance short duration flood long duration flood				
		Suggested range		0.75	to	0.85
Average House Size	240	m^2	240	m^2 is Base		
Building Size Adjustment	1.0					
Total Building Adjustment Factor	**1.98**					
CONTENTS						
Average Contents Relevant to Site	$ 60,000		Base for 240 m^2 house		$ 60,000	
Post late 2001 adjustments	1.66	From above				
Contents Damage Repair Limitation Factor	0.85	due to no insurance short duration flood long duration flood				
Sub-Total Adjustment Factor	0.85	Suggested range		0.75	to	0.85
Level of Flood Awareness	high	low or high only. Low default unless otherwise justifiable.				
Effective Warning Time	6	hour				
Interpolated DRF adjustment (Awareness/Time)	0.67					
Typical Table/Bench Height (TTBH)	0.90	0.9m is typical height. If typical is 2 storey house use 2.6m.				
Total Contents Adjustment Factor AFD <= TTBH	**0.57**					
Total Contents Adjustment Factor AFD > TTBH	**0.85**					
Most recent advice from Victorian Rapid Assessment Method						
Low level of awareness is expected norm (long term average) any deviation needs to be justified.						
Basic contents damages are based upon a DRF of	0.9					
Effective Warning time (hours)	0	3	6	12	24	
RAM AIDF Inexperienced (Low awareness)	0.90	0.80	0.80	0.80	0.70	
DRF (ARF/0.9)	1.00	0.89	0.89	0.89	0.78	
RAM AIDF Experienced (High awareness)	0.80	0.80	0.60	0.40	0.40	
DRF (ARF/0.9)	0.89	0.89	0.67	0.44	0.44	
Site Specific DRF (SRF/0.9) for Awareness level for iteration	0.89	0.89	0.67	0.44	0.44	
Effective Warning time (hours)	6	12	6			
Site Specific iterations	0.67	0.44	0.67			
ADDITIONAL FACTORS						
Post late 2001 adjustments	1.66	From above				
External Damage	$ 6,700	$6,700 recommended without justification				
Clean Up Costs	$ 4,000	$4,000 recommended without justification				
Likely Time in Alternate Accommodation	2	weeks				
Additional accommodation costs /Loss of Rent	$ 220	$220 per week recommended without justification				
TWO STOREY HOUSE BUILDING & CONTENTS FACTORS						
Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground		
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground		
Base Curves		AFD = Above Floor Depths				
Single Storey Slab on Ground/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-1.50	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Residential Property Damage Curves

Single Storey Slab on Ground/Low Set			Single Storey High Set			2 Storey Houses		
Static AFD	AFD + Wave Action	Damage	Static AFD	AFD + Wave Action	Damage	Static AFD	AFD + Wave Action	Damage
-0.50	-0.50	$ -	-1.50	-1.50	$ -	-0.50	-0.50	$ -
-0.40	-0.40	$ -	-1.40	-1.40	$ -	-0.40	-0.40	$ -
-0.30	-0.30	$ -	-1.30	-1.30	$ -	-0.30	-0.30	$ -
-0.20	-0.20	$ -	-1.20	-1.20	$ -	-0.20	-0.20	$ -
-0.10	-0.10	$ -	-1.10	-1.10	$ -	-0.10	-0.10	$ -
0.00	0.00	$ 2,000	-1.00	-1.00	$ 2,000	0.00	0.00	$ 2,000
0.10	0.10	$ 2,000	-0.90	-0.90	$ 2,000	0.10	0.10	$ 2,000
0.20	0.20	$ 2,000	-0.80	-0.80	$ 2,000	0.20	0.20	$ 2,000
0.30	0.30	$ 62,116	-0.70	-0.70	$ 33,579	0.30	0.30	$ 46,818
0.40	0.40	$ 64,211	-0.60	-0.60	$ 35,051	0.40	0.40	$ 48,285
0.50	0.50	$ 66,307	-0.50	-0.50	$ 36,524	0.50	0.50	$ 49,751
0.60	0.60	$ 68,402	-0.40	-0.40	$ 37,996	0.60	0.60	$ 51,218
0.70	0.70	$ 70,498	-0.30	-0.30	$ 39,468	0.70	0.70	$ 52,685
0.80	0.80	$ 72,593	-0.20	-0.20	$ 40,941	0.80	0.80	$ 54,152
0.90	0.90	$ 74,689	-0.10	-0.10	$ 42,413	0.90	0.90	$ 55,619
1.00	1.00	$ 88,118	0.00	0.00	$ 68,256	1.00	1.00	$ 65,019
1.10	1.10	$ 90,780	0.10	0.10	$ 71,428	1.10	1.10	$ 66,883
1.20	1.20	$ 93,442	0.20	0.20	$ 74,601	1.20	1.20	$ 68,746
1.30	1.30	$ 96,104	0.30	0.30	$ 77,773	1.30	1.30	$ 70,610
1.40	1.40	$ 98,766	0.40	0.40	$ 80,946	1.40	1.40	$ 72,473
1.50	1.50	$ 101,429	0.50	0.50	$ 84,118	1.50	1.50	$ 74,337
1.60	1.60	$ 104,091	0.60	0.60	$ 87,290	1.60	1.60	$ 76,200
1.70	1.70	$ 106,753	0.70	0.70	$ 90,463	1.70	1.70	$ 78,064
1.80	1.80	$ 109,415	0.80	0.80	$ 93,635	1.80	1.80	$ 79,927
1.90	1.90	$ 112,077	0.90	0.90	$ 96,807	1.90	1.90	$ 81,791
2.00	2.00	$ 114,740	1.00	1.00	$ 99,980	2.00	2.00	$ 83,654
2.10	2.10	$ 115,702	1.10	1.10	$ 103,152	2.10	2.10	$ 84,328
2.20	2.20	$ 116,664	1.20	1.20	$ 106,325	2.20	2.20	$ 85,001
2.30	2.30	$ 117,626	1.30	1.30	$ 109,497	2.30	2.30	$ 85,675
2.40	2.40	$ 118,588	1.40	1.40	$ 112,669	2.40	2.40	$ 86,348
2.50	2.50	$ 119,550	1.50	1.50	$ 115,842	2.50	2.50	$ 87,022
2.60	2.60	$ 120,513	1.60	1.60	$ 119,014	2.60	2.60	$ 87,695
2.70	2.70	$ 121,475	1.70	1.70	$ 122,187	2.70	2.70	$ 132,510
2.80	2.80	$ 122,437	1.80	1.80	$ 125,359	2.80	2.80	$ 133,568
2.90	2.90	$ 123,399	1.90	1.90	$ 128,531	2.90	2.90	$ 134,627
3.00	3.00	$ 124,361	2.00	2.00	$ 131,704	3.00	3.00	$ 135,685
3.10	3.10	$ 125,323	2.10	2.10	$ 133,176	3.10	3.10	$ 136,744
3.20	3.20	$ 126,286	2.20	2.20	$ 134,648	3.20	3.20	$ 137,802
3.30	3.30	$ 127,248	2.30	2.30	$ 136,121	3.30	3.30	$ 138,860

Commercial Property Damage Curves

Depth	Shops and small retailers			Industrial properties				
above	up to approx. 200m square			Between approx. 200m and 600m square			Large Commercial & Industrial	
work	CODE	CODE	CODE	CODE	CODE	CODE	CODE	CODE
area	CL	CM	CH	IL	IM	IH	L1	L2
(m)	offset =	offset =	offset =	offset =	offset =	offset =	offset =	offset =
	1	2	3	4	5	6	7	8
-999999	$0	$0	$0	$0	$0	$0	$0	$0
0	$0	$0	$0	$0	$0	$0	$0	$0
0.01	$580	$3,480	$6,670	$4,930	$10,150	$20,300	$29,000	$406,000
0.05	$3,480	$8,700	$15,080	$13,340	$25,230	$50,460	$203,000	$609,000
0.1	$6,670	$15,080	$30,160	$25,230	$50,460	$100,920	$203,000	$609,000
0.2	$14,500	$29,000	$60,900	$49,300	$101,500	$203,000	$609,000	$609,000
0.25	$20,300	$37,700	$75,400	$60,900	$118,900	$234,900	$667,000	$609,000
0.3	$23,200	$43,500	$84,100	$66,700	$133,400	$269,700	$783,000	$609,000
0.4	$29,000	$55,100	$109,330	$84,100	$168,200	$336,400	$841,000	$638,000
0.5	$31,900	$66,700	$133,400	$101,500	$203,000	$403,100	$870,000	$667,000
0.6	$37,700	$78,300	$150,800	$118,900	$234,900	$469,800	$1,015,000	$667,000
0.7	$42,050	$89,030	$174,870	$141,230	$269,120	$538,240	$1,131,000	$725,000
0.75	$49,300	$101,500	$185,600	$150,800	$287,100	$571,300	$1,189,000	$754,000
0.8	$50,750	$104,400	$195,170	$158,050	$302,760	$605,520	$1,363,000	$754,000
0.9	$52,200	$107,300	$217,500	$168,200	$336,400	$672,800	$1,682,000	$841,000
1	$58,000	$118,900	$234,900	$185,600	$371,200	$722,100	$2,030,000	$1,015,000
1.1	$62,350	$126,150	$252,300	$195,170	$397,010	$783,870	$4,060,000	$841,000
1.2	$66,700	$133,400	$269,700	$203,000	$420,500	$841,000	$5,916,000	$1,015,000
1.25	$69,600	$142,100	$287,100	$217,500	$437,900	$875,800	$6,757,000	$1,537,000
1.3	$70,470	$145,000	$289,420	$222,140	$443,990	$884,500	$7,105,000	$1,624,000
1.4	$71,340	$147,900	$295,800	$228,810	$457,620	$904,800	$8,120,000	$1,827,000
1.5	$72,500	$150,800	$301,600	$234,900	$469,800	$925,100	$8,468,000	$2,030,000
1.75	$78,300	$159,500	$319,000	$252,300	$487,200	$974,400	$8,468,000	$5,916,000
2	$84,100	$168,200	$336,400	$269,700	$504,600	$1,009,200	$8,468,000	$8,468,000
3	$87,000	$174,000	$348,000	$275,500	$507,500	$1,015,000	$8,468,000	$8,468,000
9999999	$87,000	$174,000	$348,000	$275,500	$507,500	$1,015,000	$8,468,000	$8,468,000

Codes: CL – Commercial Low Value, CM – Commercial Medium Value, CH – Commercial High Value

IL – Industrial Low Value, IM – Industrial Medium Value, IH – Industrial High Value

L1 – Large Industrial / Commercial Medium Value, L2 – Large Industrial / Commercial High Value

Appendix C Structural Option Concept Designs

C.1 Yoogali Levee

C.1.1 Description of Works

The proposed works as discussed in Section 7.2 and presented in the general arrangement shown in Figure C1 incorporates:

- Construction of approximately 1km length of levee along McCormack Road from Main Drain ‘J’ to beyond Newman Road. The levee alignment runs along the southern bank of DC 605J from the confluence with Main Drain ‘J’ to the McCormack Road / Bosanquet Road intersection. The alignment continues further along McCormack Road on the southern bank of DC 621J beyond Newman Road and the confluence with DC 1406J. The proposed levee is of constructed earth embankment with a typical height of 0.3m to 0.5m above natural surface. The design crest level of the embankment varies according to location along the drainage canal in accordance with peak flood level profiles.
- Upgrade of existing pipe culverts on DC605J at Bosanquet Road and Yenda Road (discharging to Main Drain ‘J’). Existing culverts are twin 1650mm diameter pipes. Proposed structures are minimum 2 x 2.4m x 1.8m box culverts, although clear span bridge units are an alternative design providing further increase in design capacity. The typical section of DC 605J in these locations has a base width of some 5m and depth to top of bank of some 2.4m.

The flood depth and inundation extents shown in Figure C1 represent the existing design 0.5% AEP flood condition (pre-mitigation).

C.1.2 Hydraulic Performance / Flood Impacts

The hydraulic performance of the proposed works in terms of flood mitigation function and potential impacts are summarised below:

- The intended function of the levee is the control of floodwaters spilling from the DC 605J and DC 621J across McCormack Road and through to the township of Yoogali. The localised spilling across McCormack is characterised by relatively shallow depths of flow (as experienced in March 2012) such that only relatively modest levee height is required (<0.3m). Figure C1 includes the simulated peak 0.5% AEP flood depths (similar to March 2012 event magnitude) confirming the relatively shallow depths of flow at critical spill points. The levee provides effective control of spilling across Main Drain ‘J’ and therefore affording the required flood protection to Yoogali township (>0.5% AEP flood standard).
- The retention of floodwater behind the levee (that would flow through to Yoogali under existing conditions) provides for increases in peak flood levels to lots on the northern side of McCormack Road. Additional flow capacity in DC 605J somewhat alleviates this impact by providing more effective discharge to the Main Drain ‘J’. However, increases of flow to Main Drain ‘J’ from the DC 605J system provides some further impacts in terms of increased spilling of floodwaters on the right bank of Main Drain ‘J’.
- Flows through the DC 605J system are already limited via the Collina siphons. However, the flow constriction provided by the existing culverts on DC 605J limit the in-bank flow capacity resulting in spilling from the channel in major flood events (1% AEP event and above). The

provision of culvert upgrades increases peak discharge capacity to Main Drain 'J' offsetting the retention of floodwaters behind the levee.

C.1.3 Design Constraints / Issues

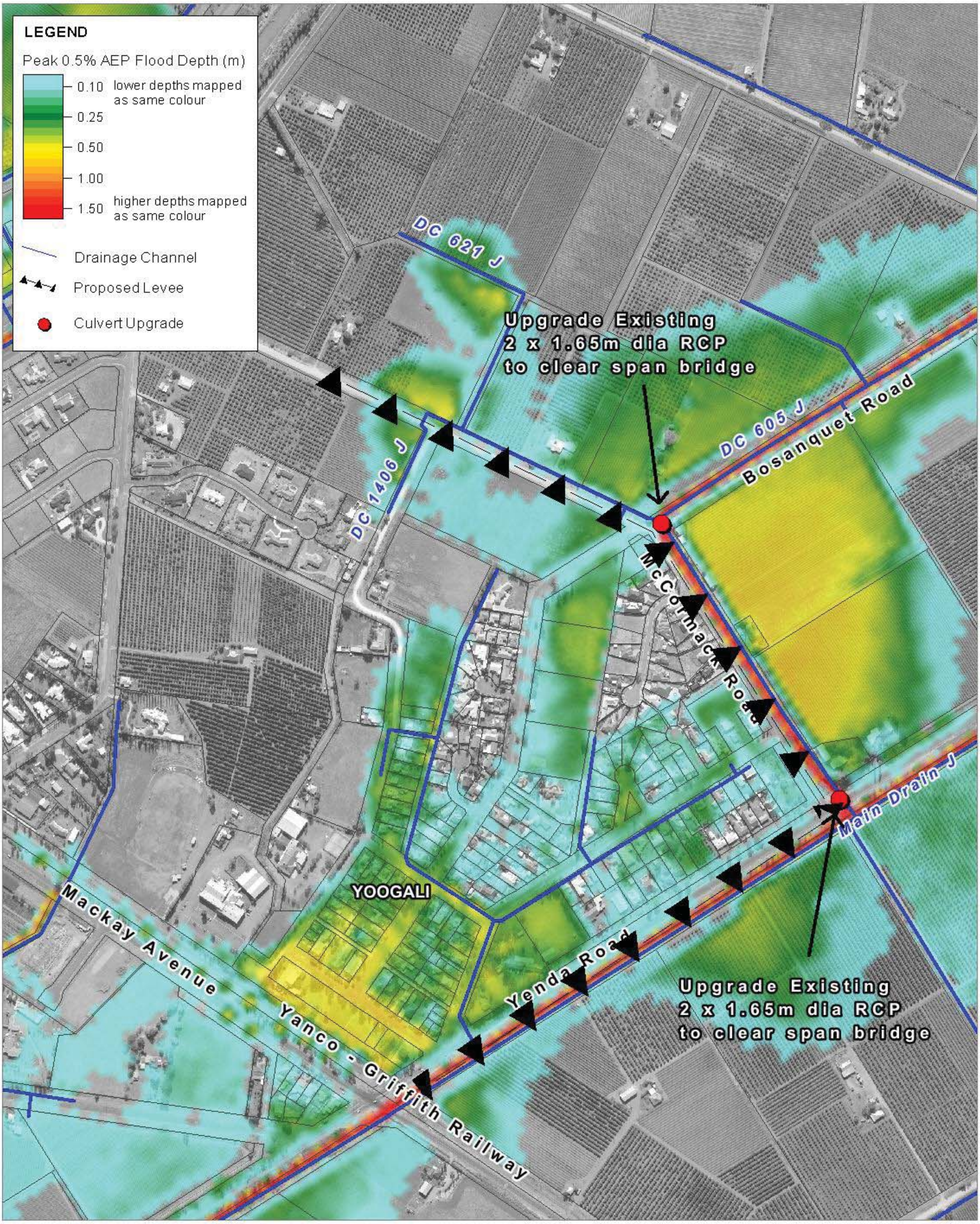
Key design constraints and construction issues for the proposed works are identified as:

- The levee alignment traverses across Bosanquet Road at the intersection with McCormack Road. In order to maintain the levee integrity, localised road raising or traffic hump may need to be incorporated into the road profile.
- Similar to Bosanquet Road, there are two accesses to private property from McCormack Road that traverse the DC 605J and DC 621J channels. Appropriate local modification to the accesses may be required to again ensure the full bank height protection afforded by the levee.
- The culvert structure across Yenda Road discharging to Main Drain 'J' may need to incorporate appropriate one way flap gates to prevent backwater inflows into DC 605J from elevated Main Drain 'J' levels.
- The works impact on both existing Council and Murrumbidgee Irrigation infrastructure.

C.1.4 Environmental Impacts

The following environmental concerns or impacts have been identified to be addressed in the approvals and design phases of the works:

- There are no significant environmental constraints identified for the proposed works. Normal construction safeguards, such as erosion and sediment control plans, would be appropriate for the works.



Title:

Yoogali McCormack Road Levee and DC605J Culvert Upgrade

Figure: C-1

Rev: A

N

0 200 400m

Approx. Scale

BMT WBM

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C.2 EMR Flood Escape Upgrade

C.2.1 Description of Works

The proposed works as discussed in Section 7.2.2 and presented in the general arrangement shown in Figure C2 incorporates:

- Construction of new flood relief structure at the East Mirrool Regulator as a replacement of the existing structure. The existing five bay and eight bay flood check in the northern and southern bank of the Main Canal respectively is proposed to be replaced with 9 bay 2.4 x 1.8m gated structure (or similar) on each bank. There may be a number of alternative structure arrangements including bay dimensions and gate types which would be determined at preliminary design phase. The structure as proposed in the concept design provides for the required flow capacity under flood operations in which both the northern and southern bank structures are fully open to pass Mirrool Creek floodwaters across the Main Canal.
- Scour protection works at the structure inlets/outlets are provided to protect the receiving channel/floodplain from excessive erosion. Flow through the structures provides for concentrated high velocity discharge of Mirrool Creek floodwater (and Main Canal flows in certain operations) at the structure inlet and outlet.
- Channel modification works are required both upstream and downstream of the structure to provide appropriate transition of flow to the existing channel/floodplain of Mirrool Creek. Similar channel transitions exist for the existing structures, however, with a proposed widening of the structure additional channel modification is required.
- Raising and strengthening of the right bank of the Northern Branch Canal to increase the level of overtopping providing for an effective levee protection. Note that the NBC embankment is already elevated above the natural ground surface thereby providing some levee type protection to Yenda under existing conditions. The works may involve a length of some 4km (of the total 6km from the EMR to the Griffith-Temora Railway) with bank raising typically less than 0.5m required. Bank raising of this order may be undertaken by placement of compacted fill (of appropriate material) on the existing embankments.

C.2.2 Hydraulic Performance / Flood Impacts

The hydraulic performance of the proposed works in terms of flood mitigation function and potential impacts are summarised below:

- The design of the flood gate structures is to provide a nominal flow capacity to discharge Mirrool Creek floodwater across the Main Canal. Under existing conditions, the maximum headwater level at the structure before flow diversion towards Yenda is initiated is 134.3m AHD. This flow to Yenda is initiated via overtopping of the NBC at localised low points. The top of bank elevation of the Main Canal at the existing flood relief structures is some 134.8m AHD. Accordingly, the NBC bank raising proposed as part of the works provides for a similar maximum headwater level.
- Table 7-3 provided a summary of the performance of the flood gate upgrade with the NBC levee works. The proposed structure provides for a discharge capacity of the order of 140m^3/s (0.5% AEP) at a design peak headwater level of ~134.5m AHD. This provides for an effective

freeboard of some 0.3m to overtopping of the Main Canal and the NBC. Accordingly the proposed structure provides for a nominal 0.5% AEP design capacity and equivalent standard of protection to the Yenda township.

- Flows are still passed through to North Yenda via flow around the NBC and overtopping of the Griffith-Temora railway. Whilst there is some concentration of flow at this location over the railway, the nominal upgraded structure capacity provides for most flow to be transferred to the Mirrool Creek floodplain downstream.
- The increase in flow to the Mirrool Creek floodplain downstream of the structure provides for increase in peak flood water level for the inundated floodplain areas beyond the confluence with Main Drain J. Whilst covering an extensive area, the magnitude of the flood level impacts are typically of the order of 0.1m – 0.2m for the 1% AEP and 0.5% AEP events.

C.2.3 Design Constraints / Issues

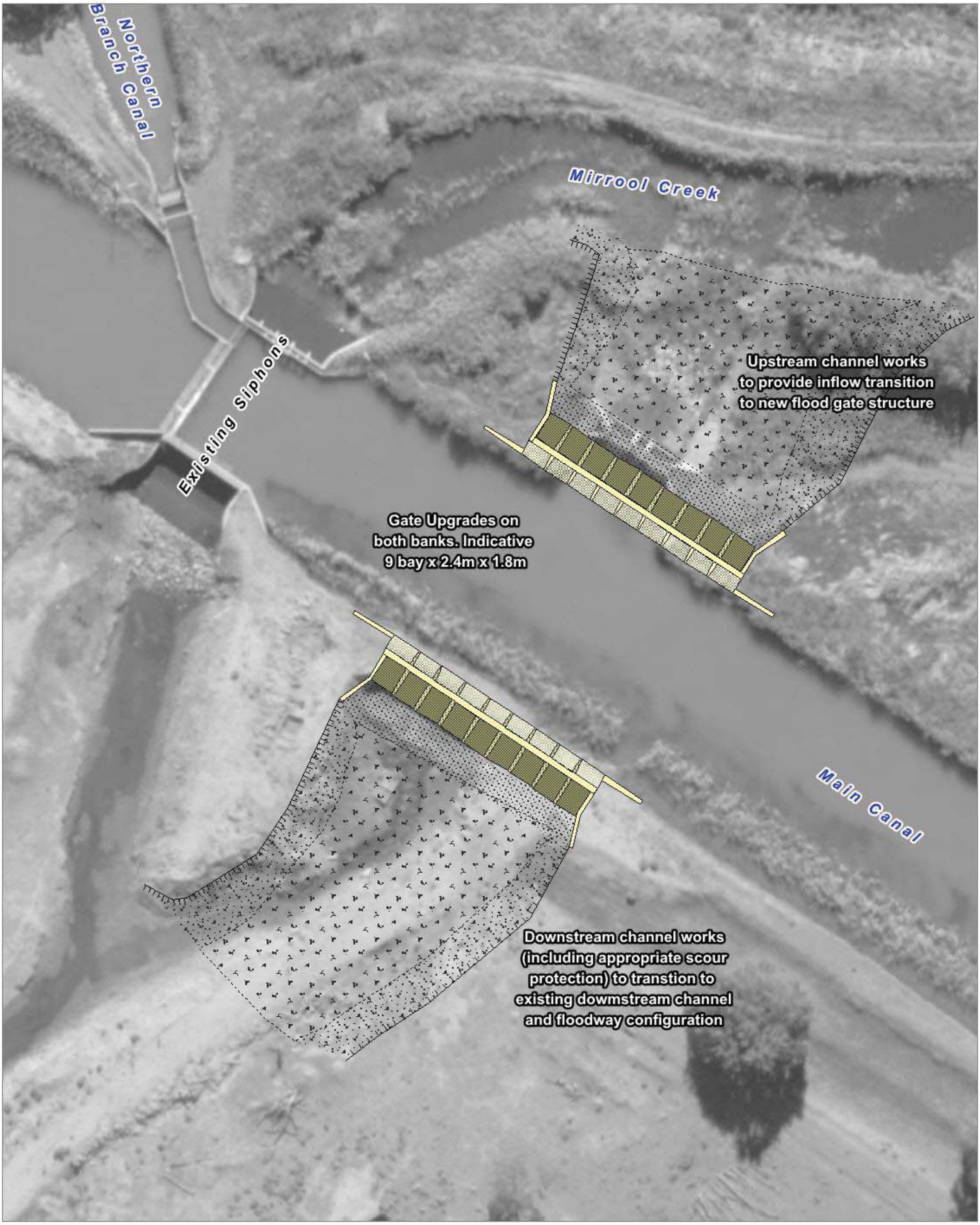
Key design constraints and construction issues for the proposed works are identified as:

- Murrumbidgee Irrigation is one of the major stakeholders in any future upgrade works. MI's ongoing operations represent one of the major constraints within design of upgrade options with consideration of construction phase impacts and potential disruption to MI business and impacts to customers, integrating works within the existing operational supply system, and maintenance and operational responsibilities.
- The works would become an integral component of Murrumbidgee Irrigation’s infrastructure including the operation of the gates for flood mitigation purposes. Operational procedures and protocols for flood operations would need to be developed, including clear identification of responsibilities and the interaction with other flood emergency response agencies under appropriate disaster management plans (e.g. Local Flood Plan).
- In the context of the above, the nominal flood gate arrangement presented represents a single option considered only in terms of design discharge capacity. Alternative arrangements/designs would be expected that offer a more suitable design solution considering other design constraints. These alternative solutions have limited impact on the Floodplain Risk Management Plan recommendations provided a similar design capacity is provided ensuring the key outcomes in terms of Yenda flood risk protection is maintained.
- Although the proposed raising of the NBC does not require major increases in bank height, there are numerous accesses and other irrigation infrastructure that need to be considered. The detail of the integration of existing infrastructure has not been considered at this stage. The overarching requirement is to provide a consistent bank level along the NBC to prevent overtopping to an appropriate design flood standard (nominally this has been the 0.5% AEP + 0.3m freeboard as discussed above).

C.2.4 Environmental Impacts

The following environmental concerns or impacts have been identified to be addressed in the approvals and design phases of the works:

- The proposed works represents a major construction and the design approvals process is expect to require a Review of Environmental Factors or other environmental impact assessment in accordance with scale and nature of the works.
- Typical construction phase impacts such as noise, dust and air quality, water quality etc. would need to be considered in terms of the existing environment and neighbouring property.
- The structure inlet and outlet transitions require modification to existing watercourses including excavation within the riparian corridor. Whilst the Mirrool Creek channel and floodplain in the immediate locality of the structure is largely a modified / engineered channel, further modification of the existing waterways is required as part of the works.
- The existing siphons are to be retained such that the normal flow regimes of Mirrool Creek will be retained. The flood relief structures only come into effect for major flood event (>20% AEP) and accordingly have no real impact on the typical flow properties of the system that would impact on ecology. Flood flows are effectively being retained in terms of flow frequency albeit with some minor changes in peak flood level elevations and inundation extents. However, these changes are only for the higher order events of the 1% AEP and greater and accordingly would have limited impact on the downstream environment. Whilst peak flows and flood levels may increase marginally downstream, overall flood volumes and durations of inundation have no material change. This perhaps most significant in terms of Barren Box Swamp towards the downstream end of the Mirrool Creek system in the current study.



Title:

EMR Flood Escape Gate Upgrade General Arrangement

Figure: C-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 12.5 25m

Approx. Scale

BMT WBM

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C.3 EMR Main Canal Siphon

C.3.1 Description of Works

The proposed works as discussed in Section 7.2.2 and presented in the general arrangement shown in Figure C3 incorporates:

- Replacement of the existing flood relief structures with a "Lawson Siphon" type arrangement. This arrangement includes an approximate 70-100m wide clear floodway opening for the Mirrool Creek floodplain in which the existing Main Canal embankments are removed. The Main Canal flows would be passed under the Mirrool Creek floodplain by way of siphons through corresponding intake and outflow structures.
- A separate offtake structure may be provided upstream of the siphons providing operational flexibility to release Main Canal flows to Mirrool Creek. This would be required as a replacement of the existing northern check structure and siphons which currently provide this function. The existing offtake structures may be retained subject to the design and performance of the Main Canal siphons.
- Channel modification works are required both upstream and downstream of the structure to provide appropriate transition of flow to the existing channel/floodplain of Mirrool Creek. The floodway opening and corresponding siphon span is located off the existing Mirrool Creek channel alignment. Accordingly, realignment of the normal/low flow channel may be required if the existing siphons are not retained. Nevertheless, in removing the existing Main Canal embankments, some floodplain excavation and rehabilitation would be required to reinstate a "natural" floodway opening.

C.3.2 Hydraulic Performance / Flood Impacts

The hydraulic performance of the proposed works in terms of flood mitigation function and potential impacts are summarised below:

- The Main Canal Siphon arrangement provides a similar general function as the flood gate structures in providing a nominal flow capacity to discharge Mirrool Creek floodwater across the Main Canal. As discussed, under existing conditions the maximum headwater level at the structure before flow diversion towards Yenda is initiated is 134.3m AHD as initiated via overtopping of the NBC at localised low points. The NBC bank raising proposed as part of the works provides for an increased maximum headwater level of ~134.8m AHD. However the siphon design width of 100m is based on a maximum headwater level of ~134.5m AHD for the 0.5% AEP event, providing for a 0.3m freeboard.
- Having similar discharge capacity to the flood gate arrangement, the hydraulic performance and flood impacts of the siphons are as discussed in C.2.2.

C.3.3 Design Constraints / Issues

Key design constraints and construction issues for the proposed works are identified as:

- As for the major flood gate upgrade, MI's ongoing operations represent one of the major constraints within design of upgrade options with consideration of construction phase impacts and potential disruption to MI business and impacts to customers, integrating works within the existing operational supply system, and maintenance and operational responsibilities.

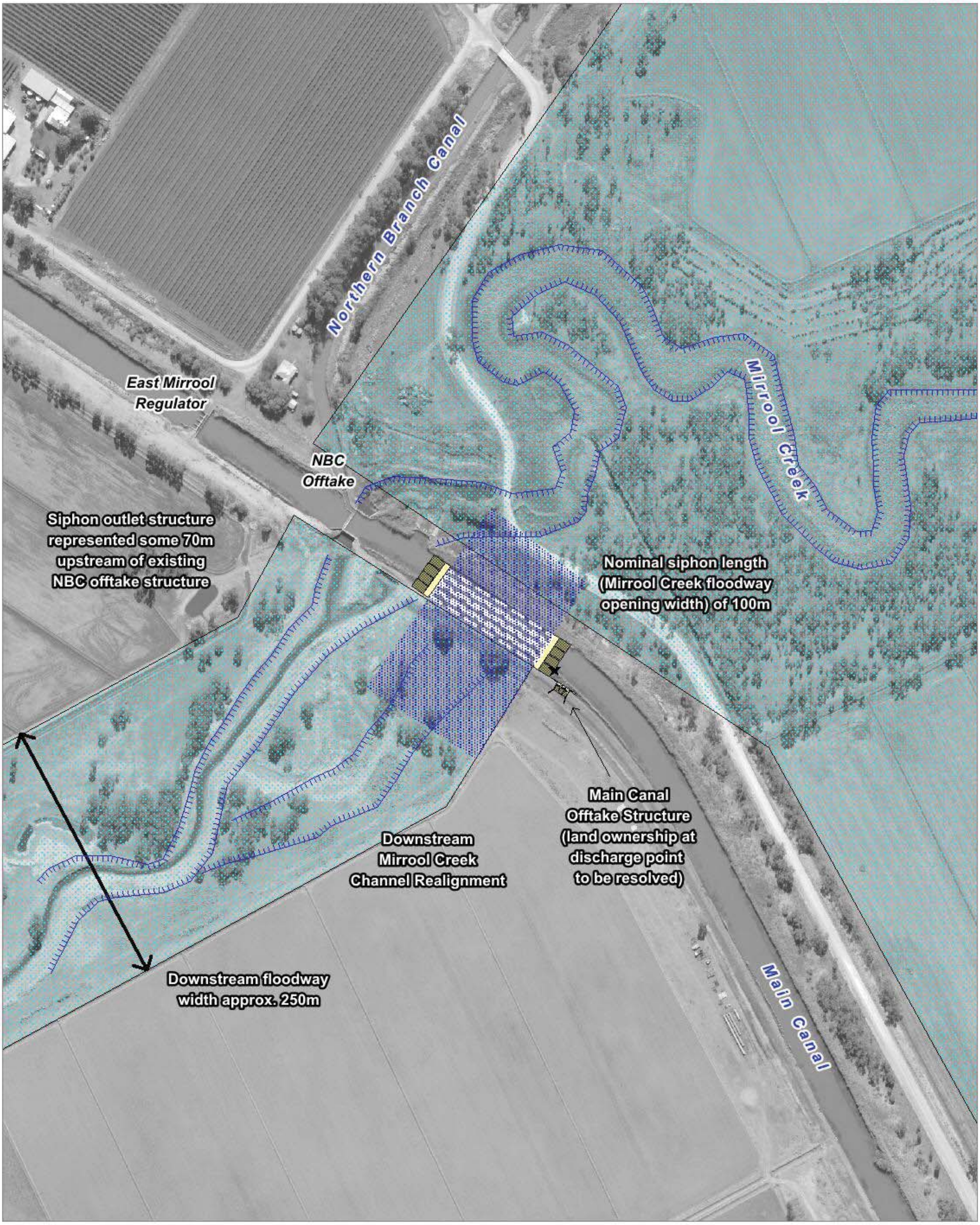
- The location of the floodway opening/siphon reach is a major design issue from a number of perspectives:
    - Proximity to the Northern Branch Canal Offtake – the siphon outlets need to be an appropriate distance upstream of the NBC offtake to provide MI with operational functionality/flexibility. This may depend on flow conditions from the outlet structure and how headwater conditions at the offtake are affected.
    - Bend in Main Canal Alignment – as evident in Figure C3, the nominal siphon location is immediately downstream of a change in the Main Canal alignment. If the siphon cannot be located as shown between the bend and NBC offtake, the siphon would either need to be relocated upstream, or contain pipe bends. The relocation option has its own issues in being off the existing Mirrool Creek floodplain alignment and potential land ownership constraints. The requirement for bends in the siphon may impact on flow efficiencies and compromise the design to some degree.
    - Location of existing Mirrool Creek floodplain and adopted floodways. The blue highlighted area of the Mirrool Creek floodplain on Figure C3 represents the nominal floodways. The existing floodway provides for a relatively limited location opportunity for the siphons which is complicated to some degree by the bend in the Main Canal alignment.
    - Any works located outside of the existing floodways, either the siphons or auxiliary Main Canal offtake structures would need further consideration of land ownership, particularly on the downstream side of the Main Canal.
- Dependent on the retention of the existing siphons and any realignment of the Mirrool Creek channel, the existing Halse Road immediately upstream of the Main Canal may require some modification including cross drainage provisions.

C.3.4 Environmental Impacts

The following environmental concerns or impacts have been identified to be addressed in the approvals and design phases of the works:

- The proposed works represents a major construction and the design approvals process is expect to require a Review of Environmental Factors or other environmental impact assessment in accordance with scale and nature of the works.
- Typical construction phase impacts such as noise, dust and air quality, water quality etc. would need to be considered in terms of the existing environment and neighbouring property.
- The location of the siphons requires modification to existing watercourses including excavation within the riparian corridor. Whilst the Mirrool Creek channel and floodplain in the immediate locality of the structure is largely a modified / engineered channel, further modification of the existing waterways is required as part of the works.

- There is some existing floodplain vegetation within the alignment of the proposed new floodway opening which may be impacted on by construction works. Similarly there is existing vegetation on the downstream side of the works which may be impacted upon by a realignment of the low flow / normal channel of Mirrool Creek.
- Similar to the flood gate upgrade option, normal flow regimes of Mirrool Creek will be retained with no real impact on the typical flow properties of the system that would impact on ecology. Flood flows are effectively being retained in terms of flow frequency albeit with some minor changes in peak flood level elevations and inundation extents. However, these changes are only for the higher order events of the 1% AEP and greater and accordingly would have limited impact on the downstream environment. Whilst peak flows and flood levels may increase marginally downstream, overall flood volumes and durations of inundation have no material change. This perhaps most significant in terms of Barren Box Swamp towards the downstream end of the Mirrool Creek system in the current study.



Title:

EMR Main Canal Siphon General Arrangement

Figure: C-3

Rev: A

N

0 75 150m

Approx. Scale

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Appendix D Flood Warning Opportunity and Flood Intelligence Data

The review of March 2012 observed flood conditions and the development of numerical flood models of the catchments as part of the Griffith Main Drain J and Mirrool Creek Flood Study (BMT WBM, 2014) has provided an enhanced understanding of the catchment flood behaviour. On the basis of this improved understanding, opportunities to improve the current flood warning and emergency response particularly in relation to the Mirrool Creek catchment have been identified.

The contributing catchment area of Mirrool Creek to the EMR at Yenda is some 6,500km^2. Accordingly, given the size of the catchment the response times are typically of the orders of days from the onset of major rainfall to significant flood conditions.

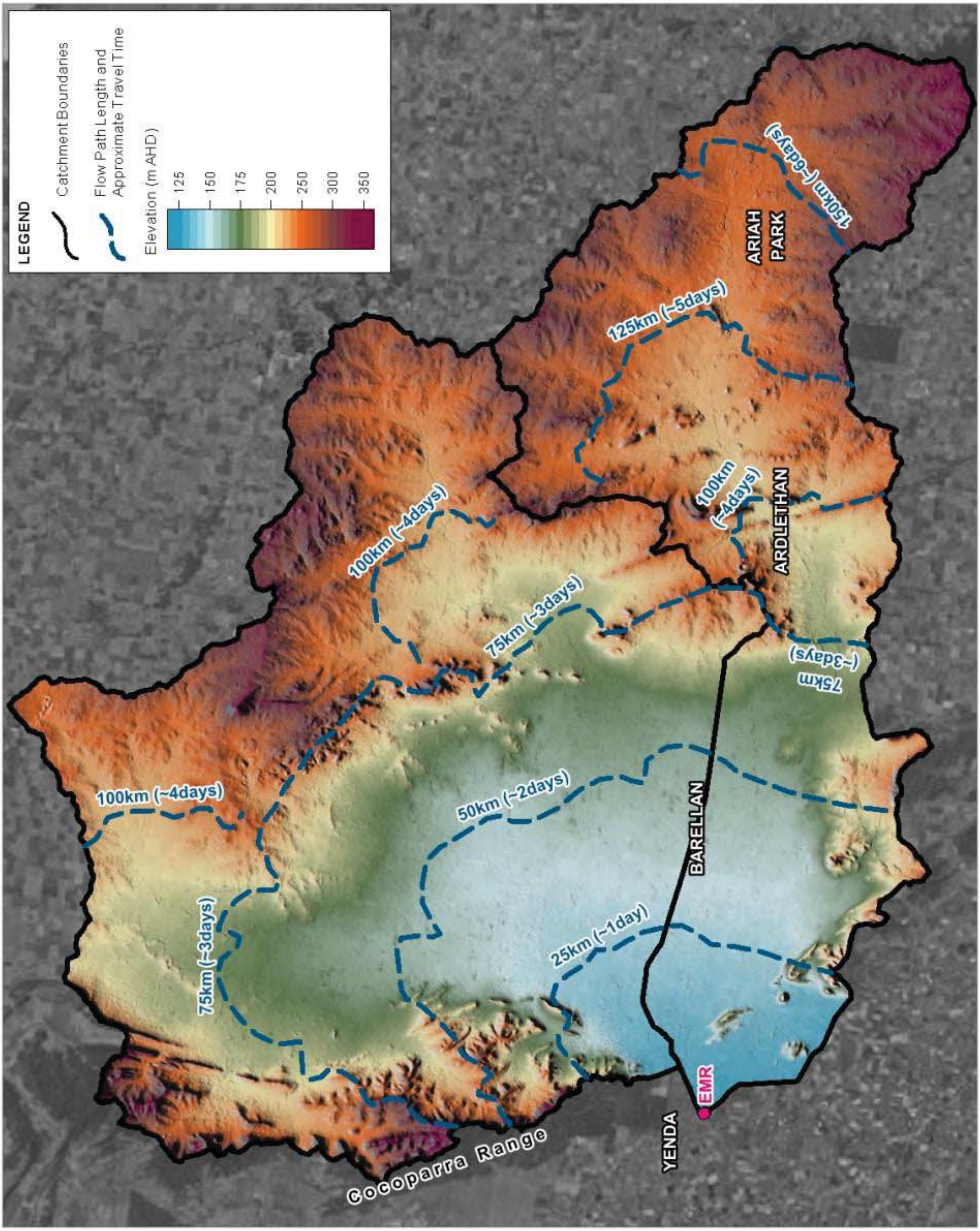
Figure D-1 shows the indicative flow path lengths and travel times from various parts of the catchment to the EMR. Significant rainfall occurring in the upper catchment upstream of Ardlethan can be expected to take of the order of 4-days to reach the EMR. High flood conditions at the EMR however can be experienced in shorter durations when there are significant contributions from the local Barellan and Colinroobie catchments.

There is currently no formal flood warning system in place on the Mirrool Creek catchment. It is understood however local flood advices are provided by the SES, utilising water level reference points at Ardlethan and Barellan. No automatic water level recorders are located in the catchment upstream of the EMR.

Murrumbidgee Irrigation (MI) operates a number of active water level gauges in the catchment downstream of the EMR. These include gauges on Mirrool Creek at McNamara Road, and Main Drain J at Warburn Escape. Additionally, MI also operate a number of continuous rainfall stations. As noted however, the existing recording stations are located downstream of the EMR, thereby limiting the opportunity to provide effective flood warning to locations such as Yenda. Nevertheless, these existing locations would provide benefit to a catchment wide flood warning system, particularly in relation to flood warning for areas downstream to Barren Box Swamp and beyond.

For the main study area however, potential improvements to flood warning focus on additional gauge data recording and analysis in the catchment are upstream of the Main Canal. The catchment is already serviced by a large number of daily rainfall gauges. The distribution of these gauges is shown in Figure D-2. Continuous rainfall gauges are located at Wattle Ck @ Dudauman (near Temora), Yanco Agricultural Institute and Naradhan, each of which are located outside of the Mirrool Creek catchment. Further gauges at Griffith Airport and Griffith CSIRO are located within the catchment, however, given the size of the catchment and expected variability in spatial rainfall distribution, are unlikely to be representative of conditions across the broader catchment area.

Given the nature of flooding in the catchment and extensive travel times, detailed continuous rainfall data in the upper catchment would not add significant benefit to flood warning in the lower catchment over and above the existing daily rainfall stations. There may be some merit however in a mid-catchment rainfall gauge somewhere in the vicinity of Barellan. This is in the vicinity of the catchment with shorter travel times to the EMR of 1-2 days where an earlier indication of intense sub-daily rainfall may be beneficial in triggering a flood watch.



Title:
Mirrool Creek Catchment Flow Path Lengths to the EMR

Figure: D-1

Rev: A

BMT WBM
www.bmtwbm.com.au

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As noted, Ardlethan and Barellan represent existing flood level reference points used by the SES for flood monitoring purposes. Both of these locations represent suitable locations for water level monitoring to provide advance flood warning data for Yenda and areas downstream.

Figure D-2 shows the major flow paths as simulated in the hydraulic model. Ardlethan and Barellan are located on these major flows and accordingly confirm the sites as appropriate locations for flood level monitoring. The main flood flow path through Ardlethan is relatively well confined to the main Mirrool Creek channel and floodplain. However, at Barellan there is a significant widening of the Mirrool Creek floodplain as the general flow splits between some major flood runners. Accordingly, to provide effective monitoring of flood water levels, multiple locations covering the main flow paths through Barellan may be appropriate.

As experienced in March 2012, significant local rainfall generated a significant flow around Merribee Hill. This consists of both local runoff and flows from the upstream Barellan area that split around Merribee Hill in major flood events. Given the potential contribution of flow in these locations to Mirrool Creek at the EMR, some benefit would also be realised in monitoring levels at these locations.

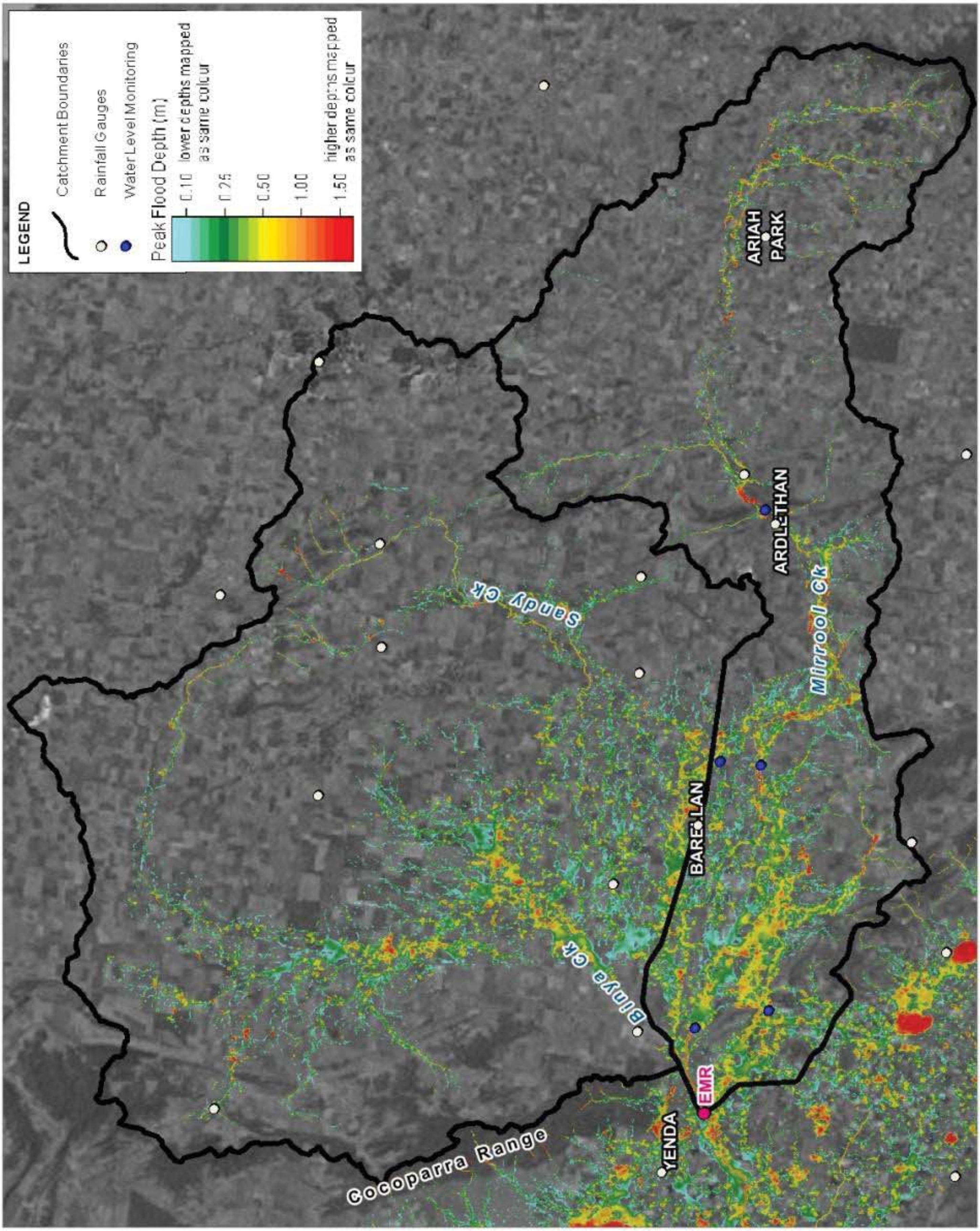
Figure D-2 shows the approximate locations of potential gauge locations to support an overall flood warning network for the Mirrool Creek catchment. Shown for reference are simulated major flow paths in the catchment with potential monitoring locations located at significant flow/contribution points along the system between Ardlethan and the EMR.

The March 2012 flood response at various locations in the catchment is shown in Figure D-3. Representative flow hydrographs are shown for combined floodplain flows at Barellan, Merribee Hill, total inflow to the EMR, outflow from the EMR flood escape structures and flow at MacNamara Road further downstream along Mirrool Creek. The simulated response hydrographs show potential window times for flood warning in the catchment. With significant flows generated more locally around Merribee Hill, and with contributions from Barellan, a nominal flood warning window for the EMR/Yenda may be of the order of 1-2 days dependent on the actual event rainfall distribution and subsequent runoff response. This represents a potential warning time prior to exceedance of the existing EMR flood escapes.

The available warning time to the peak of the flood event, as experienced in March 2012, is a somewhat longer period of the order of 3-4 days. Similarly, an extended flood warning opportunity is available for areas further downstream such as MacNamara Road, in which of the order of 7-10days may be available as the flood wave progresses downstream through the Mirrool Creek floodplain.

The Floodplain Risk Management Plan provides a recommendation to further develop flood warning capability in the catchment. This would require the development of an appropriate network of monitoring locations, and procedures/protocols for disseminating data and comparing with model results and other flood intelligence to establish flood predictions and appropriate response measures. The development of the scheme would include:

- Identification/installation of appropriate flood water level monitoring locations;
- Installation of additional pluviometers (e.g. Ardlethan/Barellan) to provide live rainfall data (supplemented by the already extensive daily rainfall locations);
- Utilise links to existing MI monitoring network;
- Establish reference points/calculations/algorithms to develop flood magnitude/prediction capability based on observed conditions and flood model data; and



Title:
Mirrool Creek Flow Paths and Potential Monitoring Locations

Figure: **D-2**

Rev: **A**

N

0 10 20km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

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- Develop appropriate flood warning and emergency response procedures on basis of predictive information.

It is noted that MI are current developing an operations model which supports some level of flood warning capability. Opportunities to utilise and enhance the existing systems should be explored to provide the mutual benefits to Council, MI, SES and the broader community.

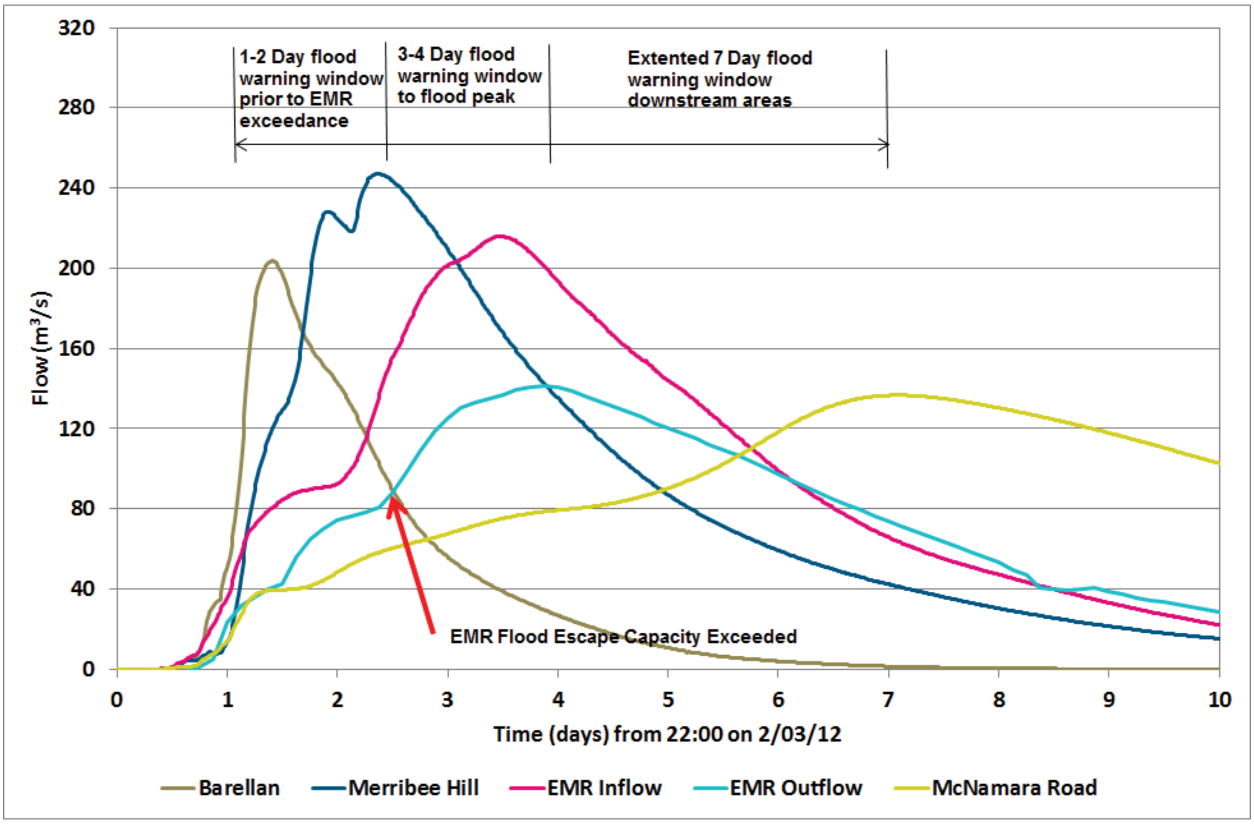

Figure D-3 – Mirrool Creek Catchment Response and Flood Warning Times

Appendix E Community Consultation

- Public Exhibition Media Release
- Summary of Public Exhibition Responses

MEDIA RELEASE

Wednesday 27 May, 2015

DRAFT GRIFFITH MAIN DRAIN J AND MIRROOL CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN ON PUBLIC EXHIBITION

Following the devastating flood event in March 2012 which impacted the Griffith community, in particular the Yenda community, Council commissioned consultants BMT WBM to review the 2011 Griffith Floodplain Risk Management Study and Plan.

Director Utilities, Mr Graham Gordon said given the March 2012 flood event in Yenda was contributed from Mirrool Creek flood waters overtopping Northern Branch Canal and spilling into the Main Drain J catchment, BMT WBM produced a new Flood Study 'Griffith Main Drain J and Mirrool Creek Flood Study' which was adopted by Council in 2014.

"The Flood Study defined the flood behaviour of the catchment, both in terms of local catchment runoff and flood flow contributions from Mirrool Creek, and produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions," said Mr Gordon.

"The outcomes of the Flood Study 2014 established the basis for subsequent flood mitigation measures in which both planning and structural measures that have been presented in this draft Report (Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan). This draft Report now has been put on exhibition for public comment."

This draft Report (Griffith Main Drain J Catchment Floodplain Risk Management Study and Plan):

- Documents the analysis of flooding behaviour in both Main Drain J and Mirrool Creek catchments, and evaluates the capacity of existing hydraulic structures e.g. Yenda East Mirrool Regulator (EMR) siphon and flood gates;
- Identifies and evaluates structural measures for the mitigation of existing flood risk e.g. Lawson siphon, upgrade of EMR siphon and or flood gates for Yenda, Yoogali levee and Hanwood local drainage works etc., and presents cost/benefit analysis and impacts of each mitigation option;
- Identifies and evaluates planning and development controls to reduce future flood risks e.g. MoU between Council and MI to improve opportunities for collaboration on future flood mitigation options; and; and
- Presents a recommended floodplain management plan both structural and planning that outlines the best possible measures to reduce flood damages in the Main Drain J catchment.

Griffith Mayor, Councillor John Dal Broi encourages residents in the Local Government Area to read through the report.

"This is a very important Study and it is essential Council receives feedback from the community," said Cr Dal Broi.

Media Information:

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Graham Gordon
Director – Utilities
02 6962 8100
Graham.Gordon@griffith.nsw.gov.au

“Two information sessions will be held on Tuesday 16 June, the first at Griffith City Library from 10am to 1pm and the second at the Yenda Diggers Club from 7.30pm.

“Council staff along with representatives from BMT WBM will be on hand to answer questions.”

The draft Study is available for viewing on Council’s website at www.griffith.nsw.gov.au as well as Griffith City Library and Council’s Administration Building at 1 Benerembah Street Griffith.

Submissions close 7 July 2015.

Should you wish to discuss the Study and Plan or if you require additional information, please contact Griffith City Council on 6962 8100 to arrange an appointment with Council staff.

end

E.2 Summary of Public Exhibition Submissions

Following the close of public exhibition, fifteen (15) submissions were received from the community as below:

- 2 Yoogali residents;
- 1 Myall Park resident;
- 9 Yenda residents;
- Yenda Progress Association;
- Yenda Flood Victims Association; and
- Carrathool Shire Council

A formal response to each submission was provided, including where appropriate additional information in response to any specific issue raised. A summary of the submissions and key issues raised is provided hereunder.

Yoogali Residents

- Concern was raised on the potential impact of levee for properties on the upstream side
- Some discussion with landholders took place at Yoogali community meeting during the exhibition period
- Additional information on local flood conditions was provided to the landholders including floor level survey of properties and comparison to flood levels. Additional data supported the adopted Plan measures flood impact assessment
- Council staff had on-site meeting with landholders
- Council undertaking ongoing consultation with landholders to resolve any remaining concerns.

Myall Park Resident

- Presented new flood information for March 2012 particularly in relation to impacts of a farm access (very small culvert) restricting outflow from Myall Park through DC North
- Meeting was held with landholder during the community information session at the Library during the exhibition period
- The culvert represents an example of impact of unapproved works on floodway – all major channels have been classified as floodways in the Main Drain J system
- Recommendations:
    - Reinforcement of development controls on major drainage networks classified as floodways (of which DC Northern is included)
    - Upgrade of structure to remove flow constriction (provides for drainage from Myall Park, no D/S impacts as Main Canal siphons control flows)
- Council and MI have noted the issue and will further investigate the options for removal/upgrade of the structure

Yenda Residents

- General support for Lawson Siphon type structure
- Additional commentary on ownership / responsibility for decommissioned structure and obligation for funding a solution

Yenda Progress Association

- The submission included a petition addressed to the General Manager, Griffith City Council, with some 156 signatures supporting:

"we the undersigned, Yenda residents severely affected by the March 2012 Yenda Flood recommend Griffith City Council, as the 'consenting authority' on flood planning process install the Lawson Siphon Option as per the draft document mentioned above as a permanent and proper solution to prevent Yenda being flooded again"

- The submission described impacts of the March 2012 flooding on the Yenda community;
- Acknowledgement / expression of gratitude for various inputs to the study and ongoing risk management process;
- Comments on the emergency response, responsibilities and post-flood recovery;
- Support for the siphon option in replacing the East Mirrool Regulator flood relief structures;
- Support for other flood warning and emergency response measures; and
- Recommendation for formalisation of agreements/responsibilities under the Council/Murrumbidgee Irrigation Memorandum of Understanding in management of drainage/flood infrastructure

Yenda Flood Victims Association

- YFVA comprises 276 financial resident members
- Submission included summary of flood impacts on Yenda community
- Summary of advantages / disadvantages of different structural options
- Support for the siphon option in replacing the East Mirrool Regulator flood relief structures
- Requested consideration of extension to proposed Northern Branch Canal levee and additional flood relief structures at Little Mirrool Creek and Dalton runner; and
- Indicated support for other flood warning and emergency response measures

Carrathool Shire Council

- Concerns were raised of potential impacts of EMR upgrade works on the timing and volume of flows through to Barren Box Swamp and subsequent impact on downstream areas within Carrathool Shire
- Whilst total volume changes are minor, the submission noted the concern of increased flow rates over the first 15 days of the design event and subsequent increase in flows downstream of Barren Box Swamp if the storage is at or near capacity

- Response provided some additional flow information for Mirrool Creek (McNamara's Rd) for EMR upgrade options. No major changes in total volume, peak flows and timing to downstream areas particularly up to 100-year ARI event, slightly more change for higher events (200-year)
- Upgrade works would not particularly change flood response – D/S areas more impacted upon by actual operations of Barren Box. MI will have access to all flood intelligence data derived from modelling. It is noted however, that MI have no responsibility in operation of Barren Box Swamp as a flood management measure.

E.3 March 2012 Flood Community Impacts

The Yenda Progress Association and Yenda Flood Victims Association submissions included commentary on the impacts of the March 2012 event. These records provide a valuable insight into community sentiment and accordingly have been included in the FRM Plan documentation for records.

Yenda Progress Association March 2012 Community Impact

Yenda Progress Association is incorporated under the auspices of Griffith City Council and has been representing the views of Yenda residents for almost 100 years. Yenda has a population of 1064 people (2006) residing in approximately 650 registered addresses.

The March 2012 Yenda flood was more than financially devastating for Yenda residents, it was emotionally traumatic. Residents left for work on Monday morning 5th March 2012 not expecting to be losing almost everything they owned of sentimental value. In particular clothing, vehicles, photos, keep sakes, children's school projects, toys and pets etc.

The flood was traumatic for many Yenda residents because of the way they were given fifteen minutes notice and ordered to leave their homes. Some Yenda residents coming from work in Griffith were not allowed to enter the town after the order to evacuate was given by SES Wollongong Commander, Mr James McTavish.

Consequently, not having enough time to evacuate their homes properly many residents were not able to lift furniture, pack clothing, secure photos, items of sentimental value or collect pets. Forced to leave by sometimes rude SES volunteers and backed up by Police, Yenda residents left their homes in a state of disbelief. They couldn't see any flood water. It didn't enter the town for another 24 hours.

This is the traumatic experience many Yenda residents had burned into their memories. This is why only the best flood mitigation option will heal that bad experience.

Yenda Flood Victims Association March 2012 Community Impact

Please find attached a submission prepared by Yenda Flood Victims Association on behalf of 276 financial members being residents of Yenda and district severely affected by the March 2012 Floods.

The 2012 flood has been called the worse flood in living memory and severely impacted 450 homes, approximately 12 businesses, approximately 100 farms with crop losses as well as some homes lost and 4 Public & Government buildings, one of which is being repaired currently, Memorial Hall, one will stay shut- the police station, two schools and one preschool.

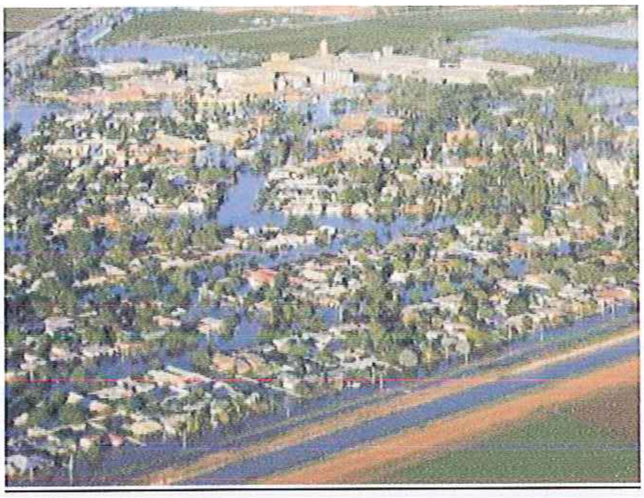
Anecdotal calculations put private and public sector losses arising from the flood, which includes immediate direct flood water damage, business losses and or business alternate carrying on costs and clean up costs including Council at approximately ninety million dollars. ($90,000,000.00)

The Yenda Community hopes with diligent flood planning measures residents will not have to face the emotional trauma and financial losses of a flood again.

E.4 March 2012 Flood Behaviour from Community Description

The Yenda Progress Association provided additional description of the observed flooding behaviour in Main Drain J and Mirrool Creek from a local community perspective. The report in the submission is included for reference in the FRM Plan documentation hereunder.

YENDA 2012 March Flood



SUBMISSION

- **Documents the analysis of flooding behaviour in both Main Drain J and Mirrool Creek catchments, and evaluates the capacity of existing hydraulic structures e.g. Yenda East Mirrool Regulator (EMR) siphon and flood gates.**

BACKGROUND

Yenda residents have always been very cognisant of nuisance flooding problems particularly with the Dredge St. double siphons under the Main Canal. Central CBD areas near all the major shops. PO, service station and club are areas that suffer from nuisance flooding. Council under leadership by Mayor Dal Broi commenced a staged plan of refurbishing many drains with Stage 1a & 1b completed In 2014. ($450,000.00)

In 2010 after a large local downpour the Dredge St siphons became blocked and threatened to flood three homes. Griffith City Council and Murrumbidgee Irrigation were quick to act and alleviate the problem by clearing debris from in front of the siphons.

Residents, particularly those living close to the Dredge St siphons became vigilant keeping the siphons free of debris.

MARCH 2012 YENDA RAIN EVENT

On March 3 2012 250mm of rain fell in 24 hours, the Dredge St. siphons cleared the local rain water from the township. Yenda was dry by late Sunday 4th March and Monday morning 5th March. Therefore it was a cruel twist of fate and a huge surprise to everyone at Monday lunch time when news broke that Mirrool Creek was over topping the Northern Branch Canal and threatening to flood Yenda.

FRUSTRATIONS

What's more cruel are reports after the flood that local SES were concerned with rising flood waters in Mirrool Creek and had unsuccessfully requested information from Murrumbidgee Irrigation regarding flood mitigation plans on the 2nd March. Local SES officers tried valiantly to gain information by contacting retired channel attendants when in discussions it was discovered existing flood gates at the EMR had been decommissioned by State Government agencies DWR & DWLR and sealed with dirt by Murrumbidgee Irrigation Ltd. This was Friday March 2, 84 hours before flood waters entered Yenda Township.

The above photo is believed to be of Brobenah Hills and Colinrobie Ranges area.

March 3 On the evening of 3rd March residents upstream of the EMR living adjacent to the Main Canal began contacting each other and evacuating their homes in the middle of the Saturday night for fear of being trapped by rising flood waters over topping the Main Canal.

March 4 Sunday, most weirs and bridges upstream of the EMR were being overtopped by flood waters entering the Main Canal from Colinrobie Ranges and Brobenah Hills via the Dalton Runner. The local resident farmer reported seeing two 'peak surges'. Mirrool Creek proper at the EMR was still at halfway level with tops of guide posts still visible on Halse Road. The author of this paper saw this on Sunday afternoon.

Late Sunday afternoon 4th March reports were at hand of Binya Creek running and cutting the Yenda to Binya rail line in two places 3 kms west of Binya. The Burley Griffin Way became impassable by late Sunday afternoon with flood water approximately 1 metre high. Emeritus mayor Neville, local parish priest Fr. Neru and friends of the author were all travelling back from Wagga Wagga and just made it through. Except for Fr Neru's car, it became disabled.

5th March, Early Monday morning Murrumbidgee Irrigation Mirrool Creek Project Officer, Mr Rob Kelly inspected the EMR and concluded that MI could not open the decommissioned flood gates. Murrumbidgee Irrigation then closed the new regulator irrigation doors in the Main Canal on the corner of Gordon Road and opened the mechanical doors on the northern bank forcing Main Canal flood waters into the path of Mirrool Creek rising flood waters.

Meanwhile Mirrool Creek was building up behind the Northern Branch Canal from the addition of Binya Creek flood waters arriving. By 10.30 am Monday morning 5th March 2012 flood waters began over topping the Northern Branch Canal on the corner of Benzobas Vineyard.

Lunchtime on Monday 5th March saw Main Canal EMR structures being overtopped. By 5.00pm all that was visible of the structures were the hand rails of catwalks because everything else was overflowing with flood water. A short 1.49 min video is available on 'You Tube Yenda Floods NSW 05/03/12'.

THE EVACUATION

Monday 5th March approximately lunchtime the Yenda evacuation order was given by SES Wollongong Commander Mr James McTavish. SES volunteers went knocking door to door telling Yenda residents they had 15 minutes to leave their homes as a wave of flood water was coming. If they didn't get out now they would be trapped. Police were on standby if any resident resisted leaving Police went and insisted they leave.

Not having the opportunity to adequately evacuate their homes properly, many Yenda residents lost irreplaceable items of sentimental value e.g. photos, clothing, jewellery, school children's projects, pets & toys as well as furniture, vehicles, tools and machinery.

FLOOD WATERS ENTER YENDA

March 6 Tuesday morning 6th March 2012 first flood waters entered Yenda Township. Another 1.48 min video is available on 'You Tube Yenda NSW Flood Waters Approaching 06/03'.

Also because the electricity being cut off many homes that didn't get over the floor flooding lost food stuffs in fridges and freezers to the point that blood ran out of freezers and stained floors.

Mould became a huge issue with many homes closed up for a week with water sitting over the floors. Residents were not able to get back and open their windows up to 8 days after the flood entered the town.

THE DEVASTATION

Homes The count was 450 homes were flooded in the Yenda area. 90 families were refused insurance coverage due to a recent change in fine print. Insurance premiums have since quadrupled as insurance companies rerate Yenda unofficially a high risk flood area.

The worrying aspect about higher insurance premiums in the order of seven thousand dollars per home for full flood cover is that many households, possibly a majority remain uncovered. This only leads to a more desperate situation next time.

Businesses A dozen businesses incurred damage to buildings, lost stock, materials and business opportunity for weeks afterwards as well as incurring extra costs in carrying on business at alternate sites on contract rates. A winery was lost and closed due to flooding.

Farms Approximately 100 farms lost homes, machinery, tools as well as late crops of grapes and prunes.

Public Buildings Four Government and public buildings were damaged as well as two schools, a pre-school and a church. A convent recently renovated a few years earlier was deemed unrepairable and demolished.

- **Identifies and evaluates structural measures for the mitigation of existing flood risk e.g. Lawson siphon, upgrade of EMR siphon and or flood gates for Yenda, Yoogali levee and Hanwood local drainage works etc. and presents cost/benefit analysis and impacts of each options:**

AWARENESS

It's been mentioned earlier Yenda residents are cognisant of flooding issues in the town with lots of nuisance flooding and blocking of Dredge St. siphons occasionally.

HISTORY

Yenda residents vividly recall the floods of 1989, 1984, 1976, 1956 & 1957, 1939 & 1931 with a smaller flood in 1921. During the previous large flood in 1989 the decommissioned flood gates were operational and successfully transferred all the Mirrool Creek upper catchment flood water across the Main Canal. It was reported by Department of Water Resources at the time the structure was considerably weakened with significant gouging fore and aft. However the good news was it did its job and no Yenda homes were lost in during the 1989 flood.

AFFECT ON MAIN DRAIN J

The same can't be said for Bilbul and Yoogali with significant flooding issues from Main Drain J. Each time there is a Mirrool Creek flood pressure is put on the Main Drain J system of drainage channels to dispel the flood waters.

THE PROBLEM IDENTIFIED

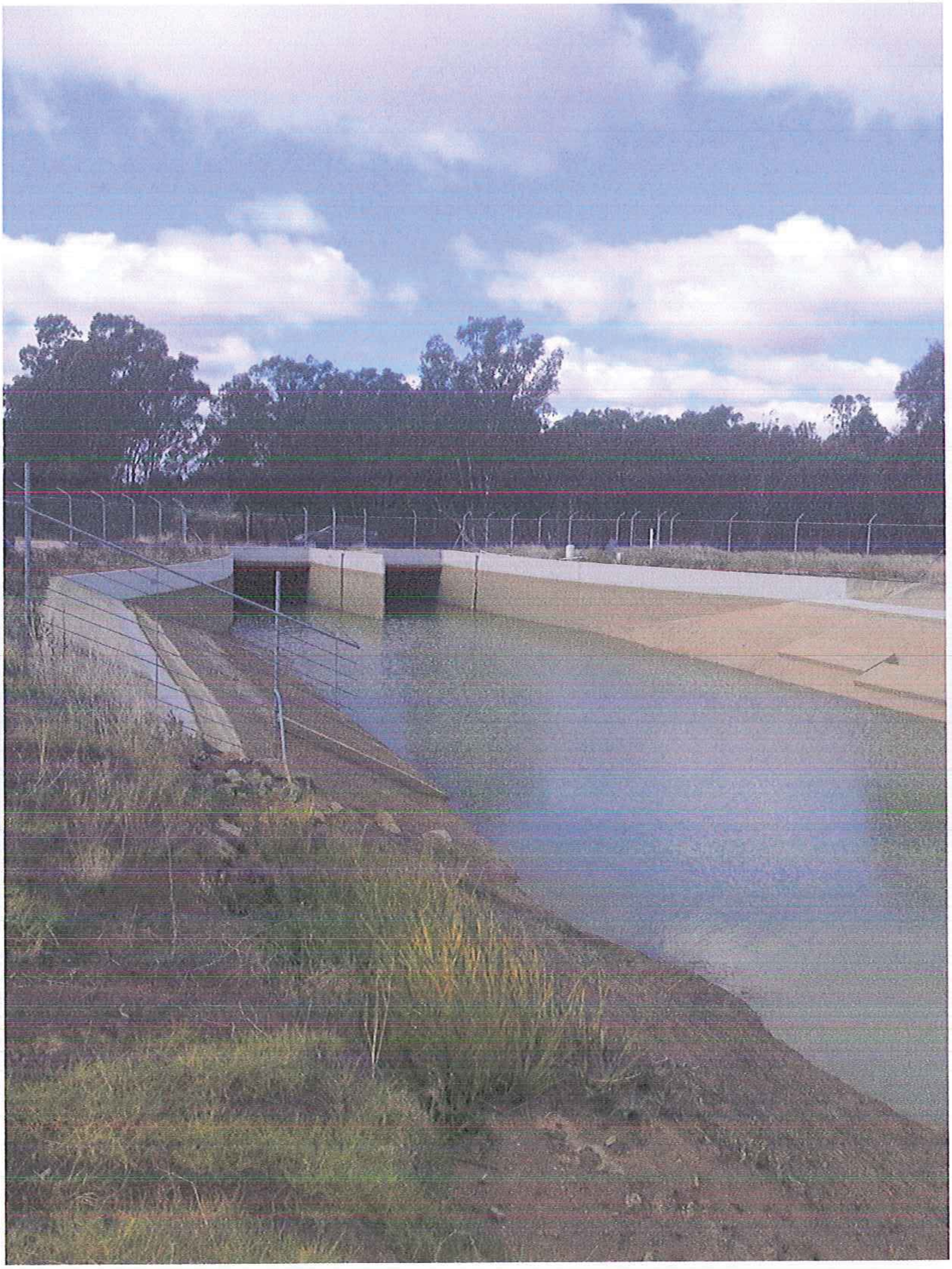
The 2014 Griffith Main Drain J & Mirrool Creek Flood Study states Yenda flood immunity has reduced since the decommissioning of the flood gates from 1:50 ARI in 1989 to 1:20 during 2012 flood. Therefore any rain event in excess of 1:50 ARI could potentially see Yenda flood again.

RECOMMENDATION

It is in this state of anxiety Yenda Progress Association recommends the Lawson Siphon design principle as the best option to solve Yenda's reduced flood immunity. Any other option is a waste of time and money.

The Lawson Siphon pictured on the following page is at Lawson Siphon Road, Deniliquin and directs Mulwala Canal under Aljoe's Creek for a distance of 120 metres when it surfaces again to continue as an open irrigation canal. The openings, called barrels are 3.6 metres in diameter and according to Murray Irrigation carry 2400 mega litres (ML) of irrigation water per day.

Aljoe's Creek is not measured, however speaking with residents living nearby following the March 2012 floods they said they were not overly concerned about the creek flooding. Upon a casual look the creek was running about half full.



E.5 Community Views on Proposed Options

The Yenda Progress Association and Yenda Flood Victims Association submissions included a summary of perceived disadvantages/advantages of the structural flood management options assesses in study. This is generally reflective of the community support or otherwise for various options and is included in the FRM Plan documentation hereunder for reference.

POINT 2.

Identifies and evaluates structural measures for the mitigation of existing flood risk e.g. Lawson siphon, upgrade of EMR siphon and or flood gates for Yenda, Yoogali levee and Hanwood local drainage works etc. and presents cost/benefit analysis and impacts of each options:

Following are four tables outlining the advantages & disadvantages of each option. The points are discussed in greater detail later:-

Option A – **Build up Northern Branch Canal**

Advantages	Disadvantages
Easy to do	Too short, flood water will flank around forest
Cheap for Government	Cannot act like a Dam, water will over top
MI preferred, doesn't interfere with irrigation	Cost underestimated
Increases size of canal, more D/E's for irrigators	Bridges, Weirs & dethridges will have to be lifted
	False security while decision to open flood gates
	Council to pay 1/3 share ($166,666.00)
	Increase costs to MI irrigators

Option B - **Re-instatement of decommissioned flood gates**

Advantages	Disadvantages
Quickest flood immunity from 1:20 to 1:40	Northern bank mechanical doors need replacing
Cheaper for Gov. & Council	Waste of money as structure is too old & small
Doesn't require consensus among community	Doesn't meet 1:100 ARI or decrease flood risk
	Doesn't instil confidence in community
	Council to pay 1/3 share ($700K)
	Increased costs to MI irrigators for maintenance

Option C- **Build New Flood Gates**

Advantages	Disadvantages
Easier to install than a Lawson Siphon	In principle not the best option
Cheaper than Lawson Siphon to build	Requires mechanisation which could fail
Construction will not interfere with irrigation	Requires human intervention to operate
	When operational will interfere with irrigation
	Doesn't inspire confidence in community
	Requires a firm MoU with MI on operation
	Requires early warning weather alerts, rain risk
	Insurance premiums may remain high
	Council share 1/3 ($3,533,333/00)
	Increased costs to MI Irrigators for maintenance

Option D - **Inverted Canal Siphon (Lawson Siphon)**

Advantages	Disadvantages
In principle Best option	Requires consensus amongst stakeholders
Best outcome for all involved	Requires lobbying of Gov.
Permanent solution	Requires extra effort to design and build
No interference with irrigation delivery	
No human involvement in decision making	
Full confidence restored to community	
Lower insurance premiums	

Emergency Protocol – **Breaching Main Canal**

Advantages	Disadvantages
Provides failsafe mitigation to protect Yenda	Requires strict MoU with MI
Relatively easy to plan	Requires planning & preparation sacrificial banks
Relatively cheap to implement	Requires decision making to implement plan
	Increased costs to MI for repairs to Canal banks

Optional Additional measures – **Levee Extension**

Advantages	Disadvantages
Prevent flood waters flanking NBC levee	Additional costs
Directs flood waters south to Mirrool creek	Requires easement on dry area property (tank)
Protects two additional properties	

Optional Additional Measures – **Little Mirrool Creek Siphon enlargement**

Advantages	Disadvantages
Facilitate more flood water flows west	Additional cost
Reduce flood water flow to EMR	Requires drainage channel work Murrami
	Requires drainage channel work Calorafield

Optional Additional Measures - **Dalton Runner**

Facilitate more flood water flows west	Additional costs
Reduce flood water flows in Main Canal to EMR	No drainage canal to carry flows west

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