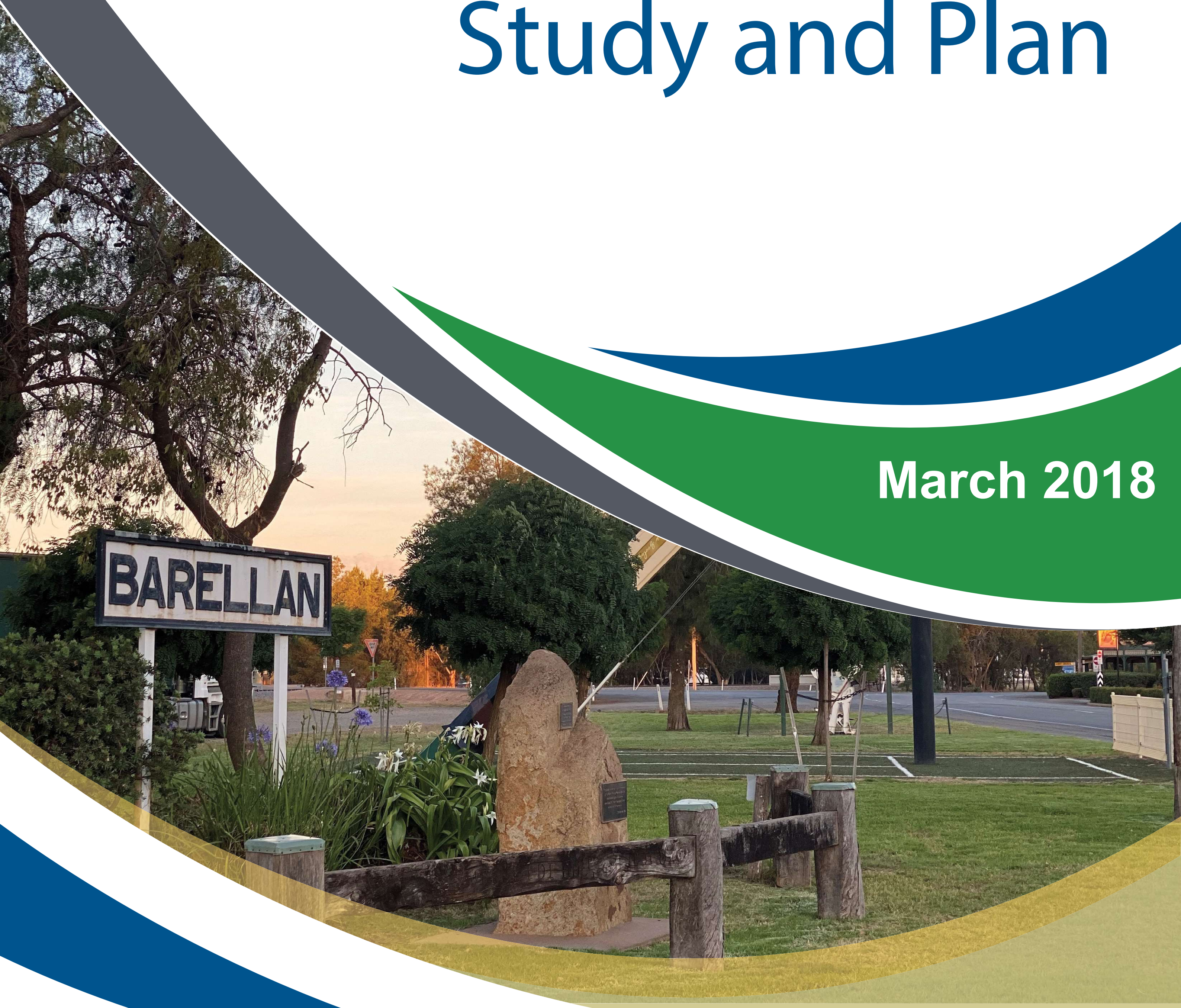
Barellan Floodplain Risk Management Study and Plan



March 2018

Narrandera
Shire Council

Barellan Floodplain Risk Management Study and Draft Plan

Prepared for:	Narrandera Shire Council
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Document:	R.N20551.002.04.docx
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Client Reference:	T-14/15-9

Synopsis: **This report documents the Barellan Floodplain Risk Management Study and Plan which investigates and presents a flood risk management strategy for the town of Barellan in the Mirrool Creek 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	15/11/2017	DXW		DXW	
1	27/11/2017	DXW		DXW	
2	29/11/2017	DXW		DXW	
3	30/11/2017	DXW		DXW	
4	19/03/2018	DXW		DXW	

DISTRIBUTION

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Narrandera Shire Council	e	e	e	e	e						
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Executive Summary

Introduction

Barellan is located in the Riverina region of south-west NSW. The closest city is Griffith located approximately 50 km to the west. The town of Ardlethan lies some 30 km to the east. The Mirrool Creek catchment totals an area of around 2,000 km^2 upstream of Barellan. A flood study for Barellan was completed by BMT WBM in 2017, concurrently with this study.

Study Objectives

The primary objective of the flood study was to define the flood behaviour in Barellan through the establishment of appropriate numerical models. 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 Barellan Flood Study established the basis for subsequent floodplain risk management activities in Barellan. 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 Barellan 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 risk management plan that outlines the best possible measures to reduce flood damages in the Barellan township.

This report documents the Floodplain Risk Management Study and presents a recommended Floodplain Risk Management Plan for Barellan.

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 risk management measures and a recommended Floodplain Risk Management Plan.

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

Flooding Behaviour

The flood behaviour in the study area is complex and is heavily influenced by antecedent catchment conditions (i.e. the relative dryness or wetness of the soil). The township of Barellan is situated at the south-eastern limit of the well-draining sandier soils that comprise much of inland Australia. As such, flooding of the town is a relatively rare occurrence, as floodplain flows often dissipate prior to reaching town.

The Barellan floodplain is characterised by flat topography which is criss-crossed by a network of field boundaries and access roads, providing significant attenuation of flood flows entering the floodplain area.

The Barellan floodplain is fed by the following sources:

- Flows from the upper Mirrool Creek catchment, which is well-defined downstream to Ardlethan;
- Local catchment runoff from the Colinroobie area to the south; and
- Rain falling directly on to the floodplain.

The township of Barellan is known to have flooded only once in living memory – in the recent event of March 2012.

The soils of the Mirrool Creek floodplain to the south of Barellan are heavier in nature and are known to result in periodic runoff, and subsequent flooding within the broader Barellan floodplain area. During major rainfall events, a flood runner from Kamarah to Barellan can become activated. This flood runner can extend beyond the limit of the heavier soils and be conveyed across the sandier area between Mirrool Creek and Barellan, particularly if local soils are saturated. This occurs from one (or both) of the following mechanisms:

- Local rainfall-runoff processes from the floodplain area around Kamarah; and
- Significant flood flows generated from the upper Mirrool Creek catchment upstream of Barellan.

In the event of flood flows entering the town of Barellan, flood waters quickly build behind the raised road alignments before spilling over the road crests.

Given the size of the Mirrool Creek catchment, the critical flood conditions for Barellan could be in the order of 24 hours to three days after the initial onset of rainfall. Shorter response times relates to flooding resulting from intense rainfall on the local catchment area, with a longer response expected for flood flows emanating from the upper Mirrool Creek catchment.

A flood damages databases has been developed to identify potentially flood affected properties and to quantify the extent of damages in economic terms for existing flood conditions. The floor levels for 244 dwellings located within the floodplain where estimated from the LiDAR DEM, with floor level above ground level estimated from a drive-by assessment. Key results from the flood damages database indicate:

- 69 residential homes and 13 commercial buildings in Barellan would be flooded above floor level in a 1% AEP event; and
- the AAD was calculated as being $134,000.

Floodplain Risk Management Options Considered

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

<u>Flood Modification Measures</u>

- *Barellan town levee construction* – Three levee alignments around the Barellan township have been considered. Each alignment would tie into the elevated rail embankment to the north of the town and as such would involve roadworks to locally raise Burley Griffin Way. The levee works have considered providing flood immunity to the 1% AEP flood. From the four options considered, two alternate levee alignments have merit. A levee option feasibility study to further investigate the potential for a levee upstream of the town has been recommended in the Plan.

- *Mirrool Creek levee construction* – One levee alignment adjacent to the Mirrool Creek channel has been considered in detail. Although this alignment does provide some reduction to peak flood levels in town, it has not been recommended in the Plan due to its unfavourable cost benefit ratio.
- *Upgrade of road drainage capacity in town* – The merit of increasing the capacity of existing cross drainage infrastructure in town has been assessed. Although the modelled results of the assessment indicated that flow conveyance under roads was increased, this did not translate to a reduction in peak flood levels. This option was therefore not recommended in the Plan.
- *Provision of lowered road floodway sections* – The potential to lower sections of Kooba Street, Yarran Street, Boree Street, Myall Street and Kurrawang Street (north-south aligned roads) between Bendee Street and Mallee Street to provide continuous drainage of floodwater through the town has been assessed. Lowering various sections of road crests within the hydraulic model resulted in a minor change in peak flood compared to existing flood conditions. This option was therefore not recommended in the Plan.

Property Modification Measures

- *Flood-proofing of commercial buildings* – Flood proofing is proposed as part of the Plan for commercial properties that are below the 1% AEP flood level. For those properties identified within the 1% AEP flood area, advice may be provided to individual business owners on available opportunities to reduce on-site flood damages. Temporary flood barriers in particular are identified as a feasible option for mitigating against flooding of businesses on Yapunyah Street and accordingly have been recommended in the Plan.
- *Planning and development controls* – Land use planning and development controls are key mechanisms by which Council can manage flood-affected areas within Barellan. This will ensure that new development is compatible with the flood risk, and allows for existing problems to be gradually reduced over time through sensible redevelopment. The Plan has recommended the adoption of 1% AEP flood level plus 0.5 m freeboard as the flood planning level and a review of current land-use zoning with respect to floodway areas.
- *Rural floodplain development guidelines* – There is a need for Narrandera Shire and Griffith City Councils to develop and regulate a set of guidelines governing agricultural development within the Mirrool Creek floodplain between Barellan and Barren Box Storage and Wetland. The guidelines need to be accepted by the landowners and the broader community, to balance both the need to make a living from the land and the requirement to manage flood risk in a responsible manner. Establishment of such guidelines is therefore recommended in the Plan.

Response Modification Measures

- *Augment Mirrool Creek catchment flood warning system* – A flood warning system is currently being implemented in the Mirrool Creek catchment by Griffith City Council to provide flood warning at Yenda. This Plan recommends implementation of an additional two new gauges to the Mirrool Creek flood warning system (a rainfall gauge in the vicinity of Kamarah and a rainfall gauge and streamflow gauge on Mirrool Creek at Beckom). These gauges would provide local reference points for the Barellan community as well as the BoM and SES to gauge the imminent flood risk, and respond accordingly.

- *Update to Local Flood Plan and emergency response* – The information provided by the FRMS will enable flood mapping to be updated and aid the SES in prioritising the areas within the LGA with the highest flood risk. The Plan recommends that SES update response plans based on information from this study. Occupants of flood prone properties are to be encouraged to have private flood emergency response plans. There is also the potential for a "Community Flood Emergency Response Plan".
- *Ongoing community education and awareness* – Raising and maintaining flood awareness will provide the community with an appreciation of the flood problem and what can be expected during flood events. An ongoing flood awareness program should be pursued through collaboration of the SES and Council (e.g. FloodSafe program specific for Barellan).

The Recommended Floodplain Risk Management Plan and Implementation

A recommended floodplain risk management plan showing preferred floodplain risk management measures for Barellan is presented in Section 8 in the main body of the report. The key features of the plan are tabulated on the following page with indicative costs, priorities and responsibilities for implementation.

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

- Council allocates priorities to components of the Plan, based on available sources of funding and budgetary constraints;
- Council negotiates other sources of funding as required such as through OEH and the "Natural Disaster Mitigation Package" (NDMP); and
- 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.

Option	Estimated Cost	Responsibility	Priority	BCR
Recommended options that modify flood behaviour				
Investigate the feasibility of the levee protection options for Barellan and if warranted proceed to further design stages	$100k#	Council	High	0.53 - 0.48*
Recommended options that modify property				
Flood proofing of commercial buildings	$5k / property	Business owner	Low	1.3
Planning and development controls	Staff costs	Council	High	NR
Rural floodplain development guidelines	$40k	Council	High	NR
Recommended options that modify flood response				
Augment Mirrool Creek catchment flood warning system	$95k	Council	High	NR
Update to Local Flood Plan and emergency response	Staff costs	Council / SES	High	NR
Ongoing community education and awareness	Staff costs	Council / SES	High	NR

Notes: NR – Not a capital cost orientated option, or benefits difficult/impossible to quantify in financial terms.

 # Cost does not include further design investigations or construction

** BCR estimate range based on construction of parallel standalone Levee Options 1b or 1c*

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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.

Acknowledgements

Narrandera Shire Council has prepared this document with financial assistance from the NSW and Commonwealth Governments through the Natural Disaster Resilience Program. This document does not necessarily represent the opinions of the NSW or Commonwealth Governments.

We would like to acknowledge the stakeholders and community members who have provided valuable input to the Barellan Floodplain Risk Management Study, without their local knowledge and expertise the Study would not have been as comprehensive. The key contributors to the Study include, but are not limited to, the following:

- Narrandera Shire Council;
- NSW Office of Environment and Heritage;
- Floodplain Risk Management Committee; and
- Community members that attended the floodplain risk management options workshop.

1 Introduction

During the March 2012 flood event the community of Barellan was inundated with flood water emanating from the south-east of the town across Mirrool Road, near Moombooldool. Flood water in the town remained elevated for many days. This was the first time that floodwaters had inundated the town of Barellan in living memory. Following from the March 2012 event, BMT WBM was commissioned by Narrandera Shire Council (Council) in 2016 to complete the Barellan Flood Study and the Floodplain Risk Management Study and Plan as detailed investigation into flooding at Barellan had not previously been completed.

The Barellan Flood Study defined the flood behaviour of the catchment, both in terms of local catchment runoff and flood flow contributions breaking out 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 established the basis for subsequent floodplain risk 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 Barellan 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 risk management plan that outlines the best possible measures to reduce flood damages in the Barellan township.

This report documents the Floodplain Risk Management Study and presents a recommended Floodplain Risk Management Plan for Barellan.

1.1 Study Location

Barellan is located in the Riverina region of NSW. The closest city is Griffith, located approximately 50 km to the west. The town of Ardlethan lies some 30 km to the east. The Mirrool Creek floodplain, south of Barellan, is broad and flat, with typical field grades of approximately 0.1%. The location of Barellan relative to the Mirrool Creek catchment, downstream to Barren Box Storage and Wetland, is shown in Figure 1-1.

1.2 The Need for Floodplain Risk Management at Barellan

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

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 Barellan township and the broader Mirrool Creek catchment.

1.3 The Floodplain Risk 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).

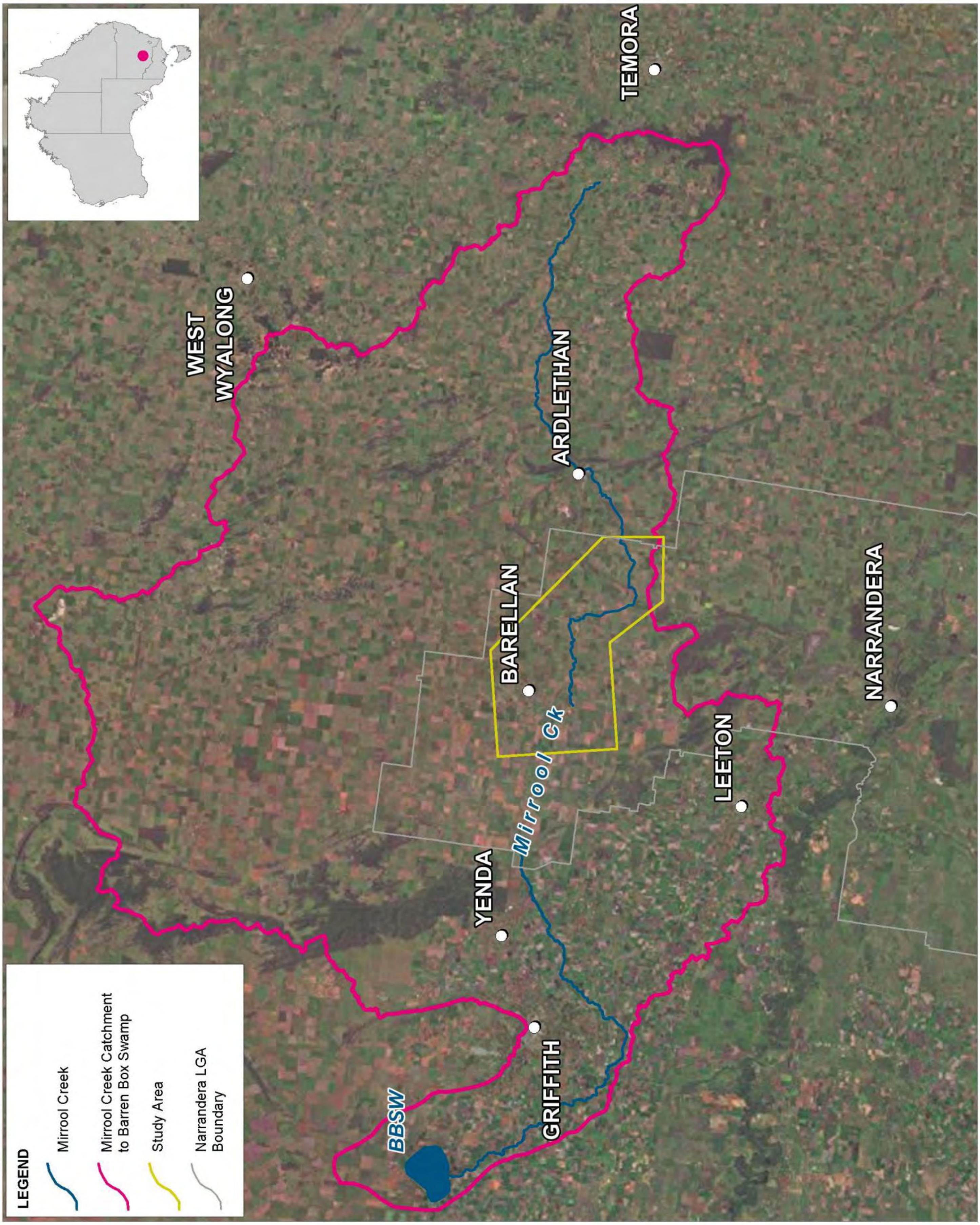
Under the Policy the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain risk management responsibilities.

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 Barellan Floodplain Risk Management Study and Plan (this document) constitutes the fourth and fifth stages of the management process. It has been prepared for Narrandera Shire Council to provide the basis for future management of flooding in the township of Barellan.



Title:
Study Locality

Figure: **1-1**

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.

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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.

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 Mirrool Creek catchment totals an area of around 8500 km^2 downstream to Barren Box Storage and Wetland, with some 2000 km^2 upstream of Barellan.

The topography of the catchment is shown in Figure 2-1. The upper catchment is approximately situated between Ardlethan and Temora and is largely elevated between 200 m and 400 m AHD. The mid-catchment area is a relatively flat expanse, with poorly defined catchments and channel alignments. Elevations are typically between 130 m AHD to 180 m AHD. Substantial irrigation supply and drainage infrastructure has modified the natural drainage of the lower catchment, downstream of the Murrumbidgee Irrigation (MI) Main Canal.

The catchment has been predominantly cleared for farming purposes, being irrigated agriculture in the lower catchment. There are also small areas of remnant vegetation, most notably on the Coccoparra Range.

The nature of the soils is relatively complex, as the catchment is situated within an area of transition between the sandy inland soils and the heavier soils of the western slopes.

There are a number of major transport routes traversing the catchment, the most significant being Burley Griffin Way and the Temora-Griffith Railway.

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 1928, 1931, 1939, 1956, 1974, 1984, 1989 and most recently in 2012.

The June 1931 event was not in itself overly severe, with rainfall records indicating a daily total of 57 mm being recorded at Barellan on 24th. This constitutes less than a 20% AEP (roughly equivalent to a one in five year occurrence) rainfall event when compared to standard intensity frequency duration (IFD) curves. More significant was the rainfall in preceding months, which totalled around 100 mm across the Mirrool Creek catchment in the month preceding the event and around 200 mm for the two months preceding the event. This represents an extremely wet antecedent condition, when compared to the average annual rainfall of around 450 mm. These conditions resulted in the highest flow conditions in Mirrool Creek on record prior to the March 2012 event.

The January 1984 event resulted in the largest flood in recorded history at Ardlethan and in the upper Mirrool Creek catchment, with 125 mm rainfall being recorded at Ariah Park on 26th. This constitutes in excess of a 1% AEP rainfall event when compared to standard intensity frequency duration (IFD) curves.

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 103 mm 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.

The March 2012 flood was the largest in recorded history at Barellan. The continuous rainfall record at Griffith Airport indicates that a total of 147 mm fell in a 16-hour period, which is in excess of a 0.1% AEP magnitude design event when compared to the IFD curves. Even more rainfall was recorded at Barellan (~164 mm), but total rainfall depths reduced to around half of this amount at the eastern edge of the Mirrool Creek catchment.

Further details of the known flood behaviour within the region are presented in Section 4.

2.3 Previous Studies

A number of investigations into the management of flood risk in the region have been undertaken in the past. Various studies have looked at the design flood conditions and the management of the flood risk along Mirrool Creek, largely with focus on specific townships. Also of interest in this study is the management of flood risk within the wider LGA, which includes flooding of the Murrumbidgee River and floodplain.

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 embankments 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 embankments if the land holders desired. Consideration is also provided to the removal of floodplain “pondage” areas and the impact this may have on flood attenuation.

The document includes mapping of the defined floodways downstream of Barellan Road, constituting around 10% of the current study area. The floodway identified in the report was designed to be of similar magnitude to the October 1974 flood. For reference, the flood frequency analysis completed in the Flood Study estimated the October 1974 event to have an average return interval of approximately 30 years.

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)

Additional investigation into the flood management of the Murrumbidgee Irrigation Area (MIA), including the Mirrool Creek floodplain downstream of Barellan was completed as part of the *MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works Options on Floodway Lands* (Water Resources River Management Branch, 1994).

For the Barellan to Yenda section of the floodplain, the study advised that the Water Resources Commission (1978) guidelines were the most suitable means for managing flood risk.

2.3.3 Narrandera Floodplain Risk Management Study and Plan (SKM, 2009)

The Narrandera Floodplain Risk Management Study and Plan (FRMS&P) were completed by SKM in 2009 following the Narrandera Flood Study (SKM, 2000) and the Narrandera Flood Study

Review (SKM, 2007). These studies focused on the township of Narrandera which is located 50 km south of Barellan on the Murrumbidgee River. A number of flood risk management measures were recommended as a result of the study and included property modification, response modification and flood modification measures.

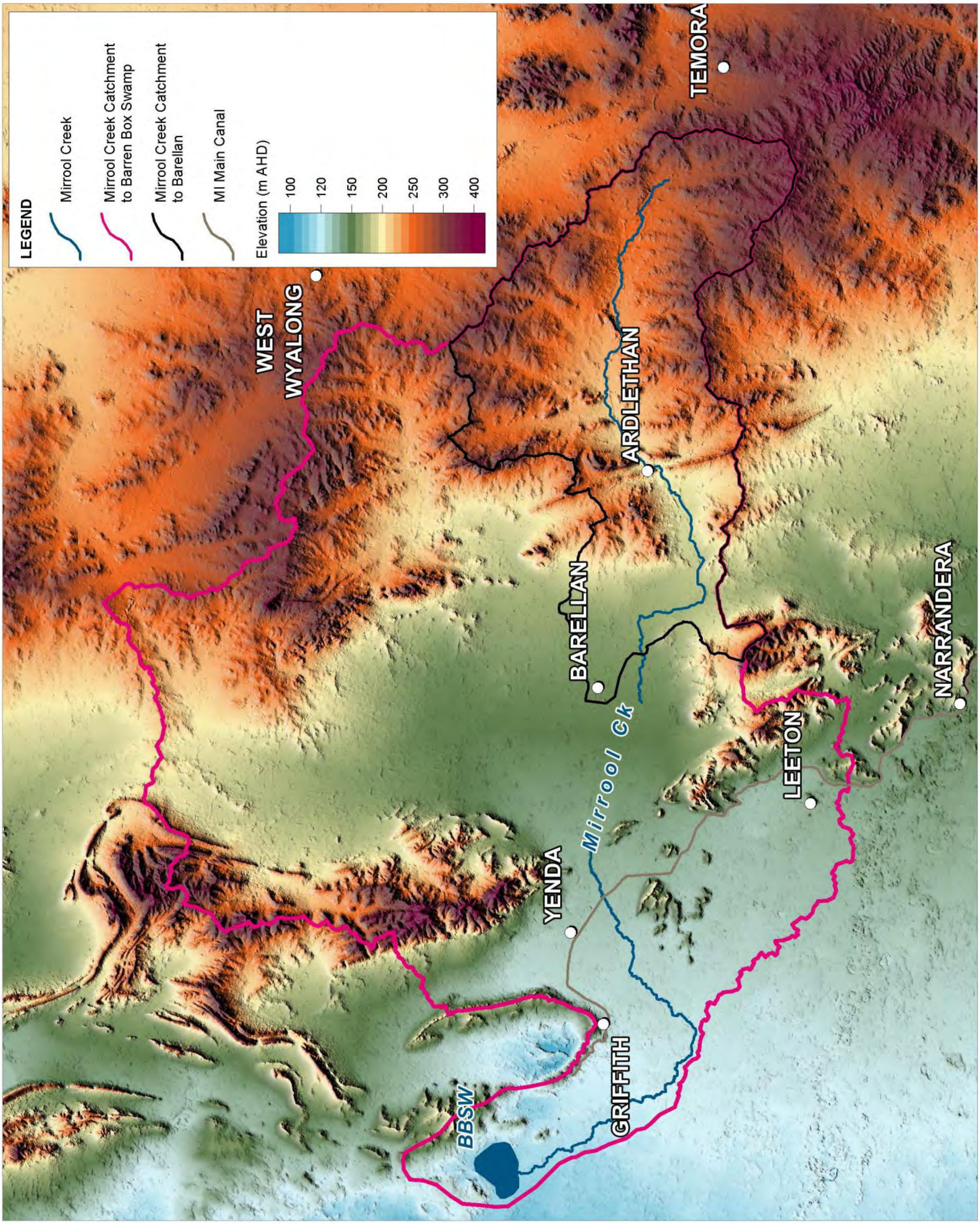
One of the key recommendations of the Narrandera FRMS&P was updates to the Narrandera Local Environment Plan (LEP) and Narrandera Development Control Plan (DCP) to define and control development on flood liable land. To inform updates to the DCP, the Narrandera FRMS&P developed a “Flood Policy Matrix” to define the development controls applicable to each different development type, depending on where it is to be located within the flood plain.

Another major recommendation was levee upgrade works and proposed new levee construction to increase existing flood protection to the 1% AEP design flood level plus a 0.5 m freeboard, and to protect additional areas of flood liable land.

2.3.4 Barellan Flood Study (BMT WBM, 2017)

The Barellan Flood Study was completed concurrently with this study. Both studies were commissioned by Narrandera Shire Council in 2016 following from the March 2012 flood event.

The Flood Study defined the flood behaviour of the catchment, with specific focus on flooding of the township and considered local catchment runoff and flood flow contributions breaking out 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. As detailed investigation into flooding at Barellan had not previously been completed, the information in the Flood Study formed the basis for the floodplain risk management investigation considered herein.



Title:

Topography of the Mirrool Creek Catchment to Barren Box Swamp

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.

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3 Community Consultation

3.1 The Community Consultation Process

Community consultation has been an important component of the floodplain risk management study. 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 concerns regarding flooding issues and to collect feedback and ideas on potential floodplain risk management measures and other related issues.

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

- Feedback through the Floodplain Risk 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 Risk Management Committee

The study has been overseen by the Barellan Floodplain Risk Management Committee (Committee). The Committee has assisted and advised Council in the development of the Barellan 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

Additional meetings were held throughout the course of this study following from community sessions completed for the Flood Study. The purpose of the meetings was to provide the community with an opportunity to be involved in preliminary discussions around potential flood management options for the study area. Overall, a levee to protect the town appeared to have good support from the general community. The option for other drainage upgrade works in town was also highlighted by several community members as worth investigating.

The meetings were highly successful, as the implementation and success of a Floodplain Risk Management Plan depends on community support and acceptance of proposed floodplain risk management measures.

3.4 Public Exhibition

The Draft Barellan Floodplain Risk Management Study and Plan was placed on public exhibition from December 2017 with the report being made available on Council's website, the Barellan Post Office and the Council Administration Building. Landowners, residents and businesses were invited to participate in the study by providing comment on the Draft report with submissions closing February 2018.

As part of the public exhibition of the Draft, a community information session was held at the Barellan Bowling Club on 15 January 2018. The session was well attended by some 30 residents. Questions raised during the information sessions included:

- The possibility of an alternative levee alignment that ties in to the Burley Griffin Way at the rise some 1 km to the east of Cemetery Road. Although this alignment would involve additional length and cost, it may offer a more straightforward integration with the existing high ground
- The possibility of a drainage channel to divert flood water around the town, rather than a levee. It was explained that to offer a similar standard of protection to a levee, the channel would need to much larger than is practical
- The potential for drainage works within Barellan to alleviate flooding. It was explained these had been assessed as part of the study and found to be ineffective for major flood events. However, they would assist to some degree in more frequent flood events and would help to alleviate the local drainage issues that are experienced following heavy rainfall
- The potential for levee and drainage works remote from Barellan, in the vicinity of Mirrool Creek. Although these may provide some level of flood reduction in Barellan, they had been assessed as part of the study and had identified potential flood impacts associated with flow redistribution. Also, the works would not afford Barellan protection from runoff generated between Mirrool Creek and the town – which was the source of peak flood inundation during the March 2012 event

A total of two submissions were received from the community during the public exhibition period, albeit one of the submissions was lodged jointly as a representation of 17 residents. The submissions and the individual responses are provided in Appendix H. The content of the submissions is consistent with the issues that were discussed at the community information session.

4 Existing Flood Behaviour

4.1 Flood Behaviour

The flood behaviour in the study area is complex and is heavily influenced by antecedent catchment conditions (i.e. the relative dryness or wetness of the soil). The township of Barellan is situated at the south-eastern limit of the well-draining sandier soils that comprise much of inland Australia. As such, flooding of the town is a relatively rare occurrence, as floodplain flows often dissipate prior to reaching town. A schematisation of the Barellan township flood behaviour is presented in Figure 4-1.

4.1.1 Barellan Floodplain

The Barellan floodplain is characterised by flat topography which is criss-crossed by a network of field boundaries and access roads. Downstream of Barellan Road, the Mirrool Creek alignment dissipates so that there is no natural creek alignment through the area, but a defined floodway extent is maintained. The flat topography, coupled with elevated field boundaries, provides significant attenuation of flood flows entering the floodplain area.

The Barellan floodplain is fed by the following sources:

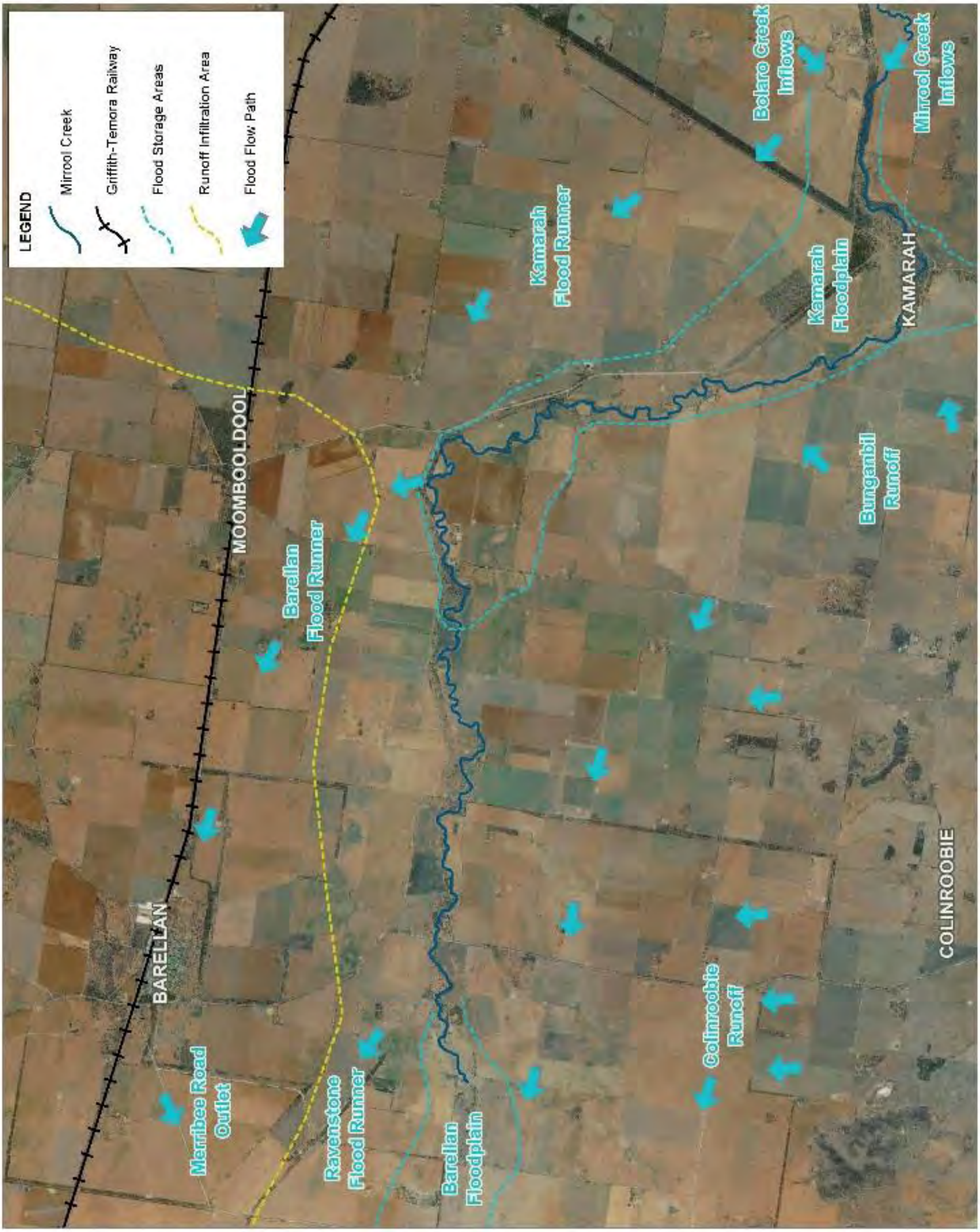
- Flows from the upper Mirrool Creek catchment, which is well-defined downstream to Ardlethan;
- Local catchment runoff from the Colinroobie area to the south; and
- Rain falling directly on to the floodplain.

Flood flows through the floodplain area are often characterised by a dual response. Rainfall over the Barellan floodplain and Colinroobie area 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 occuring. 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.

4.1.2 Barellan Township

The township of Barellan is known to have flooded only once in living memory – in the recent event of March 2012. However, it is understood that flood waters reached just short of the town in a 1928 event, and that other events have likely initiated flood flows towards Barellan on several other occasions. Additionally, periods of intense rainfall are known to result in ponded surface water within the town, although not to the extent of flooding any dwellings.

The soils of the Mirrool Creek floodplain to the south of Barellan are heavier in nature and are known to result in periodic runoff, and subsequent flooding within the broader Barellan floodplain area. During major rainfall events, runoff from the floodplain area around Kamarah initiates an active flood flow path that heads towards the Barellan township. When a sufficient volume of runoff is generated, particularly if local soils are saturated, this flood runner can extend beyond the limit of the heavier soils and be conveyed across the sandier area between Mirrool Creek and Barellan.



Title:
Schematisation of Flood Behaviour at Barellan

Figure: **4-1**

Rev: **A**

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As well as from local rainfall-runoff processes, this flood runner from Kamarah to Barellan can also be activated by significant flood flows generated from the upper Mirrool Creek catchment upstream of Barellan, as occurred during the January 1984 event. During the flood event of March 2012 the Barellan flood runner was initially activated from local runoff and was then subsequently augmented by flood flows emanating from the upper Mirrool Creek catchment.

In the event of flood flows entering the town of Barellan, the streets that are aligned on a north-south orientation obstruct the progression of flood flows through the town. With only minor provision of cross-drainage infrastructure servicing local drainage needs, the flood waters quickly build behind the raised road alignments before spilling over the road crests. This essentially results in the flooding of properties to the east of each road alignment to a depth equivalent to the height of the road crest. During the March 2012 event, flood waters were eventually drained by mechanical intervention that cut some of the critical obstructions. The flood waters then drained back to the broader Mirrool Creek floodplain area via Merribee Road.

4.2 Flood Risk Mapping

The flood results from the Draft 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 Flood Planning Area. The mapping outputs relevant to flood related planning and development are discussed below.

4.2.1 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 0.1 m 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 across the Barellan floodplain and through the town whereby floodplain flows are expansive with relatively shallow depths, the different methods for defining floodways produce the same result – where floodways are essentially restricted to the Mirrool Creek channel. Ultimately, the method used to define the hydraulic categorisation for the broader Mirrool Creek floodplain outside of Barellan township was chosen to provide consistency with the Narrandera Floodplain Risk Management Study and Plan.

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

Table 4-1 Hydraulic Categories

Hydraulic Category	Categorisation Criteria for Barellan township	Categorisation Criteria for broader floodplain	Description
Floodway	Velocity * Depth > 0.1 at the 1% AEP event	Floodplain extent defined at the 5% 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	Floodplain extent defined 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	Floodplain extent defined at the extreme flood event	Floodplain extent defined at the extreme flood event	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

Hydraulic category mapping for the Barellan floodplain and the Barellan township was defined in the flood study. It has been reproduced and included in Appendix A.

Based on the hydraulic category mapping, the floodway is largely contained within the Mirrool Creek channel and the adjacent floodplain. However, a number of tributary channels and flood runners are also identified. This includes the Kamarah to Barellan flood runner and extensive locations within the broad expansive floodplain area to the south of Barellan.

4.2.2 Flood Hazard

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
- Rate of Rise and Effective Warning Time
- Community Awareness

- Duration of Inundation
- Effective Flood Access

4.2.2.1 Size of the 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 Flood Study indicated that Barellan has a low level of flood affectation in minor flood events with the town remaining relatively flood free up to, but not including, the 2% AEP design event.

However, for flood events of equal to or greater than the 1% AEP design event, the extent of inundation is relatively large, with broadly the entire town becoming inundated by over 0.3 m of flood water. 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 Barellan.

4.2.2.2 Rate of Rise and Effective Warning Time

The rate of rise of floodwaters is typically a function of the topographical characteristics of the catchment such as size, shape and slope, and other 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 flat nature of the study area and large contributing catchments provides for extended periods of rise of floodwaters. For the Barellan township, the typical rates of rise of floodwater don't pose significant additional flood risk.

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.

During the March 2012 event, there was around 24 hours from the onset of rainfall to when the Barellan town became inundated with floodwater. This was a relatively fast response for the catchment and resulted from intense rainfall on the local catchment area. Within the March 2012 event, a second flood wave approached the town around three days after the initial onset of rainfall. This flood wave was generated from flood flows emanating from the upper Mirrool Creek catchment (i.e. upstream of Ardlethan), which broke the banks of Mirrool Creek near Mirrool Road / Moombooldool-Willows Road. The catchment response modelled for the March 2012 event is presented in Figure 4-2.

With reference to Table 4-2, the Barellan township can be considered to have a good warning time (over 12 hours) of an approaching flood event.

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.

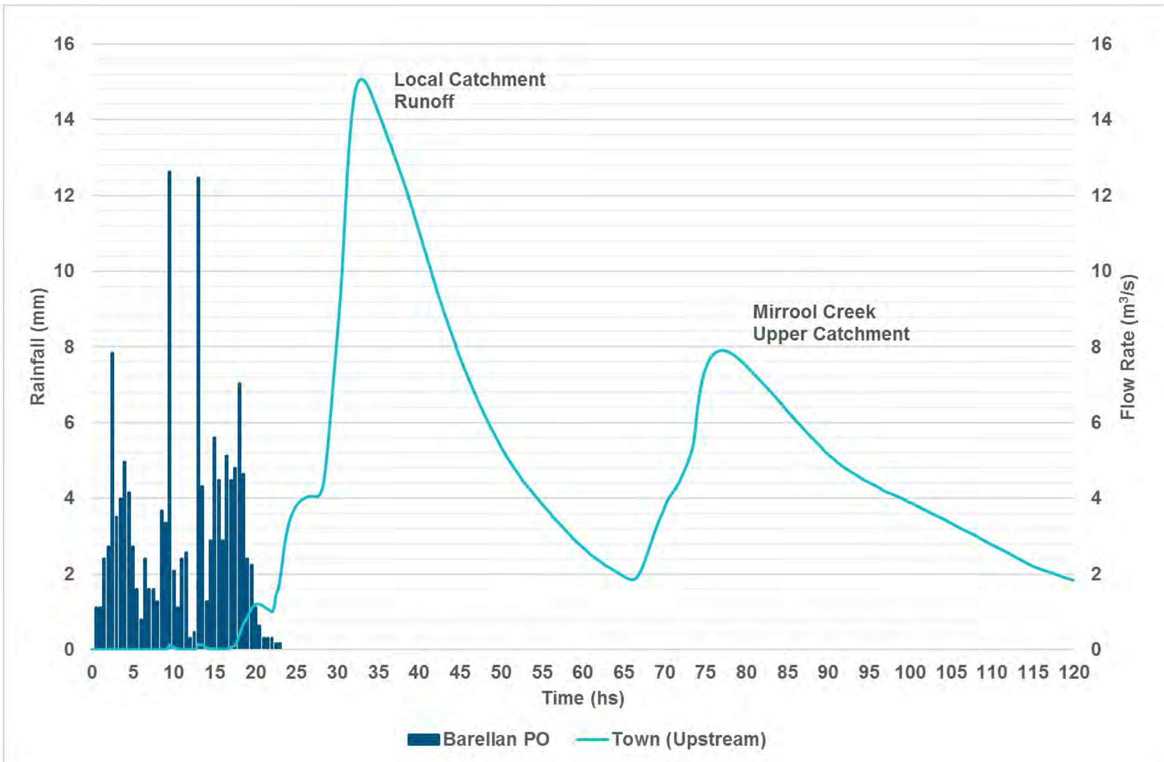


Figure 4-2 Modelled Catchment Response for the March 2012 Event

4.2.2.3 Community Awareness

The term community awareness or '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 Barellan floodplain has flooded multiple times in the past and it is expected that many landowners affected by these events would have a reasonable level of flood awareness, particularly in relation to flood effects on their own property.

The March 2012 even provided for first-hand experience of major flooding and indication to the community of the potential flood risk to the town. As this was the first event to result in flooding within the town, many residents here were not aware of the flood risk. Although this event would have highlighted the vulnerability of the town to flooding, it is anticipated that the residents will have limited knowledge of the flood risk, particularly in relation to the likely magnitude of the event and other factors (such as antecedent catchment conditions) that can significantly influence the flood behaviour in the catchment.

4.2.2.4 Duration of Inundation

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, in which inundation affected extensive parts of the township for days. Additionally, inundation of septic systems was a major impact of the March 2012 flood in town. Reports from residents indicated that all properties inundated above ground level were unable to return to their homes due to damaged systems and/or sanitation issues.

4.2.2.5 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.

Road inundation can potentially result in the isolation of flood affected property and have serious implications for emergency response.

As evident from March 2012 flood event, a number of roads in the local area are expected to be inundated in major flood events. However, even for the highest order events, the flooding behaviour in town poses limited restriction to safe evacuation and egress due to its typical low velocity.

4.2.2.6 Adopted Flood Hazard Categories

The Updating National Guidance on Best Practice Flood Risk Management (NFRAG, 2014) considers a holistic approach to consider flood hazards to people, vehicles and structures. It recommends a composite six-tiered hazard classification, reproduced in Figure 4-3. The six hazard classifications are summarised in Table 4-3.

It can be seen that the flood hazard level is determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities generally have no major threat.

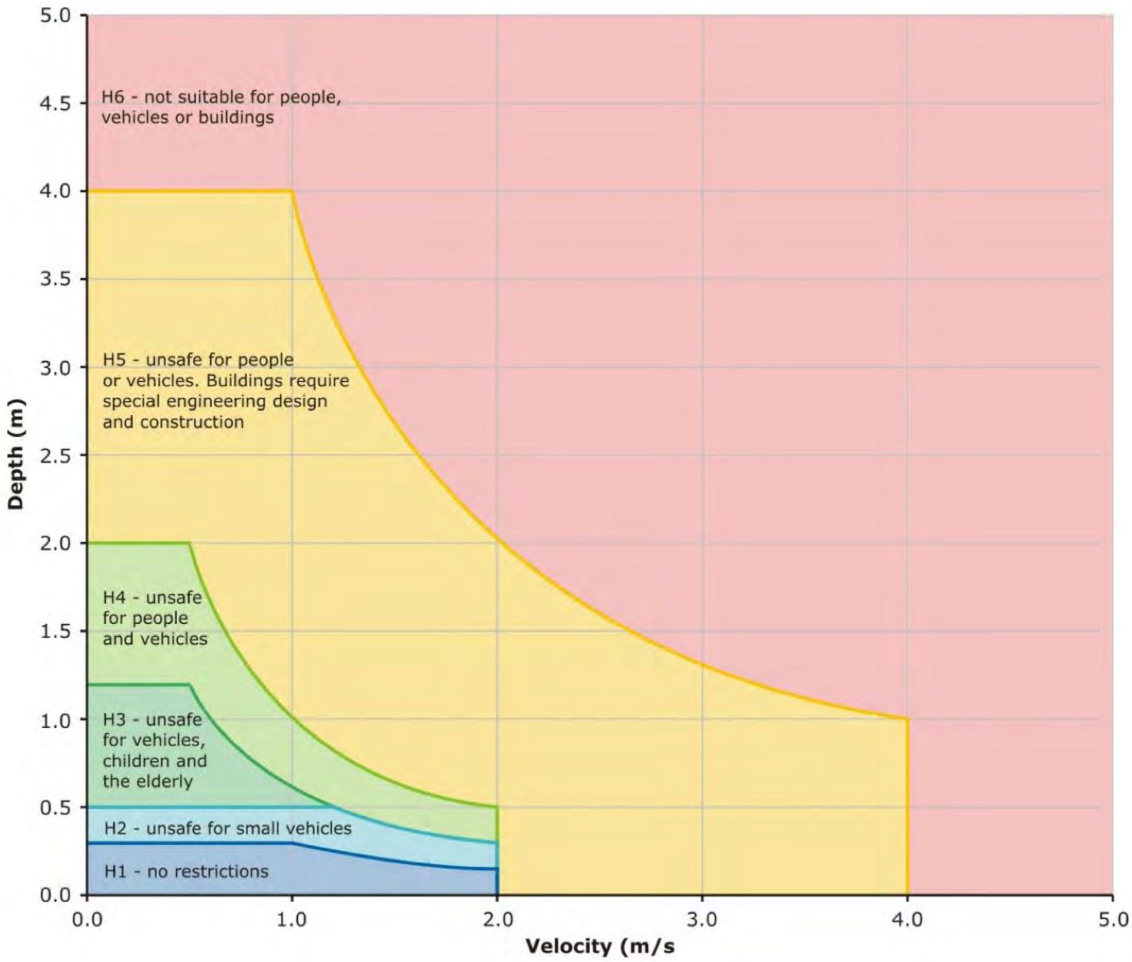


Figure 4-3 Combined Flood Hazard Curves

The Barellan Flood Study developed Provisional Flood Hazard Maps, based on hydraulic considerations only. Following review of the additional key factors, it is recommended that no modification is required to the provisional flood hazard and that the mapping is adopted as a True Flood Hazard, as presented for the 1% AEP and Extreme Flood design events in Appendix A.

Table 4-3 Combined Flood Hazard Curves – Vulnerability Thresholds

Hazard Classification	Description
H1	Relatively benign flow conditions. No vulnerability constraints.
H2	Unsafe for small vehicles.
H3	Unsafe for all vehicles, children and the elderly.
H4	Unsafe for all people and vehicles.
H5	Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

For the 1% AEP event, most of the floodplain including the town is classed as hazard category H1, and is indicative of relatively benign flow conditions that would not pose a significant flood risk to people, animals and vehicles. The floodplain hazard increases to H2 in some areas, including a portion of the Barellan township. The exception is the Mirrool Creek channel, where higher depths and flow rates modelled result in a hazard category of H5 to H6 for the 1% AEP event. For the Extreme Flood event, the township hazard increases to H3. This is a relatively low hazard for an extreme event and is largely driven by low flood velocities. However, it does present an increased risk for children and the elderly.

5 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 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.

5.2 Basis of Flood Damage Calculations

Flood damages have been calculated using a database 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.

There is no existing property floor level survey available for Barellan. The floor levels for 244 dwellings located within the floodplain where estimated from the LiDAR DEM, with floor level above ground level estimated from a drive-by assessment. The results of this assessment were validated using information relating to the March 2012 flood event, during which approximately one third of properties are understood to have been inundated above floor.

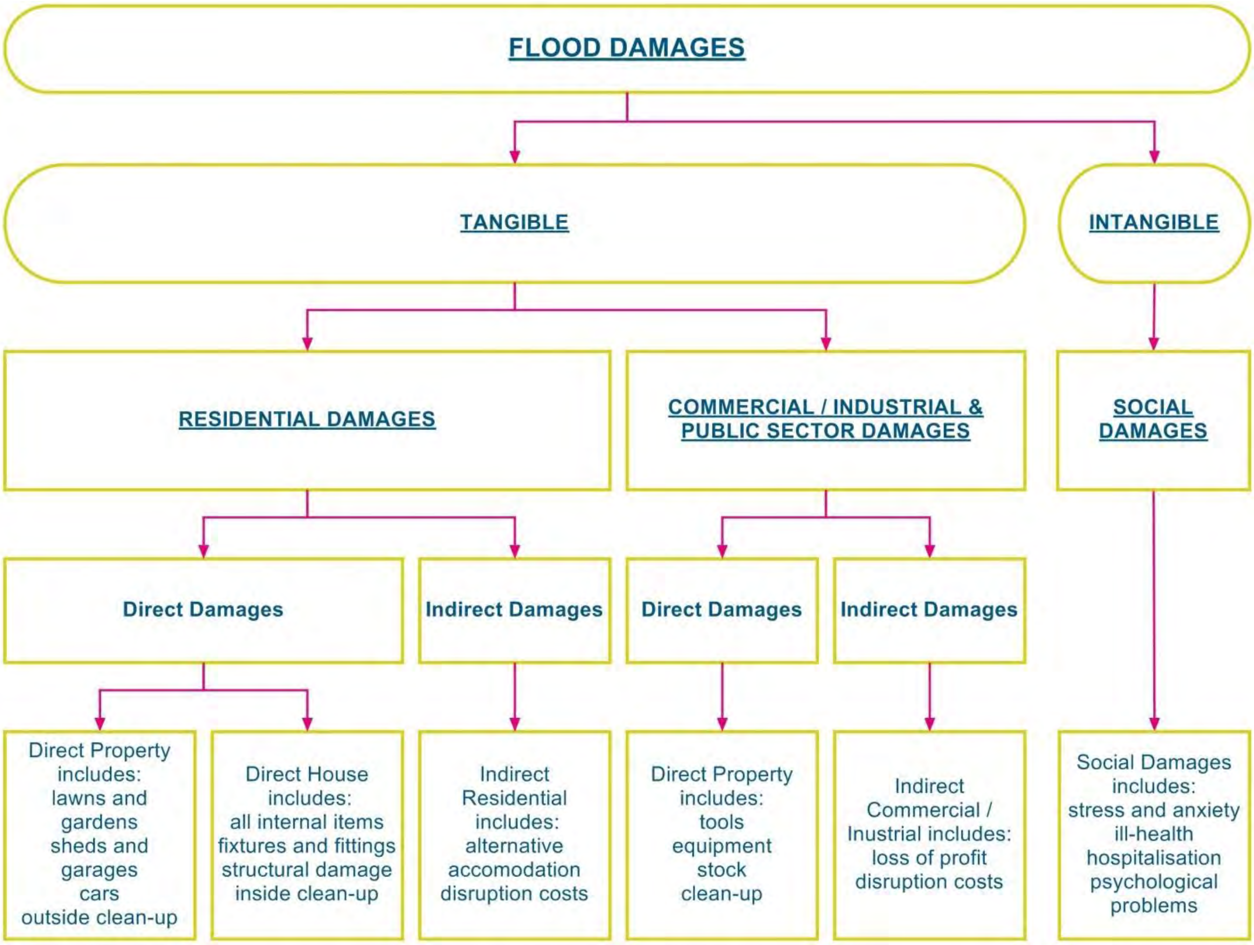


Figure 5-1 Types of Flood Damage

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

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

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;
- Infrastructure damage, based on a percentage of the total value of residential and business flood damage; and
- Intangible damages that 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 preliminary 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 Tangible Flood Damages

5.3.1 Assessment of Direct Damages

The peak depth of flooding was determined at each property for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and the Extreme Flood event. The associated direct flood damage cost to each property was then estimated from the stage-damage relationships. The flood damage curves include a flat $11,725 cost of external damages for any level of flood inundation incurred below floor level. For instances where the property is not inundated above floor level and the external flood depth is below 0.3 m, this value is considered to be overly conservative. Therefore, a nominal $5,000 value has been adopted for external flood damages for below floor flooding of less than 0.3 m. This value includes costs associated with septic system repair and disinfection – as this was a major impact of the March 2012 flood event. Total damages for each flood event were determined by summing the predicted damages for each individual property.

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 risk management measures (i.e. the reduction in the AAD), investigated in Section 7.

5.3.2 Estimation of Indirect Damages

The indirect damages are more difficult to determine and would vary for each flood event, particularly with the duration of the flood inundation. Previous studies detailing flood damages from actual events have found that the indirect damages for residential properties are typically in the order of 20% of the direct damages. Given the relative uncertainty associated with the indirect damages a value of 20% of the direct damages has also been adopted for this study.

The indirect damages associated with commercial properties are typically higher and a value of 40% of the calculated direct damages has been adopted.

5.4 Barellan Flood Damages

5.4.1 Residential Flood Damages

The assessment of the residential flood damages is presented in Table 5-1. From this data the AAD for residential properties was calculated as being $79,000 in direct damages and $19,000 in indirect damages, giving a total value of $98,000.

5.4.2 Commercial Flood Damages

The assessment of the commercial flood damages is presented in Table 5-2. From this data the AAD for commercial properties was calculated as being $4,000 in direct damages and $1,000 in indirect damages, giving a total value of $5,000.

5.4.3 Infrastructure and Public Sector Flood Damages

Public utilities and infrastructure include roads, railways, parklands and underground water, sewerage, power and telephone services and installations. The damages sustained by public utilities comprise the replacement or repair of assets damaged by floodwaters, the cost of clean-up of the installations, as well as the collection and disposal of clean-up material from private property.

Damage incurred to public utilities and infrastructure during a flood event was estimated as 30% of the combined tangible (direct and indirect) damages to residential and commercial properties.

Table 5-1 Summary of Residential Flood Damages

Design Event	Properties Flooded Above Floor (and Ground)	Direct Damages ($)	Indirect Damages ($)	Total Damages ($)
20% AEP	0 (0)	$0	$0	$0
10% AEP	0 (0)	$0	$0	$0
5% AEP	0 (0)	$0	$0	$0
2% AEP	22 (40)	$461,000	$110,000	$571,000
1% AEP	69 (110)	$2,559,000	$602,000	$3,162,000
0.5% AEP	118 (94)	$5,250,000	$1,230,000	$6,480,000
0.2% AEP	163 (58)	$7,820,000	$1,801,000	$9,622,000
Extreme Flood	208 (14)	$11,331,000	$2,614,000	$13,945,000
AAD	**-**	**$79,000**	**$19,000**	**$98,000**

Table 5-2 Summary of Commercial Flood Damages

Design Event	Properties Flooded Above Floor	Direct Damages ($)	Indirect Damages ($)	Total Damages ($)
20% AEP	0	$0	$0	$0
10% AEP	0	$0	$0	$0
5% AEP	0	$0	$0	$0
2% AEP	1	$1,000	$0	$1,000
1% AEP	13	$131,000	$52,000	$183,000
0.5% AEP	16	$268,000	$107,000	$375,000
0.2% AEP	17	$395,000	$158,000	$553,000
Extreme Flood	20	$530,000	$212,000	$742,000
AAD	**-**	**$4,000**	**$1,000**	**$5,000**

5.4.4 Total Tangible Flood Damages

The total tangible flood damages for residential properties, commercial properties and the public sector were combined, as presented in Table 5-3. From this data, the combined AAD was calculated as being $134,000, comprised as follows:

- $98,000 from residential properties;
- $5,000 from commercial properties; and
- $31,000 from infrastructure and public sector.

Table 5-3 Summary of Total Tangible Flood Damages

Design Event	Residential Flood Damages ($)	Commercial Flood Damages ($)	Infrastructure and Public Sector Damages ($)	Total Tangible Flood Damages ($)
20% AEP	$0	$0	$0	$0
10% AEP	$0	$0	$0	$0
5% AEP	$0	$0	$0	$0
2% AEP	$571,000	$1,000	$171,000	$743,000
1% AEP	$3,162,000	$183,000	$1,003,000	$4,348,000
0.5% AEP	$6,480,000	$375,000	$2,057,000	$8,912,000
0.2% AEP	$9,622,000	$553,000	$3,052,000	$13,227,000
Extreme Flood	$13,945,000	$742,000	$4,406,000	$19,093,000
AAD	**$98,000**	**$5,000**	**$31,000**	**$134,000**

6 Review of Existing Flood Planning Provisions

Land use planning and development controls are key mechanisms by which Council can manage some of the flood related risks within flood-affected areas within their Local Government Area (LGA). Barellan is situated within the Narrandera LGA. The extent of the Narrandera LGA is shown on Figure 1-1.

The objective of this section is to:

- Review existing planning and development control framework relevant to the formulation of planning instruments and the assessment of development applications in the Mirrool Creek floodplain at Barellan. Specifically, this will include review of the Narrandera Local Environment Plan (LEP) and Narrandera Development Control Plan (DCP).
- Make specific planning recommendations in regards to flood risk management, including an outline of suggested planning controls with the aim to provide consistency in the approach adopted across the entire LGA.

6.1 Local Environment Plan

A Local Environmental Plan (LEP) is prepared in accordance with Part 3 Division 4 of the Environmental Planning and Assessment (EP&A) Act 1979 and operates as a local planning instrument that establishes the framework for the planning and control of land uses. The LEP defines land use zones and specific development standards and special considerations with regard to the use or development of land.

The Narrandera LEP 2013 (Narrandera Shire Council, 2013) has been prepared in accordance with the NSW State Government's Standard Instrument (Local Environmental Plans) Order 2006, which was created to assist Councils by guiding a common format and content for the plans.

The LEP is set out such that Part 1 to Part 5 are mandatory guidelines to be included for each LGA. Part 6 of the Narrandera LEP is for "Additional local provisions" and contains specific details in regard to flood planning considerations (Clause 6.2).

The key requirements of this study in relation to the LEP provisions include:

- Establishment of Flood Planning Levels – the general flood planning level is the 1% AEP design level plus 0.5 m freeboard, as noted in the LEP. Design flood behaviour for the full range of design events, including the 1% AEP design event, was established in the Flood Study.
- Definition of Flood Planning Area – the Flood Planning Area (FPA) encompasses the land below the Flood Planning Level (FPL). Discussion surrounding an appropriate definition of the FPA for the study area is contained in Section 7.2.2.4.
- Description of Flood Risk/Hazard – in addition to the flood inundation mapping, floodplain classifications of hydraulic category (floodway, flood storage, flood fringe) and flood hazard (low hazard high hazard) were established in the Flood Study. Additional information surrounding these mapping outputs is contained in Section 4.2.

Mapping outputs from the Flood Study that are relevant to this study have been reproduced in Appendix A.

6.1.1 Land Use

The LEP identifies a number of land use zones including existing and future development areas, based on stated objectives for each zoning and provisions made for each zoning.

There are six main land use zones identified within the Barellan floodplain study area. The distribution of these land use zones across the catchment is shown in Figure 6-1 along with the 1% AEP design flood extent for reference.

Table 6-1 Land Use Zones within the Barellan Study Area

Rural Zones
RU1 – Primary Production
RU3 – Forestry
RU5 – Village
Environmental Protection Zones
E2 – Environmental Conservation
E4 – Environmental Living
Residential Zones
R5 – Large Lot Residential

It is evident from Figure 6-1 that the majority of the study area within the 1% AEP flood extent area comprises land use zone RU1 Primary Production. Within the township of Barellan, most of the residential area is classed as RU5 Village. There are also smaller parcels of Environmental Zones E2 and E4 located on the western edge of town and areas of RU3 Forestry located in Moombooldool and Kamarah. Although floodplain inundation during the 1% AEP design flood is quite extensive the hydraulic hazard on the floodplain is relatively low (refer to Section 4.2.2).

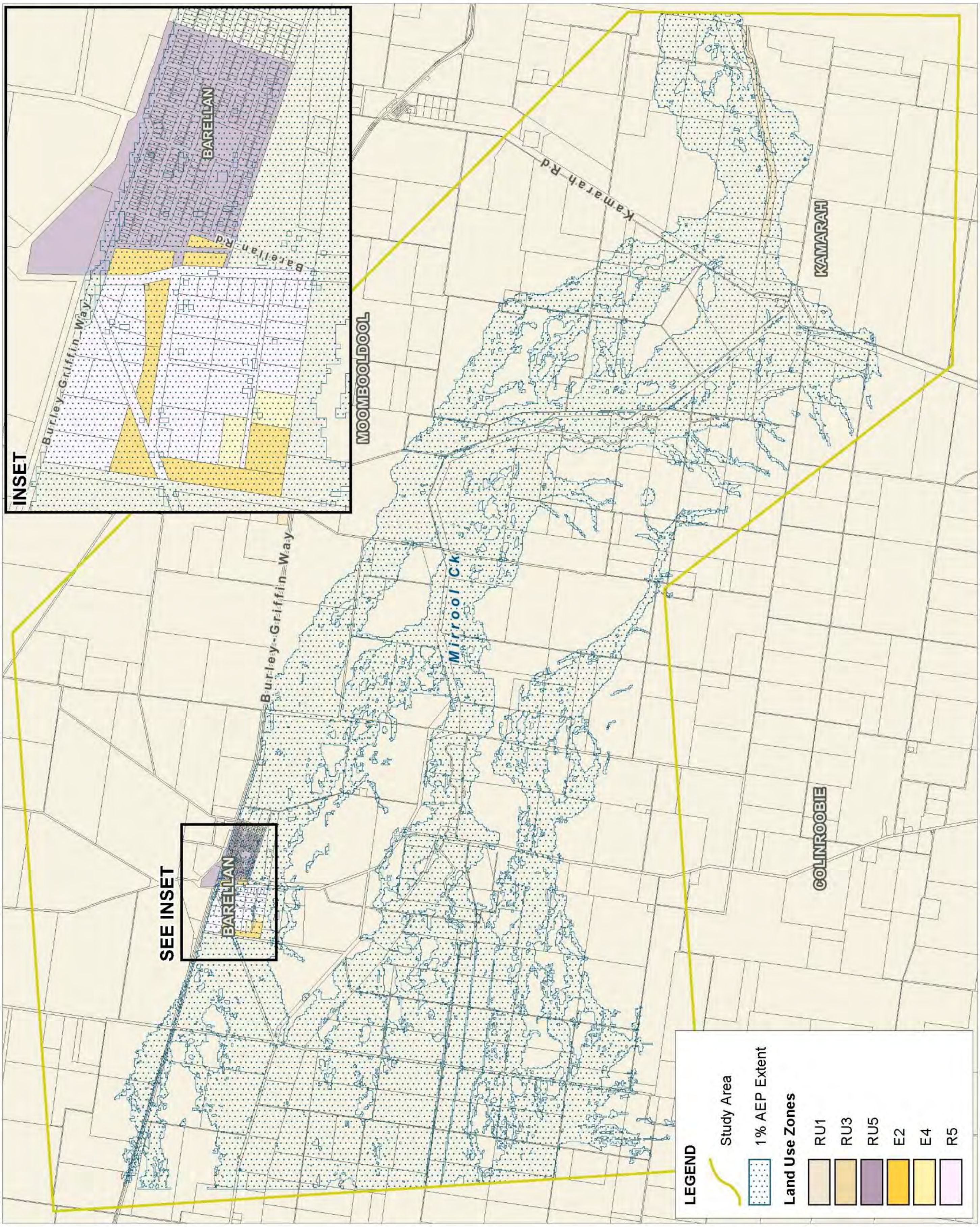
6.1.2 Flood Planning

Clause 6.2 of the Narrandera LEP 2013 relates to the use of flood liable land. The LEP provisions incorporate general considerations in regard to development of flood liable land. These provisions require the approval process to consider the impact of proposed development on local flood behaviour and the impact of flooding on the development. The Clause applies to:

- land identified as the FPA,
- other land at or below the FPL.

6.2 Development Control Plan

A Development Control Plan (DCP) is prepared in accordance with Section 72 of the Environmental Planning and Assessment Act 1979 and Clauses 16 to 25 of Part 3 of the Environmental Planning and Assessment Regulation 2000. A DCP effectively complements an LEP by providing more detailed provisions with respect to development in particular areas, and is to be considered by Council in determining development applications.



Title:
Barellan Floodplain Land Use (Narrandera LEP 2013)

Figure: **6-1**

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.

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Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_6-1_170926_Land_Use.WOR

The Narrandera DCP was adopted on 2 July 2013 and contains within one document various policies and guidelines affecting development proposals within the Narrandera Shire LGA.

6.2.1 Flood Liable Land

Specific controls applicable to flood liable land are contained in the Narrandera DCP 2013 Part E – Planning for Natural Hazards – Chapter 11 Flood liable land. The objectives of the plan are to provide clear guidelines for development of the land so that the provisions of the LEP 2013 are satisfied, while minimising the flood risk to life and property associated with the development of the land.

The two main development controls relating to flood liable land as described in the DCP 2013 are the provision of minimum height floor levels and flood proofing. House raising and filling in the floodplain are briefly discussed but are not endorsed for implementation by Council.

In addition to controls relating to minimum height floor levels and flood proofing, the "Flood Policy Matrix" (SMK, 2009) has been incorporated into the DCP as the "Flood Development Control Matrix." The matrix lists the controls applicable to different types of development depending on where it is to be located within the flood plain (i.e. floodway, flood storage or flood fringe areas).

These planning controls are discussed below.

Minimum Floor Levels

The plan adopts the following FPLs, as determined by SKM (2009), to determine minimum floor level requirements within the LGA:

- The 1% AEP design flood level plus 500 mm freeboard for residential development (in accordance with the NSW Floodplain Development Manual (OEH, 2005).
- The 5% AEP design flood level for commercial / industrial development.

The DCP currently only includes levels for the township of Narrandera and its surrounds.

Flood Proofing

Flood proofing aims to minimise damage incurred to both the structure and its contents if inundated with water.

The DCP specifically emphasises that flood proofing will not completely eliminate the flood risk but is appropriate to use in conjunction with other flood planning measures such as minimum floor level requirements. It also suggests that flood proofing is only suitable for use at commercial premises. Some flood compatible building materials and other flood proofing methods are suggested.

Flood Development Control Matrix

The purpose of the matrix is to reduce the flood risk associated with development within the floodplain. The categories included in the Flood Development Control Matrix are detailed in Table 6-2. With reference to Table 6-2, different planning considerations (e.g. flood level requirements) are applicable to different development types (e.g. residential buildings), depending on where in the floodplain they are constructed (i.e. flood fringe, flood storage or floodway).

Although permissible developments are defined on a land-use basis in the LEP (see Section 6.1.1), flood controls detailed in the matrix may prevent development being granted by Council on all or part of a site.

Table 6-2 Narrandera DCP 2013 Flood Development Control Matrix Factors

Matrix Factors	Description or Example
Floodplain Category	
Floodways	Defined as minimum bank full level for all creeks and waterways, the 5% AEP design flood inundation extent and areas within the 1% AEP design extent that are sensitive to blockage.
Flood storage	The area between the floodway and the 1% AEP design event.
Flood fringe	Remaining area located up to the extent of the Extreme Flood event.
Planning Consideration	
Floor level	Habitable and non-habitable floor level requirements.
Building components	Requirement for flood compatible building structures up to specified level.
Structural soundness	Requirements for structure to withstand forces of floodwater, debris and buoyancy up to specified level.
Flood affectation	Assessment of the flood impact that the development will have on adjoining land.
Evacuation	Requirements for evacuation routes and/or evacuation plans.
Management and design	Specific development design and/or planning to accommodate flooding (e.g. storage space requirements, collapsible fencing, building alignment).
Development Type	
Critical uses and facilities	Hospitals, police, fire and ambulance stations, SES headquarters.
Sensitive uses and facilities	Aged care housing, schools, waste disposal facilities.
Residential	Residential dwellings, flats, caravan parks (long-term sites).
Commercial	Business premises, retail, hotels, religious places.
Industrial	Light industry, livestock/plant keeping.
Recreation and agriculture	Caravan parks (short-term sites), nurseys, agriculture, forestry, mining.
Other development	Not included elsewhere.

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

As outlined in Section 2.3.1, the *Guidelines for Mirrool Creek Floodplain Development Barellan to Yenda* provide the most recent floodplain risk management guidelines applicable to the study area. The following points are advised in the document, accompanied by the designated floodway mapping:

- any system of floodways should conform as closely as is reasonably possible to the natural drainage pattern;
- land that can be protected can be maximised providing that no other properties are adversely affected as a result;
- floodways should discharge from holding as closely as practicable to the location of natural floodways;
- where floodways are of minimum width, they should be maintained in a clear condition or sown only to low crops or pastures;
- the exit of floodwater from floodways should be at rates and depths similar to those which would have been experienced under natural conditions;
- care must be taken to ensure that sufficient pondage is retained on the floodplain so that the flood wave is not unduly accelerated to downstream areas and its height is not significantly increased above the naturally occurring height;
- provisions should be made for local drainage from protected areas, but the design of such drainage is the responsibility of individual landholders.

As stated in the document, these are typical guidelines for floodplain risk management and are not specific only to the Mirrool Creek floodplain. In terms of the suitability of these guidelines to agricultural practices in the Barellan floodplain, they are relatively high-level and lack detail as to how the floodplain risk management targets listed above are to be achieved or assessed for compliance. Also, the floodways that exist on the ground do not match exactly with the extents defined within the document.

7 Potential Floodplain Risk Management Measures

This chapter identifies options for improving flood management within Barellan. 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.

Potential floodplain risk management options for Barellan have been discussed during the course of the study through the Community Consultation process (see Section 3 for further detail). From these discussions, a number of potential flood management options were identified.

This section describes the potential options and provides a first-pass assessment to determine if they would be applicable / suitable to the flooding environment of Barellan. For those options that were considered applicable / suitable, a more detailed assessment including a cost-benefit analysis was undertaken.

7.1 Overview of Potential Flood Modification Options

Potential flood modification measures are focused on options that will mitigate the flood risk to the Barellan township. 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.

Due to the rural nature and flood behaviour of the catchment, a levee to divert floodwaters away from the town was identified to be the most suitable structural flood modification measure for Barellan. A number of potential levee locations were identified. All levee locations are aligned with existing road ways and it is envisaged that the levee could be an earthen embankment along the roadside or incorporated through future road upgrade works to raise the crest elevation of the road.

Improvements to existing drainage within the town was also considered as an option to alleviate flooding within the town.

A summary of the "structural" flood modification measures considered in the preliminary assessment is provided in Table 7-1. Section 7.2 assesses the effective performance of each measure with the aim of identifying a shortlist of options to be considered for detailed investigation (in Section 7.2.1.5).

Table 7-1 Summary of Potential Flood Modification Measures

ID	Location / Description	Comments
Levee		
Opt 1a	**Barellan township:** Box Street	Construction of a levee along the alignment of Box Street located at the eastern end of the Barellan township. The levee function is to divert floodwater around the town during major flood events.
Opt 1b	**Barellan township:** Box Street / Kurrajong Street	Construction of an "L" shaped levee along the alignment of Box Street and Kurrajong Street located at the eastern and southern end of the Barellan township. The levee function is to divert floodwater around the town during major flood events.
Opt 1c	**Barellan township:** Barellan Cemetery Road / Kurrajong Street	Construction of an "L" shaped levee along the alignment of Cemetery Road (located around 600 m to the east of town along Burley Griffin Way) and Kurrajong Street. The levee function is to divert floodwater around the town during major flood events.
Opt 2a	**Mirrool Creek:** Mirrool Road / Moombooldool-Willows Road	Construction of an "L" shaped levee along the alignment of Mirrool Road and Moombooldool-Willows Road located adjacent to Mirrool Creek. The levee function is to prevent floodwater from spilling from Mirrool Creek at this location and to divert the locally generated flood runner back toward Mirrool Creek during major flood events.
Opt 2b	**Mirrool Creek:** Mirrool Road	Construction of a levee along the alignment of Mirrool Road located adjacent to Mirrool Creek. The levee function is to prevent floodwater from spilling from Mirrool Creek at this location during major flood event.
Opt 2c	**Mirrool Creek:** Moombooldool-Willows Road	Construction of a levee along the alignment of Moombooldool-Willows Road located adjacent to Mirrool Creek. The levee function is to divert the locally generated flood runner back toward Mirrool Creek during major flood events.
Drainage Works		
Opt 3a	**Barellan township:** Culvert cross-drainage upgrade	Culverts providing cross-drainage within the town have been identified by the community as potentially constraining the passage of floodwater through the town. The merit of increasing capacity at each road cross-drainage culvert structure in Barellan has been investigated.
Opt 3b	**Barellan township:** Lowering road crests	The elevated road crests within the town obstruct the progression of flood flows through the town. The merit of lowering the road crests to ground level has been investigated.

7.1.1 Levees

Effective control of floodplain flows toward the Barellan township can be achieved through the construction of a levee. Flooding of the Barellan township can be driven by local catchment runoff or by flows from the upper catchment spilling from Mirrool Creek at Mirrool Road / Moombooldool-Willows Road. During flood events, the town remains inundated by floodwater for days. The potential to remove or lessen the volume of floodwater in the town will be beneficial at reducing the direct and indirect damages, as well as the intangible damages (e.g. stress and anxiety) associated with residents displaced from their homes for an extended period of time.

The levee alignments described in Table 7-1 have been incorporated into the Ardlethan to Barellan catchment flood model developed for the Barellan Flood Study. The levee structures have been modelled in the hydraulic model as “z-shapes” (3D topographical break lines) representing the crest of the levee embankment. For the purpose of the preliminary assessment, the levee crest was assumed to be sufficiently high as to not be overtopped during the 1% AEP flood event.

For each of the levee options simulated, the change in peak flood level modelled across the Barellan floodplain of Mirrool Creek for the 1% AEP was calculated. These results have been mapped and are presented in Appendix B. The results of the preliminary assessment are summarised in Table 7-2.

7.1.2 Drainage Upgrade Works

In the event of flood flows entering the town of Barellan, the streets that are aligned on a north-south orientation obstruct the progression of flood flows through the town. With only minor provision of cross-drainage infrastructure servicing local drainage needs, the flood waters quickly build behind the raised road alignments before spilling over the road crests. This essentially results in the flooding of properties to the east of each road alignment to a depth equivalent to the height of the road crest. The low grade of the floodplain combined with inadequate local drainage resulted in floodwaters remaining elevated for days after the event. The two options considered to improve local drainage within the town were:

- Culvert cross-drainage upgrade; and
- Lowering of road crests.

Culvert cross-drainage upgrade

To simulate the culvert cross-drainage upgrade scenario, the capacity of each of the culverts modelled within the Barellan town hydraulic model was increased by a factor of four and the 1% AEP design flood event was simulated. Although flow conveyance under roads was increased, this did not translate to a reduction in peak flood levels with a negligible peak flood level impact modelled.

Lowering of road crests

The Barellan town hydraulic model was modified to reduce the crest elevation of the north-to-south aligned roads. Sections of Kooba Street, Yarran Street, Boree Street, Myall Street and Kurrawang Street between Bendee Street and Mallee Street were lowered to the adjacent ground level. The 1% AEP design flood was simulated.

Table 7-2 Preliminary Assessment of Levee Alignments

ID	Location / Description	Levee Length	Comments for the 1% AEP Event	Investigate Further?
Opt 1a	**Barellan township:** Box Street	0.8 km	Reduction in peak flood levels in town in the order of 0.1 - 0.3 m. Increase in peak flood levels upstream of levee.	Yes
Opt 1b	**Barellan township:** Box Street / Kurrajong Street	2.1 km	Complete removal of flood inundation of town. Increase in peak flood levels upstream of levee and to the south of town.	Yes
Opt 1c	**Barellan township:** Barellan Cemetery Road / Kurrajong Street	2.8 km	Complete removal of flood inundation of town. Increase in peak flood levels upstream of levee and to the south of town.	Yes
Opt 2a	**Mirrool Creek:** Mirrool Road / Moombooldool-Willows Road	4.7 km	Reduction in peak flood levels in town of around 0.2 m. Increase in peak flood levels along Mirrool Creek and adjacent floodplain of around 0.1 m. Extensive redistribution of floodwater to the north along Moombooldool-Willows Road and across Burley Griffin Way inundating previously flood-free land to the northern of Burley Griffin Way.	No
Opt 2b	**Mirrool Creek:** Mirrool Road	2.7 km	Reduction in peak flood levels in town in the order of 0.05 - 0.1 m. Increase in peak flood levels along Mirrool Creek and adjacent floodplain of around 0.1 m.	Yes
Opt 2c	**Mirrool Creek:** Moombooldool-Willows Road	1.5 km	No reduction to peak flood levels in town. Increase in peak flood levels upstream of Moombooldool-Willows Road of up to 0.7 m with additional overtopping of the road north of the levee.	No

As the drainage upgrade works considered did not translate into any significant reduction in peak flood levels in town (and hence no reduction in flood damages), these options were not considered for further investigation in this study. Whilst it is true that the road crests provide a localised obstruction to flood flows, the broader topography within Barellan still results in similar peak flood levels within the town during flood conditions. There are some localised benefits to the lowering of road crests at the 1% AEP event (as presented in Appendix B), however, these are significantly diminished for larger magnitude events. In summary, the potential benefits of road crest lowering are not significant enough to justify the option and would also become redundant if a levee option is constructed.

The observations during the March 2012 event were that the water was held in town for days until the roads were cut, after which the flood waters quickly subsided. However, the timing of the cutting of roads and draining of flood waters coincided with the recession of the Mirrool Creek flood hydrograph. Barellan was initially flooded by major overland flows from local catchment, but the duration of flooding in the town was significantly extended by subsequent spilling of flood waters from Mirrool Creek.

7.2 Options Assessment

7.2.1 Levee Options

The construction of a levee is a significant investment and involves a range of challenges that need to be overcome, including:

- Potential adverse impacts to property situated outside of the levee extent
- Constraint of potential future development outside of the levee extent
- Existing land ownership and required easement acquisition
- Relocation of existing services
- Clearing of native vegetation
- Provision of a freeboard allowance and failure mechanism for floods exceeding the standard of protection.

7.2.1.1 Levee Design Guidelines

A levee only offers protection for flood events up to the magnitude of event to which it is designed. A suitable level of freeboard is identified and the levee crest height is set at the level of the design flood plus the freeboard allowance. Whilst the constructed crest height might be higher than large flood events than the design magnitude, the levee does not guarantee protection against them and this needs to be taken into account when designing and undertaking modelling assessments of the levee.

OEH Guidelines regarding considerations of levee design principally relate to the construction of levees for the protection against mainstream flooding. Flooding at Barellan may be derived from local catchment runoff and/or mainstream flooding sources, but the remote location of the town from Mirrool Creek means that the nature of flooding is that of major overland flows. Although the flood depth of overland flows is less than that of mainstream watercourses, the design of a levee for Barellan is still required to adhere to the design principles of the guidelines if it is to be funded and maintained by the State government as a levee structure.

The level of freeboard selected during levee design typically ranges from 0.5 m to 1.0 m and considers factors such as flood depth, duration and length of fetch across the floodplain. Due to the relatively shallow flood depths of overland flood flows at Barellan, the minimum freeboard of 0.5 m is deemed suitable.

The design of a levee also needs to consider failure mechanisms for flood events greater than the design flood magnitude. For existing levees, modelling assessments include breaching of the levee for the larger flood events. For the design and construction of new levees it is standard practice to incorporate controlled breaching into the design through the construction of spillways set at a lower height than the broader levee crest. In order to achieve the desired standard of protection the spillway crests are set at the chosen design flood level plus the freeboard level and the broader levee crest is constructed to a higher level. Therefore, a levee with a 1% AEP standard of protection at Barellan requires spillways 0.5 m higher than the post-levee 1% AEP flood level and a broader levee crest height say 0.8 m higher than the 1% AEP flood.

The OEH Guidelines require a reasonably significant levee height, regardless of to what standard of protection the levee is constructed. As the 0.2% AEP flood level at Barellan is only around 0.3 m higher than that of the 1% AEP flood level, it is reasonable to design a levee to the 0.2% AEP flood event. For events in excess of the 0.2% AEP the levee becomes bypassed by flows spilling over the Burley Griffin Way and the railway along the northern boundary of Barellan, acting as a suitable failure mechanism.

7.2.1.2 Modelling Assessment

Three of the levee options listed in Section 7.1 were identified as being suitable for further investigation. The modelled levee crest was set above the 0.2% AEP post-levee flood level and design events from the 2% AEP to the Extreme Flood event were simulated. The change in peak flood level modelled across the Barellan floodplain of Mirrool Creek for each design event was calculated. The results for Option 1a, Option 1b, Option 1c and Option 2b have been mapped and are presented in Appendix C, Appendix D, Appendix E and Appendix F, respectively.

7.2.1.3 Adverse Impacts

The construction of a levee inevitably results in increased peak flood conditions within locations outside of the protected area. The intent of the levee construction is to provide for an overall greater benefit through the net reduction in flood damages. Nonetheless, it is important to consider the properties that may be adversely affected by the construction of a levee and to mitigate any impacts where possible.

Due to the rural nature of the area, the impacts affect only a few existing properties. Table 7-3 summarises the number of dwellings affected as a result of the levee construction for each of the design events considered. The magnitude of modelled increase in peak flood levels is indicated in terms of the peak and average impact for the affected properties. Modelled peak flood levels at the water storage to the east of Cemetery Road are impacted at the PMF event only, with increases in the order of 0.1 m for both levee Options 1b and 1c. It should be noted that properties located beyond the extent of the property database established for this study may also be adversely impacted as a result of levee construction.

As part of any future levee design considerations for Barellan the impacted properties will need to be assessed to determine whether the modelled flood level impacts present a significant increase in flood risk. Some of the impacted dwellings may be elevated above the flood levels and be relatively unaffected by the modelled impacts. However, other dwellings may be adversely impacted and require local mitigation measures in order to offset the modelled impacts. This may include measures such as local bunding to provide increased protection or house raising to lift the dwelling above the impacted flood level.

For this preliminary assessment, the dwellings identified as being potentially impacted by the construction of a levee have been considered within the calculation of flood damages, option costing and BCRs. For dwellings that are significantly impacted a cost for house raising has been assumed where feasible, with a higher cost being assumed where the building construction would not accommodate such mitigation. It has been assumed that these mitigated dwellings would be protected to the Flood Planning Level and therefore free from any flood damages above floor level.

Table 7-3 Dwellings Impacted from Levee Construction

Impact	Option 1a				
	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
No. of dwellings	4	13	14	11	13
Maximum flood level impact	0.07 m	0.19 m	0.26 m	0.27 m	0.24 m
Average flood level impact	0.04 m	0.04 m	0.07 m	0.08 m	0.08 m
Impact	**Option 1b**				
	2% AEP	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
No. of dwellings	4	13	15	15	16
Maximum flood level impact	0.08 m	0.20 m	0.27 m	0.29 m	0.26 m
Average flood level impact	0.04 m	0.05 m	0.07 m	0.08 m	0.08 m
Impact	**Option 1c**				
	2% AEP	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
No. of dwellings	5	11	10	9	10
Maximum flood level impact	0.30 m	0.56 m	0.54 m	0.51 m	0.46 m
Average flood level impact	0.13 m	0.19 m	0.20 m	0.21 m	0.20 m
Impact	**Option 2b**				
	2% AEP	**1% AEP**	**0.5% AEP**	**0.2% AEP**	**PMF**
No. of dwellings	-	1	1	-	2
Maximum flood level impact	-	0.02 m	0.01 m	-	0.01 m
Average flood level impact	-	0.02 m	0.01 m	-	0.01 m

Another consideration for the selection of either Levee Option 1b or 1c is the impact on future development within Barellan. The construction of a levee often constrains future development to areas within the levee protection and so it is important to consider whether future growth expectations are accommodated within the selected levee alignment. Option 1c provides for the protection of a greater area of land than does option 1b. However, future development outside of the levee alignment can still be managed from a flood risk perspective through the appropriate adoption of flood planning requirements.

7.2.1.4 Constructability Issues

There are a number of constructability issues that need to be considered when determining a preferred levee alignment. Existing land ownership can significantly impact both the logistical and economic costs of a particular alignment. Locating the levee within public space is more straightforward than having to position it within private land, which involves the purchasing of easements. The levee options 1b and 1c have been aligned along existing road reserves in order to minimise the potential land acquisition. The Kurrajong Street alignment is also adjacent to Barellan Common, allowing further flexibility in specific alignment options.

Whilst locating a levee within the road reserve limits the need for land acquisition, it increases the potential conflict with existing services. There is the potential need for existing services to be relocated or protected, which can have overall time and cost implications for construction. Locating the levee within public space such as Barellan Common will reduce the potential conflict with existing services. However, this would require the clearing of native vegetation along the proposed alignment. Although the economic cost of vegetation removal is likely to be relatively low, there is the potential for more significant environmental impacts, depending on the nature of vegetation being removed. The levee options have been costed for alignments both along the existing roads and as an adjacent standalone configuration. However, the cost of potential land acquisition has not been considered.

One of the key components of any levee option at Barellan is the tying-in to the existing rail embankment at the northern end and the crossing of Burley Griffin Way. The levee needs to tie in to the rail embankment to prevent flood waters from flowing into Barellan around the northern end of the levee. This may provide some construction challenges in terms of design and the need to impact on the existing rail infrastructure. The crossing of Burley Griffin Way would require the local raising of the road, with suitable approach grades to satisfy RMS requirements. There are also logistical challenges associated with the traffic management during construction.

7.2.1.5 Benefit-Cost Analysis of Flood Modification Measures

A preliminary benefit-cost analysis has been undertaken to assess the relative merit of the selected structural flood modification options. The benefit-cost analysis considers the capital costs and associated reduction in flood damages of each option.

The calculation methods used to predict the baseline flood damages were presented in Section 5. Updated damages have been calculated using the modelled flood results assuming implementation of the proposed works as discussed above.

Table 7-4, Table 7-5, Table 7-6 and Table 7-7 show the estimated reductions in flood damages for Levee Option 1a (Box Street), Option 1b (Box Street/Kurrajong Street), Option 1c (Barellan Cemetery Road/Kurrajong Street) and Option 2b (Mirrool Road). Levee Options 1a, 1b, 1c and 2b provide Annual Average Damage savings of $60,000, $113,000, $113,000 and $35,000, 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.

Table 7-4 Flood Damages Reductions for Barellan Township Levee Option 1a

Damage Sector	Reduction in Flood Damages ($,000)					AAD Reduction ($,000)
	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood	
Direct Residential	372	1240	2008	3076	2273	34
Indirect Residential	89	285	453	678	535	8
Direct Commercial	1	127	217	251	109	3
Indirect Commercial	0	51	87	100	44	1
Infrastructure and Public Sector	139	511	829	1231	888	14
Total	601	2214	3594	5336	3849	60

Table 7-5 Flood Damages Reductions for Barellan Township Levee Option 1b

Damage Sector	Reduction in Flood Damages ($,000)					AAD Reduction ($,000)
	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood	
Direct Residential	412	2178	4596	6925	7077	66
Indirect Residential	97	513	1071	1589	1621	16
Direct Commercial	1	131	268	395	312	4
Indirect Commercial	0	52	107	158	125	1
Infrastructure and Public Sector	153	862	1813	2720	2740	26
Total	662	3736	7854	11787	11875	113

Table 7-6 Flood Damages Reductions for Mirrool Creek Levee Option 1c

Damage Sector	Reduction in Flood Damages ($,000)					AAD Reduction ($,000)
	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood	
Direct Residential	420	2,211	4,770	7,209	5,398	67
Indirect Residential	99	526	1,122	1,661	1,251	16
Direct Commercial	1	131	268	395	213	4
Indirect Commercial	0	52	107	158	85	1
Infrastructure and Public Sector	156	876	1,880	2,827	2,084	26
Total	677	3,797	8,146	12,249	9,032	113

Table 7-7 Flood Damages Reductions for Mirrool Creek Levee Option 2b

Damage Sector	Reduction in Flood Damages ($,000)					AAD Reduction ($,000)
	2% AEP	1% AEP	0.5% AEP	0.2% AEP	Extreme Flood	
Direct Residential	131	1,113	1544	1,345	111	20
Indirect Residential	32	258	349	297	28	5
Direct Commercial	1	84	80	77	3	2
Indirect Commercial	0	33	32	31	1	0
Infrastructure and Public Sector	49	446	601	525	43	8
Total	213	1,934	2,606	2,274	186	35

Capital cost estimations were informed from a number of sources including Rawlinsons (2015), IPART NSW (2014) and Lyall & Associates (2015). Cost estimation calculations can be found in Appendix G.

For each levee option, costs have been calculated for the following alignment options:

- alignments along existing road ways (i.e. “road-topped” levee embankments), and
- standalone levee alignments, parallel to the existing roadway.

For properties outside the levee extent that are potentially impacted by increased flood levels, the magnitude of potential impact was assessed and where deemed to be significant it is assumed that some form of flood mitigation may be required. The properties adversely impacted as a result of levee construction have been included in the capital cost estimates for levee construction, with an assumed $50 000 cost per property (refer Appendix G for property locations).

The benefit-cost ratios (BCR) for each option are summarised in Table 7-8.

Levee Option 1a and levee Option 1b provide similar BCRs of 0.53 to 0.58, with levee Option 1c being slightly lower at 0.48. The Mirrool Road levee (Option 2b) has a much lower BCR of 0.19. However, it should be noted that a levee structure may have a design life of closer to 70-100-years (than the assumed 50 years), in which case there would be a greater accrued flood damages reduction benefit, providing for an improved BCR.

Levee Option’s 1a, 1b and 1c provide significant reduction to flood inundation of the township. There are considerable intangible damages associated with the trauma and ongoing difficulties in recovery of the communities from such an event. In the case of Barellan, this includes the disruption resulting from the flooding of septic tanks. Accordingly, the BCR based on the simplified economic analysis as above may understate the value of implementing these measures.

7.2.2 Property Modification Measures

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.

Table 7-8 Cost Benefit Ratio for Levee Options

Levee Option		Cost Estimate ($,000)	Reduction in AADs ($,000)	Benefit ($,000)			BCR		
				7%	11%	4%	7%	11%	4%
Opt 1a	Roadside	1,400	60	800	1,300	500	0.58	0.91	0.38
	Road-topped	3,000					0.28	0.43	0.18
Opt 1b	Roadside	2,900	113	1,600	2,400	1,000	0.53	0.83	0.35
	Road-topped	7,000					0.22	0.35	0.15
Opt 1c	Roadside	3,200	113	1,600	2,400	1,000	0.48	0.75	0.32
	Road-topped	9,100					0.17	0.27	0.11
Opt 2b	Roadside	2,600	35	500	800	300	0.19	0.29	0.12
	Road-topped	7,100					0.07	0.11	0.04

7.2.2.1 Voluntary House Purchase

The primary objective of voluntary house purchase (VHP) is to reduce risks to personal safety by purchasing houses located in areas subject to excessive hazard. A VHP scheme is generally applicable only to areas where flood mitigation is impractical and the existing flood risk is unacceptable. Such measures can only be undertaken on a voluntary basis with the property owner. Post-purchase the property should be rezoned for flood compatible use.

Due to the relatively low hazard conditions presented by flooding in Barellan and the availability of other suitable floodplain risk management options, it is considered that a VHP scheme is not required.

7.2.2.2 Voluntary House Raising

Voluntary house raising (VHR) is aimed at reducing the flood damage to houses by raising the habitable floor level of individual buildings above an acceptable design standard (e.g. 1% AEP Flood Level +0.5 m). Voluntary house raising generally only provides a benefit in terms of reduced economic damages but does not eliminate the risk. Larger floods than the design flood (used to establish minimum floor level) will still provide building damages and the option does not address personal safety aspects. These risks are still present as the property and surrounds are subject to inundation and therefore the flood access and emergency response opportunity is still compromised.

House raising does have limited application in that it is not suited to all building types. Typically, house raising is suited to most non-brick (e.g. clad, timbered framed houses) single story houses constructed on piers and not for slab on ground construction. An indicative cost to raise a house is of the order of $50,000 which can vary considerably depending on the type and size of the structure. Eligibility criteria for house raising schemes vary around the country, but funding is available for house raising in NSW and has been widely applied.

As an alternative to direct house raising, subsidies schemes have also been made available for re-building. For many properties, the opportunity to rebuild may be more attractive than raising the existing dwelling. Fairfield City Council, which arguably operates the largest house raising scheme in the country, has a subsidy scheme for residential property owners of houses with floor levels which are low enough to qualify. They can then choose to invest this subsidy into physically raising the house or into demolishing and rebuilding the house at a higher floor level.

Potential eligible properties for such a scheme in Barellan are identified based on above floor flooding over a range of flood event magnitudes as summarised in Table 7-9. It has been assumed that residential properties identified as timber framed houses on piers from the drive-by assessment will be eligible for house raising.

For the purposes of evaluating the economic viability of such a scheme, it was assumed that eligible houses would have their floor levels raised above the 1% AEP design flood level with an additional allowance for freeboard. Due to the flat gradient of flood levels in Barellan, a freeboard of 0.5 m would give each house immunity for all flood events up to and including the Extreme Flood. A mean property raising price would be $50,000.

Table 7-9 Assessment of Property Numbers for House Raising

Design Event	Number of Properties
2% AEP	0
1% AEP	6

Raising houses flooded at the existing 1% AEP flood level would account for 6 properties at a cost of some $300k. The reduction in average annual flood damages is in the order of $6,000. The number of houses viable for potential house raising is limited due to slab on ground and/or brick construction types.

When assessing the performance of the scheme over a standard 50-year life span, the reduction in damages must be reduced to a net present-day value. When adopting a discount rate of 7% this gives a benefit-cost ratio (BCR) of 0.28, or between 0.18 and 0.43 when adopting a discount rate of 11% or 4% respectively.

Notwithstanding, it must be recognised that:

- Not all timber framed, clad homes are structurally suitable for raising;
- It changes the appearance of a house;
- May create difficulties in accessing public utility services; and
- Those with mobility restrictions may not be able to easily access the house.

The broader impacts of house raising should not be overlooked, as it will potentially change the visual character of a house and possibly the street / suburb.

This is provided at an estimated cost of $50,000 per property. Council are able to apply for OEH funding for the development and implementation of VHR schemes that have been identified within an FRM Plan. However, due to the limited potential for and benefit of such a scheme in Barellan, it is not recommended as a suitable floodplain risk management option and would become redundant should a levee be constructed. However, such a scheme may be suitable to offset potential adverse impacts on properties located outside of the levee, if constructed.

7.2.2.3 Flood Resistance / Flood-proofing

Flood proofing refers to the design and construction of buildings with appropriate materials (i.e. material able to withstand inundation, debris and buoyancy forces) so that damage to both the building and its contents is minimised should the building be inundated during a flood. Flood proofing can be undertaken for new buildings or be retrofitted to existing buildings; however, flood proofing is generally more effectively achieved during construction with appropriate selection of materials and design. Generally, these works would be undertaken on a property by property basis at no cost to Council.

Of particular interest to building owners (and insurers) is making changes to building materials to reduce the costs of damages during flood. This would include for example replacing composite timber kitchen cupboards with solid timber cupboard, replacing carpet with floor tiles, replacing plasterboard wall lining with fibrous cement etc. These changes can often be done during building renovations, and at a relatively marginal additional cost.

Council's DCP already includes requirements for the use of flood compatible building components for new development in the floodplain. However, there are a number of non-structural options that can be retrofit to existing property to help reduce flood damage including changes to joinery and fittings, floor coverings and electrical services.

Alternatively, flood barriers are a form of flood proofing that is easy to install at a relatively low cost. Flood barriers can be permanent fixtures or temporary installations and effectively block floodwaters from entering through doorways assuming the rest of the building is constructed from flood compatible materials). It should be noted that flood barriers are only suited to slab-on-ground constructions.

Whilst flood proofing may limit the damage to the building and its contents, the occupant (particularly in the case of commercial property) may still suffer from the social and economic disruption of flooding such as the closure of businesses and lack of access during and after flood events. Flood barriers are easy to install at a relatively low cost and would be a recommended measure for properties that experience above floor flooding.

The installation of such measures may cost in the order of $5,000 per property. It has been assumed that the commercial properties on Yapunyah Street may be eligible for flood proofing measures. It is assumed that these properties will be "flood-proof" to the 1% AEP design flood event plus 0.5 m freeboard. It is difficult to compare directly with the major capital works, but for comparative purposes, if applied to the thirteen properties flooded at the 1% AEP event the reduction in average annual flood damages is in the order of $6,000. Over a 50-year period when adopting a discount rate of 7% this gives a benefit-cost ratio (BCR) of 1.27, or between 0.83 and 1.98 when adopting a discount rate of 11% or 4% respectively.

7.2.2.4 Land Use Planning and Development Controls

Land use planning and development controls are key mechanisms by which Council can manage flood-affected areas within the study area. Such mechanisms will influence future development (and redevelopment) and therefore the benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost.

As discussed in Section 6, Council currently has a number of land use planning and development controls in place to manage flood-affected areas within the Narrandera Shire LGA. These controls largely relate to outcomes from the Narrandera FRMS&P, with detailed flood mapping available for the Narrandera township only being incorporated into the DCP to date.

It is recommended that detailed assessment of possible alternatives to Council controls be considered in the future within the bounds of State legislation.

It is recommended that detailed assessment of possible alternatives to Councils flood policy be made prior to update of the DCP to facilitate appropriate flood mitigation controls.

Flood Planning Levels and Flood Planning Area

Flood Planning Levels (FPLs) are used for planning purposes, and directly determine the extent of the Flood Planning Area (FPA), which is the area of land subject to flood-related development controls. The FPL is the level below which a Council places restriction on development due to the hazard of flooding. Traditional floodplain planning has relied almost entirely on the definition of a singular FPL, which has usually been based on the 1% AEP flood level for the purposes of applying floor level controls.

As discussed in Section 6, FPLs adopted by Council in the DCP are the 1% AEP design flood level plus 0.5 m freeboard for residential development and the 5% AEP design flood level for commercial / industrial development. Council currently has flood mapping for the Narrandera township and surrounds only to inform these levels.

For Barellan, it is recommended that an FPA be adopted within Council's Policy include the entire township area. Due to the flat nature of the topography at Barellan it is difficult to determine an appropriate extent of the FPA based on the 1% AEP design flood level plus 0.5 m freeboard. For comparison, the peak Extreme Flood level is around 0.5 m higher than the 1% AEP design flood level. Therefore, the Extreme Flood extents are indicative of the recommended FPA for Barellan. FPA maps are provided in Appendix A.

The FPA developed as part of this FRM Plan will be "interim", pending the implementation of any recommended works and measures that may provide a 1% AEP standard of protection to various parts of the township. Major Overland Flow related planning controls may still have to be applied to Barellan even after the implementation of any levee mitigation options, if local runoff from within the town is still an issue.

Agricultural Development within the Floodplain

Agricultural development within the Mirrool Creek floodplain is coming under increased scrutiny by the community. The recent flood events of 2012 and 2016 have clearly demonstrated to land owners the extent of the floodplain and the potential for economic damages to be incurred through flooding. There are concerns within the broader community about land owners undertaking recent earthworks to protect their own assets, that may potentially come at the expense of others. These practices have the potential to locally impact neighbouring properties through the diversion of floodwaters.

There is also a potential significant regional impact brought about through cumulative floodplain modifications that may serve to exacerbate flooding downstream. This relates to the loss of potential flood storage and associated attenuation of the flood wave as it progresses through the catchment – effectively channelizing flood flows, increasing the magnitude and decreasing the travel time of flooding at downstream locations. Of particular concern is the potential implication for flood flows traversing the MI Main Canal at the EMR and the implications for flood risk in Yenda.

The 1978 floodplain development guidelines sought to address similar concerns relating to the impacts to neighbouring properties of unregulated earthworks by landowners in the Mirrool Creek floodplain between Barellan and the EMR. However, the floodway defined by that document does not match exactly what has been implemented on the ground. The scale of the identified floodway is also more applicable to more frequent flood events, rather than major flood event magnitudes such as that of 2012. To limit potential flood impacts due to agricultural development within the floodplain a review of the 1978 guidelines is required and a new set of guidelines should be established and regulated accordingly.

The process of establishing a new set of guidelines and the regulation of agricultural development within the Mirrool Creek floodplain is a significant undertaking requiring substantial stakeholder consultation. The study area requires the consensus of both Narrandera Shire and Griffith City Councils to establish and regulate the guidelines. The guidelines also need to be accepted by the landowners and the broader community, to balance both the need to make a living from the land and the requirement to manage flood risk in a responsible manner. It is envisaged that the scope of the new guidelines would broadly comprise:

- re-mapping of the existing established floodway extents for minor events, within which development is excluded
- definition of a floodway extent accommodating major flood events, within which proposed works require to adhere to a defined set of planning controls and be approved by the appropriate regulatory authority
- minor works that are exempt from approval and constitute regular agricultural practice, such as furrowing and other minor earthworks within a set height limit

This approach to floodplain development control is typically employed for the large river systems of NSW.

7.2.3 Response Modification Measures

Given the area of existing development within flood prone land, it may be necessary to evacuate a large number of residents from their homes in a major flood. The amount of time available for evacuation is largely dependent on the available warning time. Adequate warning time can give residents the opportunity to move property above the reach of floodwaters and to evacuate from the area to higher ground.

Within Barellan there would typically be sufficient warning time to prepare and respond to a major flood event (i.e. around 24 hours for local catchment flooding or over 60 hours for flooding from Mirrool Creek), as discussed in Section 4.2.2.2. In reality, most people would be largely self-reliant during a flood. Agencies can, however, help people make more appropriate decisions during these floods through giving as much warning as possible (via an integrated flood warning system), and through flood emergency planning provisions. Education and flood preparedness before the event would also greatly improve the resilience of the community to flooding.

7.2.3.1 Flood Warning

The flood warning system commences with the issue of Flood Watches and Flood Warnings from the Bureau of Meteorology (BoM) and concludes with the public receiving a detailed message about flood risk and required action. The provision of Flood Warnings enables residents to effectively prepare and respond to a major flood event.

A flood warning system is currently being implemented within the Mirrool Creek catchment by Griffith City Council, with assistance from BoM and WaterNSW. The system will utilise recorded rainfall and water level data to provide a flood warning service to the residents of Yenda. This includes data from recently installed gauges at Barellan Bridge and the East Mirrool Regulator.

Flood warning for Barellan is complicated due to potential initial inundation from local catchment runoff prior to the spilling of flood waters from Mirrool Creek, as occurred in March 2012. Whilst not directly applicable to Barellan, the Mirrool Creek flood warning system will provide flood warning information within the catchment that may assist in flood emergency preparation.

The most effective way to enable the Mirrool Creek flood warning system to provide additional benefit to Barellan would be the provision of an additional gauges in the following locations:

- **Rainfall gauge in the vicinity of Kamarah** to record rainfall occurring within the local catchment floodplain upstream of the town. It was catchment runoff across this area that initiated flooding of Barellan during the March 2012 event, with only around a 1-day warning period from the onset of rainfall.
- **Rainfall gauge and streamflow gauge on Mirrool Creek at Beckom** to record data from the upper Mirrool Creek catchment. One of the mechanisms resulting in flooding of the Barellan township is flows from the upper Mirrool Creek catchment (such as the second flood wave to flow through town during the March 2012 event). Flow travel time from Beckom to Barellan Bridge is just over 24-hours and the installation of a streamflow gauge at Beckom would provide warning to the expected magnitude of Mirrool Creek flows.

In addition to providing a potential early warning for Barellan, the additional gauges would also provide further regional benefit, significantly enhancing the existing flood warning system being developed by BoM for Griffith City Council through the inclusion of these additional gauge stations. It should be noted that that the installation of a gauge at Beckom will require consultation with Coolamon Shire Council.

7.2.3.2 Emergency Response

It is recommended that the SES review and update their response plans based on the outcomes of this study, e.g. to include risk-based prioritisation of resources and plans to manage the warning process, where there are likely to be insufficient resources to achieve the most efficient rate of evacuation.

The SES follows the Local Flood Plan (LFP), using information from Flood Intelligence (and soon, available flood warning information for Mirrool Creek) to respond in actual flood events. Local flood intelligence needs to be updated with the flood level data derived from the current flood study. The Local Flood Plan should be updated to provide design flood data for the full range of events considered in the Flood Study and Floodplain Risk Management Study (20% AEP up to the Extreme Flood).

For rapid onset of flooding in Barellan, it would not be realistic to expect the SES to be able to undertake much in the way of emergency response for several reasons:

- the SES is principally a volunteer organisation and the time required to mobilise personnel could exceed the warning time available
- a major flood event in Barellan is likely to coincide with major flooding across the broader Mirrool Creek catchment, further stretching already limited emergency response resources.

Occupants of premises within the flood prone areas should be encouraged to have private flood emergency response plans which have evacuation as the preferred initial response if that is practical. Should evacuation not be possible before floodwaters cut off evacuation routes then remaining in the building should be the alternative. While the NSW SES does not encourage people to stay inside flooding buildings, it acknowledges that a number of circumstances can prevent evacuation in some situations, and once trapped in a building, it is generally safer to stay inside than to exit into high hazard floodwaters.

The concept of a "Community Flood Emergency Response Plan" should be explored. The Plan would provide information regarding evacuation routes, refuge areas, what to do/not to do during a flood event etc. If such a plan is developed and embraced at a community level, the self-sufficiency in terms of flood response of what is a relatively concentrated community within Barellan would maximise potential for effective emergency response and a non-reliance on formal emergency services. Council and the SES would be expected to have a key role in developing the CFERP.

7.2.3.3 Classification of Communities

The SES classifies communities according to the impact that flooding has on them. The primary purpose for doing this is to assist SES in the planning and implementation of response strategies. Flood impacts relate to where the normal functioning of services is altered due to a flood, either directly or indirectly, and relates specifically to the operational issues of evacuation, resupply and rescue.

Flood Islands

Flood Islands are inhabited areas of high ground within a floodplain which are linked to the flood free valley sides by only one access / egress route. If the road is cut by floodwaters, the community becomes an island, and access to the area may only be gained by boat or aircraft. Flood islands are classified according to what can happen after the evacuation route is cut as and are typically separated into:

- High Flood Islands;
- Low Flood Islands

A *High Flood Island* include sufficient land located at a level higher than the limit of flooding (i.e., above the Extreme Flood) to provide refuge to occupants. During flood events properties may be inundated and the community isolated, however, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

The highest point of a *Low Flood Island* is lower than the limit of flooding (i.e., below the Extreme Flood) or does not provide sufficient land above the limit of flooding to provide refuge to the occupants of the area. During flood events properties may be inundated and the community isolated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown.

Trapped Perimeter Areas

Trapped Perimeter Areas are inhabited areas located at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped perimeter areas are classified according to what can happen after the evacuation route is cut as follows.

High Trapped Perimeter Areas include sufficient land located at a level higher than the limit of flooding (i.e., above the Extreme Flood) to provide refuge to occupants. During flood events properties may be inundated and the community isolated, however, as there is an opportunity for occupants to retreat to high ground, the direct risk to life is limited. If it will not be possible to provide adequate support during the period of isolation, evacuation will have to take place before isolation occurs.

Low Trapped Perimeter Areas is lower than the limit of flooding (i.e., below the Extreme Flood) or does not provide sufficient land above the limit of flooding to provide refuge to the occupants of the area. During a flood event, the area is isolated by floodwater and property may be inundated. If floodwater continues to rise after it is isolated, the area will eventually be completely covered. People trapped in the area may drown.

Areas Able to be Evacuated

These are inhabited areas on flood prone fringe areas that are able to be evacuated. However, their categorisation depends upon the type of evacuation access available, as follows.

Areas with Overland Escape Route are those areas where access roads to flood free land cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground. Anyone not able to walk out must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.

Areas with Rising Road Access are those areas where access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent, even in the Extreme Flood. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example, people living in two storey homes may initially decide to stay but reconsider after water surrounds them.

These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.

Indirectly Affected Areas

These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

Overland Refuge Areas

These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas. They should be categorised accordingly and these categories used to determine their vulnerability.

Note that Flood Management Communities identified as Overland Refuge Areas on Low Flood Island have been classified according to the SES Flow Chart for Flood Emergency Response Classification. These are areas where vehicular evacuation routes are inundated before residential areas of the Community.

Classification of Communities for Barellan

The Barellan township is classified as "Areas able to be Evacuated (with an Overland Escape Route)." This means that residents will have sufficient warning to evacuate to a flood free township (e.g. Griffith) prior to the region becoming flooded and access roads becoming closed. However, if residents do not or cannot evacuate before inundation of the town, there is no flood-free land within the town so shelter in place within buildings elevated above ground level would be required.

7.2.3.4 Community Education and Awareness

It is recognised that there are a number of flood-related messages which need to be conveyed to the public as part of a flood awareness program. These messages, along with the type of information which should be used to convey the message is provided in Table 7-10.

The conveyance of these messages can be through a range of formats; it will be necessary to select the best format for the message and the targeted audience. Possible formats include:

- informative flyer with utility bill / rates notice (can be general or targeted to flooding in specific areas)
- briefings at social and civic clubs, e.g. Rotary, Lions
- expert panels (flooding, emergency and planning experts)
- newspaper feature story on general flooding issues or historical (flood commemorations)
- information booth at community festivals, shows etc.
- information repository at libraries, Council office etc.
- newspaper insert (fact-sheet style)
- flood information website
- signposting of evacuation routes

- noticeboards in public areas to signpost floodways, structures etc.
- school projects on floods and floodplain risk management
- historical flood markers
- flood certificates
- email newsletters.

Table 7-10 Flood Awareness Messages

Message	Information
General flood information	Floods can cause damage to property and endanger human life. Different types and sizes of floods will have different impacts.
General flood preparedness advice	What to do to prepare for a flood.
You live in a flood prone area	Floods can occur in your area (and may have in the past).
Location specific flood information	Type of flooding in the area, likely speed of onset, historical flood level, residual risk (e.g. behind levees).
Location specific evacuation information	Evacuation routes and centres, where to find evacuation information (radio stations, road closure websites).
Details on flood management schemes / initiatives	What has been completed and planned, how initiatives manage flooding, timeframes for implementation etc

The community consultation program undertaken in development of the Flood Plan, and previously during the Flood Study, have initiated dialogue with the community in respect to flood risk as an initial step in increasing flood awareness.

An ongoing flood awareness program should be pursued through collaboration of the SES and Council (e.g. FloodSafe program specific for Barellan). The aim of this program would be to:

- increase community awareness of flood risk
- increase community understanding of what to do before / during / after floods
- increase awareness of SES role and other agencies.

7.3 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 Barellan, 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 7-11.

Table 7-11 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

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.

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 7-12. 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 the various structural measures assessed the flood-proofing of commercial buildings is the most straightforward and cost-effective. However, this option does not address the significant social and economic impacts to the broader community. The other structural options to score favourably are levee option 1b and 1c, which if either option was implemented would satisfy the needs of the broader community and make the need for flood-proofing of commercial buildings redundant. Of these two options, levee Option 1b performs best economically in terms of BCR.

Flood planning controls, flood awareness/education and flood emergency response planning measures are all readily implementable and therefore score highly. The implementation of a flood warning system for Barellan also scores favourably, due to the existence of the recent development of a Mirrool Creek catchment flood warning system. Incorporating additional rainfall and streamflow gauges to this system would be a beneficial and cost-effective measure to improve flood emergency response and therefore reduce flood risk.

Table 7-12 Assessment of Management Options

Performance	Performance	Practicality	Community Acceptability	Environmental	Costs/ Resources	Total Score
Flood Modification Measures						
Levee Option 1a	MED	MED	HIGH	MED	LOW	0
Levee Option 1b	HIGH	MED	HIGH	MED	LOW	1
Levee Option 1c	HIGH	MED	HIGH	MED	LOW	1
Levee Option 2b	MED	MED	HIGH	MED	LOW	0
Upgrade of road drainage capacity	LOW	MED	HIGH	HIGH	LOW	0
Provision of lowered road floodway sections	LOW	MED	HIGH	HIGH	LOW	0
Property Modification						
Voluntary house-raising scheme	MED	MED	MED	HIGH	LOW	0
Flood-proofing of commercial buildings	HIGH	HIGH	MED	HIGH	HIGH	4
Planning and Development Controls	HIGH	HIGH	MED	HIGH	HIGH	4
Rural Floodplain Development Guidelines	HIGH	MED	MED	HIGH	HIGH	3
Response Modification						
Augment Mirrool Creek catchment flood warning system	MED	HIGH	HIGH	HIGH	HIGH	4
Update to Local Flood Plan and emergency response	HIGH	HIGH	HIGH	HIGH	HIGH	5
Ongoing community education and awareness	MED	HIGH	HIGH	HIGH	HIGH	4

8 Recommended Floodplain Risk Management Plan

The Floodplain Risk Management Study and Plan (FRMSP) has been developed to direct and co-ordinate the future management of flood prone lands across the Barellan Floodplain of the 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 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. 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 Recommended Measures

8.1.1 Flood Modification Measures

8.1.1.1 Box Street / Kurrajong Street Levee (Option 1b) or Barellan Cemetery Road / Kurrajong Street Levee (Option 1c)

The flood modification measures to score favourably in the rapid options analysis presented in Section 7.3 were the two "L-shaped" levees proposed to be located upstream of Barellan town – Option 1b and Option 1c. The proposed levee alignment for each option is shown on Figure 8-1. The preferred alignment may be subject to a range of considerations, as outlined in Section 7.3.1. The proposed levee has been assumed to be constructed to the 0.2% AEP design flood level with an additional 0.5 m allowance for freeboard. A long section depicting the natural surface, modelled levee crest and 0.2% AEP peak flood levels (pre and post-levee construction) along the levee alignment are shown in Figure 8-2 and Figure 8-3, respectively, for Option 1b and 1c.

The construction of a levee appears to have community support and a preferred levee alignment should be agreed upon for future investigation. Whilst preliminary assessment has identified levee Option 1b as the most favourable from a BCR perspective, a number of additional factors need to be considered, such as the future development potential within the levee extent. Due to the relatively low calculated BCRs and other factors to consider, it is recommended that the feasibility of the levee protection options for Barellan be further investigated, to assess and select a preferred option for further investigation and design, if warranted. A preferred levee option should be identified that best serves current and future needs of the community.

Title:

Proposed Levee Alignments Option 1b and Option 1c

Figure: 8-1

Rev: A

N

0 375 750m

Approx. Scale

BMT WBM

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Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_8-1_Levee_Alignments.WOR

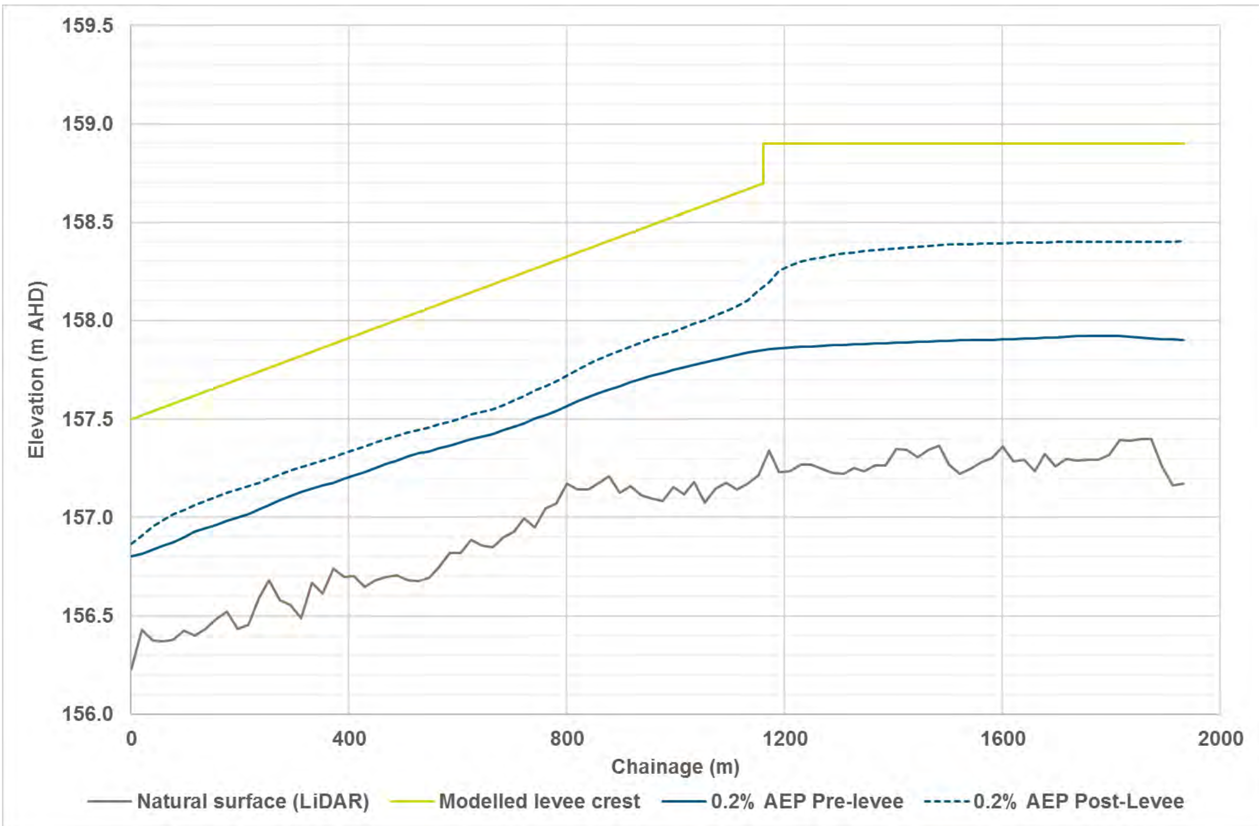

Figure 8-2 Levee Option 1b Long Section

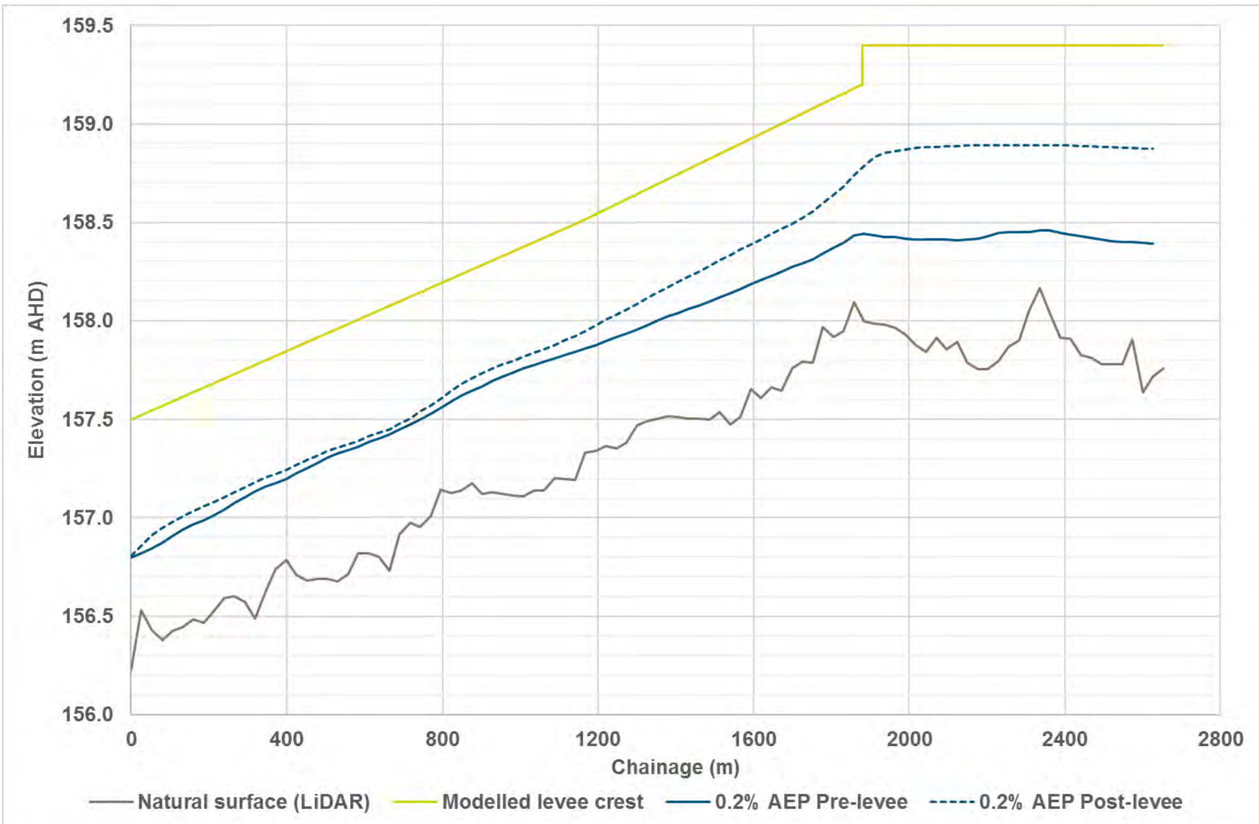

Figure 8-3 Levee Option 1c Long Section

An indicative cross section for each levee type (i.e. along existing roadway or standalone levee parallel to the existing roadway) is shown in Figure 8-2. It should be noted that these are sample cross sections only and specialist concept design will be required at a later stage. It is difficult to conclusively determine which levee type is better suited for application in Barellan.

The standalone levee parallel to the existing roadway has a substantially lower capital cost but will require a larger area of land acquisition. The trade-off between capital expense and reduced construction footprint is a matter to be considered by Council and other stakeholders.

As the levee will need to tie-in with Burley Griffin Way, major roadworks will be required to increase the crest of the road. It is expected that a freeboard allowance of 0.3 m over the 0.2% AEP design flood level will be sufficient for the roadway, resulting in required road crest raising of around 1.3 m at both the Box Street and Barellan Cemetery Road intersections. The railway embankment is elevated around the 0.2% AEP floodplain and will not require any augmentation.

Whilst both levee alignments have a high capital cost, the corresponding reduction in flood damages provides a significant financial and social benefit.

Barellan Levee Option Feasibility Study

Estimated Cost - **$100k** Responsibility – **Council** Priority – **High**

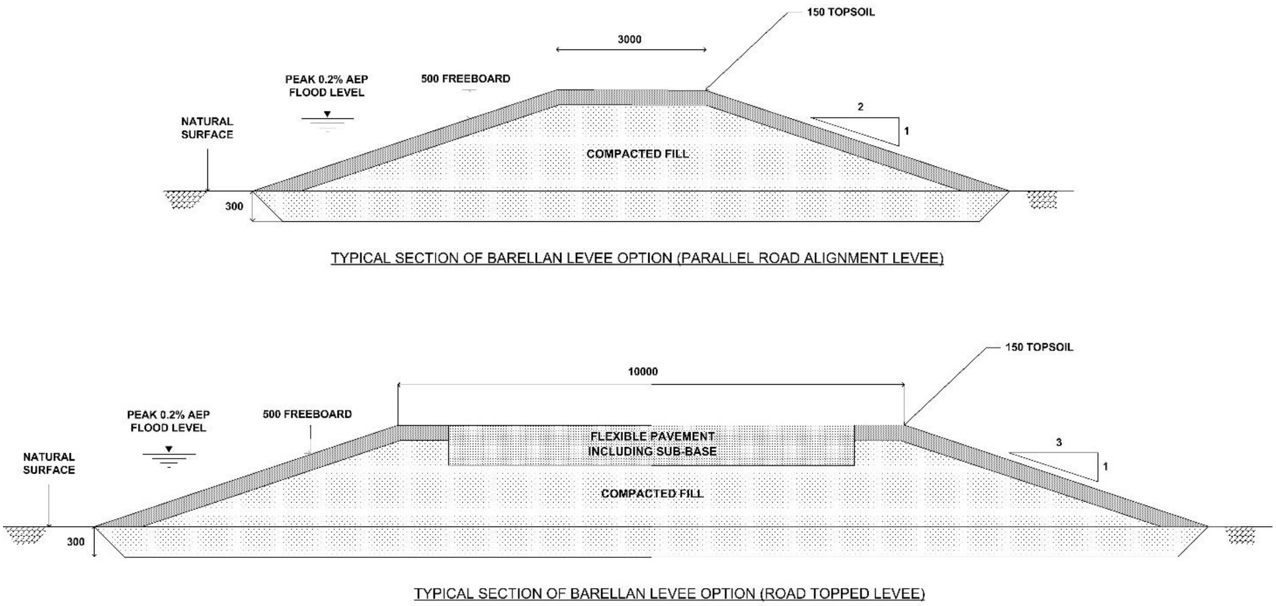

Figure 8-4 Sample Levee Cross Sections (Not to Scale)

8.1.2 Property Modification Measures

8.1.2.1 Flood-proofing of Commercial Buildings

Flood proofing refers to the design and construction of buildings with appropriate materials (i.e. material able to withstand inundation, debris and buoyancy forces) so that damage to both the building and its contents is minimised should the building be inundated during a flood. Flood proofing can be undertaken for new buildings or be retrofitted to existing buildings. Generally, these works would be undertaken on a property by property basis at no cost to Council.

Council's DCP includes requirements for the use of flood compatible building components for new development in the floodplain. It also suggests that flood proofing is only really suited to commercial buildings.

Flood barriers are a form of flood proofing that is easy to install at a relatively low cost. Flood barriers are recommended for commercial premises (slab-on-ground constructions) that have or may experience above floor flooding.

Estimated Cost - **$5,000/property** Responsibility – **Business owner** Priority – **Medium**

8.1.2.2 Planning and Development Controls

Land use planning and development controls are key mechanisms by which Council can manage flood-affected areas within the Barellan floodplain. This will ensure that new development is compatible with the flood risk, and allows for existing problems to be gradually reduced over time through sensible redevelopment.

The following planning measures are recommended:

- Adoption of the recommended FPA; and
- Inclusion of hydraulic category and hazard mapping into the Narrandera DCP.

Estimated Cost **– staff costs** Responsibility **– Council** Priority – **High**

8.1.2.3 Rural Floodplain Development Guidelines

There is a need for Narrandera Shire and Griffith City Councils to develop and regulate a set of guidelines governing agricultural development within the Mirrool Creek floodplain between Barellan and Barren Box Storage and Wetland. The guidelines need to be accepted by the landowners and the broader community, to balance both the need to make a living from the land and the requirement to manage flood risk in a responsible manner. As such they require substantial stakeholder engagement.

Estimated Cost **– $40k** Responsibility **– Council** Priority – **High**

8.1.3 Response Modification Measures

8.1.3.1 Flood Warning

A flood warning system is currently being implemented in the Mirrool Creek catchment by BoM for Griffith City Council to provide flood warning at Yenda. This Plan recommends implementation of an additional two new gauges to the Mirrool Creek flood warning system. These gauges should be incorporated into the flood warning system by BoM to develop a specific flood warning for Barellan.

Recommended gauges include a rainfall gauge in the vicinity of Kamarah and a rainfall gauge and streamflow gauge on Mirrool Creek at Beckom. This would provide local reference points for the Barellan community as well as the BoM and SES to gauge the imminent flood risk, and respond accordingly. Implementation of these gauges will not only provide flood warning to Barellan, but enables a more comprehensive forecasting system for the broader Mirrool Creek system.

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.

Estimated Cost **– $95k** Responsibility **– Council** Priority – **High**

8.1.3.2 Emergency Response

Recommended SES update response plans based on information from this study and occupants of flood prone properties encouraged to have private flood emergency response plans. Potential for a “Community Flood Emergency Response Plan”.

Information from the current floodplain risk management study (FRMS) and flood damages database will provide valuable data to enable specific detail relevant to Barellan township to be incorporated into the Narrandera Shire Local Flood Plan (LFP). The information provided by the FRMS will enable flood mapping to be updated and aid the SES in prioritising the areas within the LGA with the highest flood risk.

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 – **staff costs** Responsibility – **Council/SES** Priority – **High**

8.1.3.3 Community Education

Raising and maintaining flood awareness will provide the community with an appreciation of the flood problem and what can be expected during flood events.

An ongoing flood awareness program should be pursued through collaboration of the SES and Council (e.g. FloodSafe program specific for Barellan). The aim of this program would be to:

- Increase community awareness of flood risk;
- Increase community understanding of what to do before / during / after floods; and
- Increase awareness of SES role and other agencies.

Estimated Cost – **staff costs** Responsibility – **Council/SES** Priority – **High**

8.2 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 Floodplain Risk Management Plan (FRMP) would be implemented progressively over a 2 to 5 year time frame as funding becomes available.

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

(1) Council funds;

(2) Other stakeholder funds;

(3) Section 94 contributions;

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

(5) 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. The level of funding assistance varies from Council to Council. Although much of the FRMP 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 risk management plan.

8.3 Plan Summary

The recommendations of the Barellan FRMP have been summarised within Table 8-1. A brief description of each option, together with the estimated cost, responsible body and priority for implementation are presented.

Table 8-1 Summary of Plan Recommendations

Option	Estimated Cost	Responsibility	Priority	BCR
Recommended options that modify flood behaviour				
Investigate the feasibility of the levee protection options for Barellan and if warranted proceed to further design stages	$100k#	Council	High	0.53 - 0.48*
Recommended options that modify property				
Flood proofing of commercial buildings	$5k / property	Business owner	Low	1.3
Planning and development controls	Staff costs	Council	High	NR
Rural floodplain development guidelines	$40k	Council	High	NR
Recommended options that modify flood response				
Augment Mirrool Creek catchment flood warning system	$95k	Council	High	NR
Update to Local Flood Plan and emergency response	Staff costs	Council / SES	High	NR
Ongoing community education and awareness	Staff costs	Council / SES	High	NR

Notes: NR – Not a capital cost orientated option, or benefits difficult/impossible to quantify in financial terms.

 # Cost does not include further design investigations or construction

** BCR estimate range based on construction of parallel standalone Levee Options 1b or 1c*

8.4 Plan Review

The FRMP 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 five years is warranted to ensure the ongoing relevance of the FRMP.

9 References

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SKM (2009) *Narrandera Floodplain Risk Management Plan*

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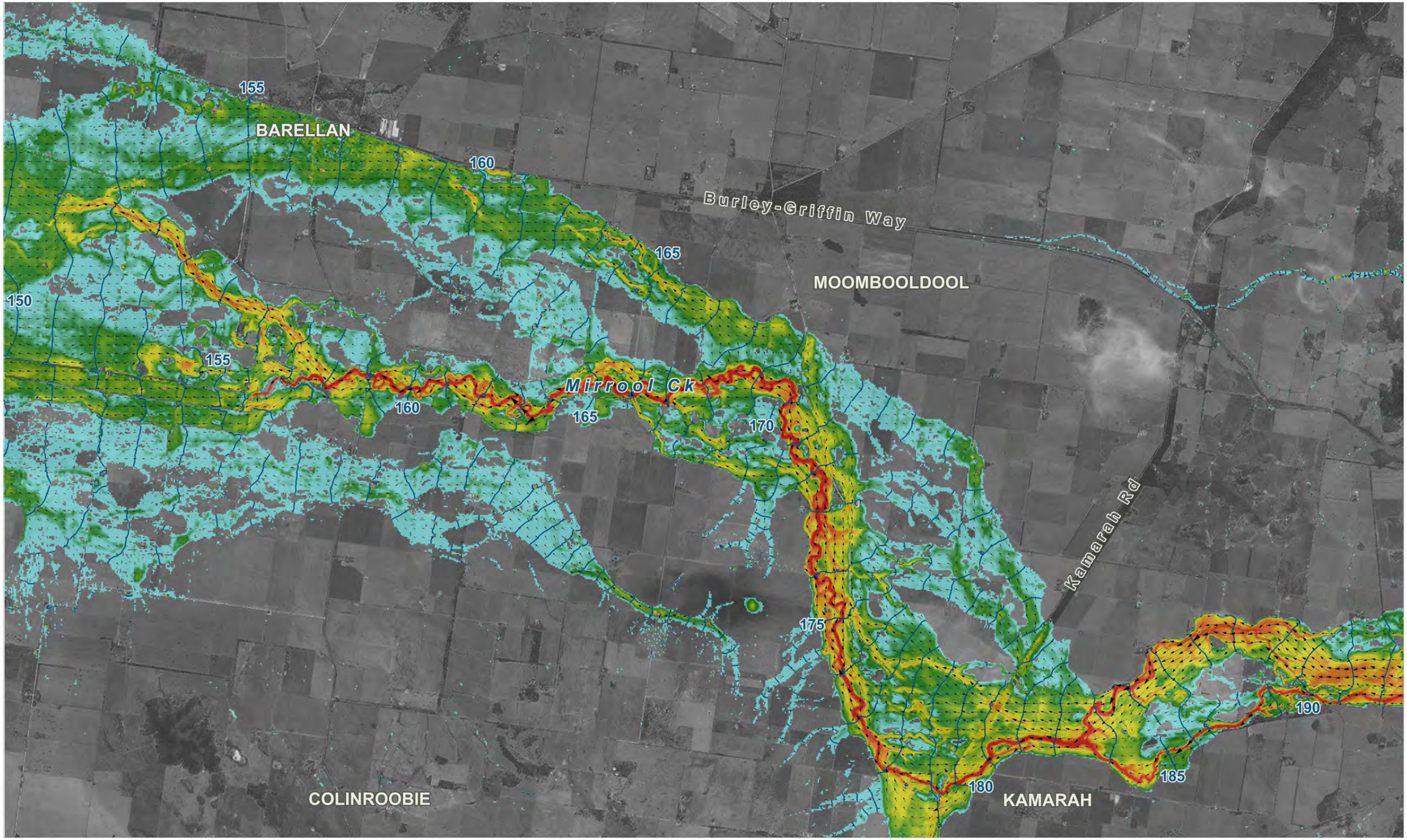
Appendix A. Flood Risk Mapping



LEGEND

Peak Flood Depth (m)

- 0.1 (lower depths mapped as same colour)
- 0.2
- 0.5
- 1.0
- 2.0 (higher depths mapped as same colour)

Peak Flood Velocity (m/s)

Scale: 1mm = 0.125m/s @A3

- 0.125
- 0.25
- 0.50
- 0.75

1:5 Peak Flood Level Contours (m AHD)

Title:

Barellan Flood Study 1% AEP Modelled Peak Flood Depths, Velocities & Water Levels - Barellan Floodplain

Figure: **A-1**

Rev: **A**

N

0 2 4km

Approx. Scale

BMT WBM

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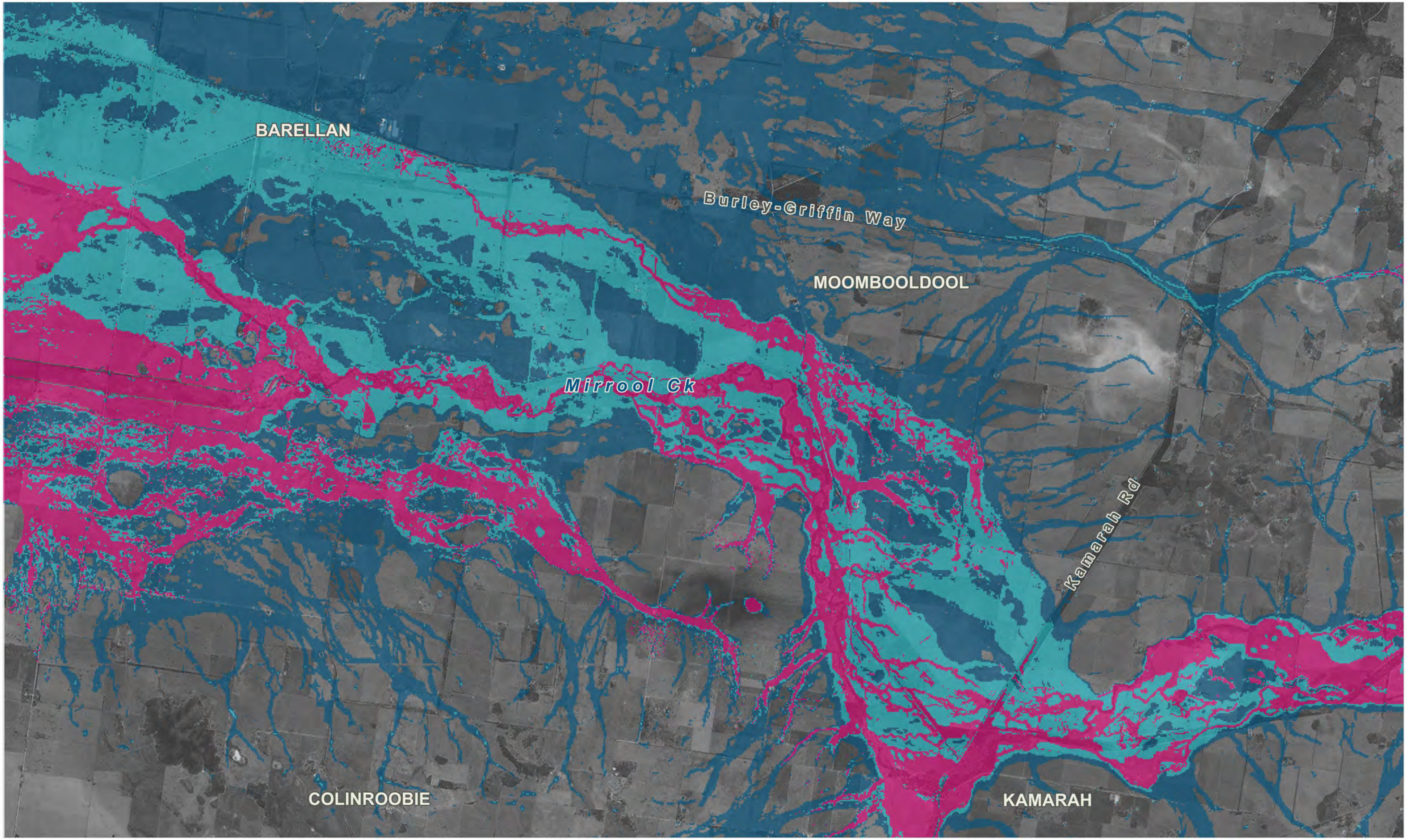

LEGEND

Hydraulic Category

- Flood Fringe - floodplain extent defined at the extreme flood event
- Flood Storage - floodplain extent defined at the 1% AEP event
- Floodway - floodplain extent defined at the 5% AEP event

Title:
Barellan Flood Study Hydraulic Categorisation
Barellan Floodplain

Figure: **A-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

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Approx. Scale

BMT WBM
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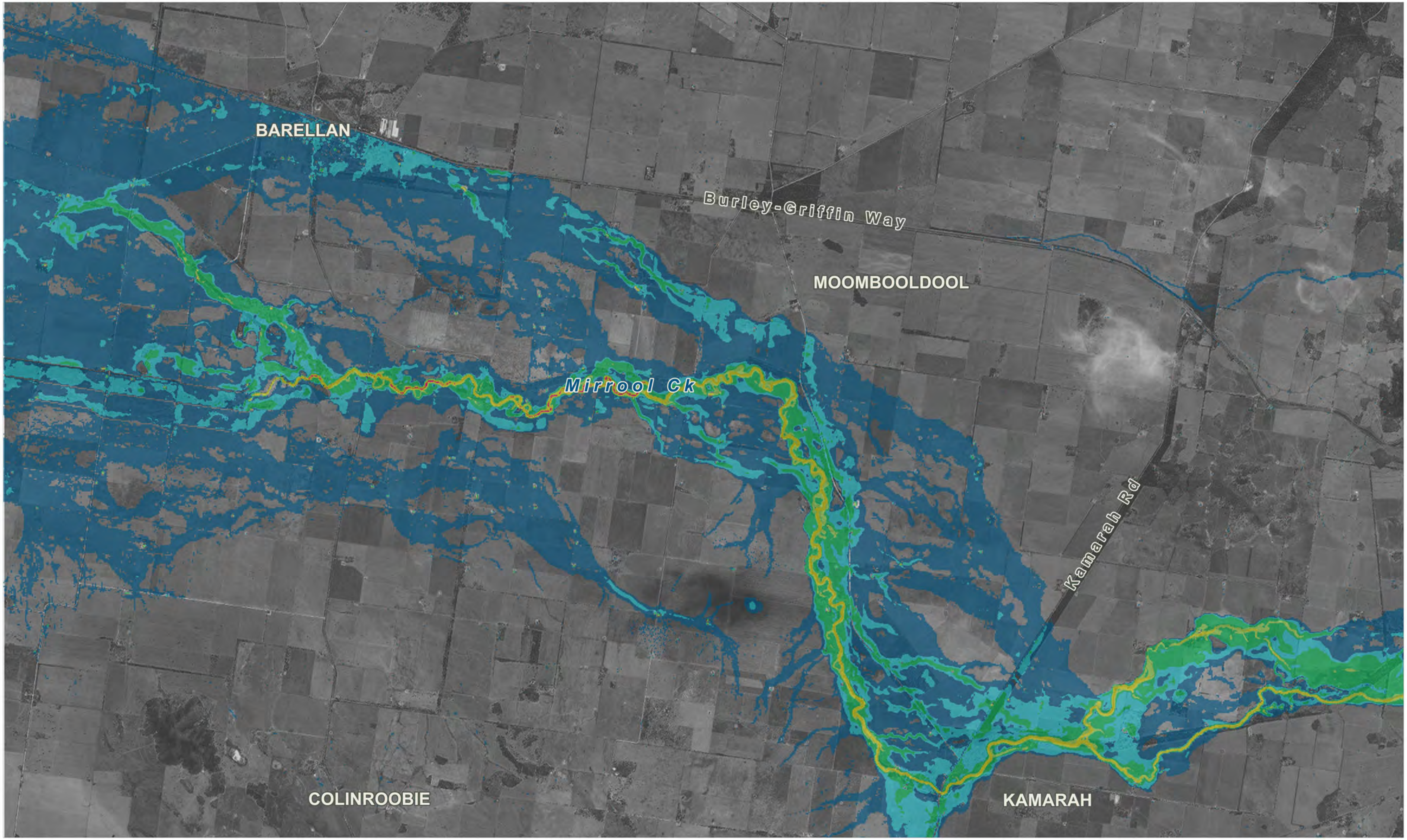

LEGEND

Hazard Classification

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

Title:

Barellan Flood Study 1% AEP Hazard Categorisation
Barellan Floodplain

Figure: **A-3**

Rev: **A**

N

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Approx. Scale

BMT WBM

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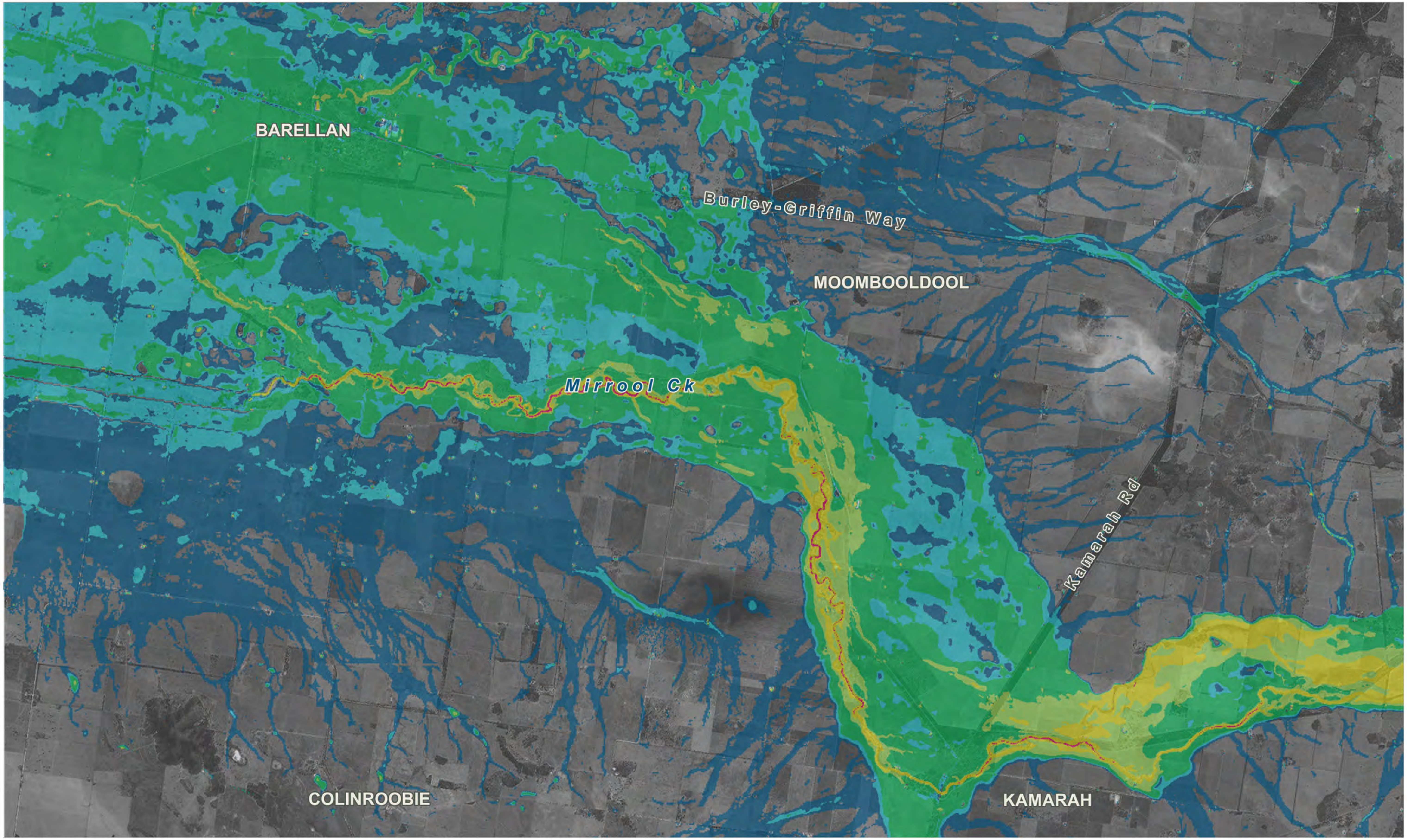


LEGEND

Hazard Classification

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

Title:

Barellan Flood Study Extreme Flood Hazard Categorisation Barellan Floodplain

Figure: A-4

Rev: A

N

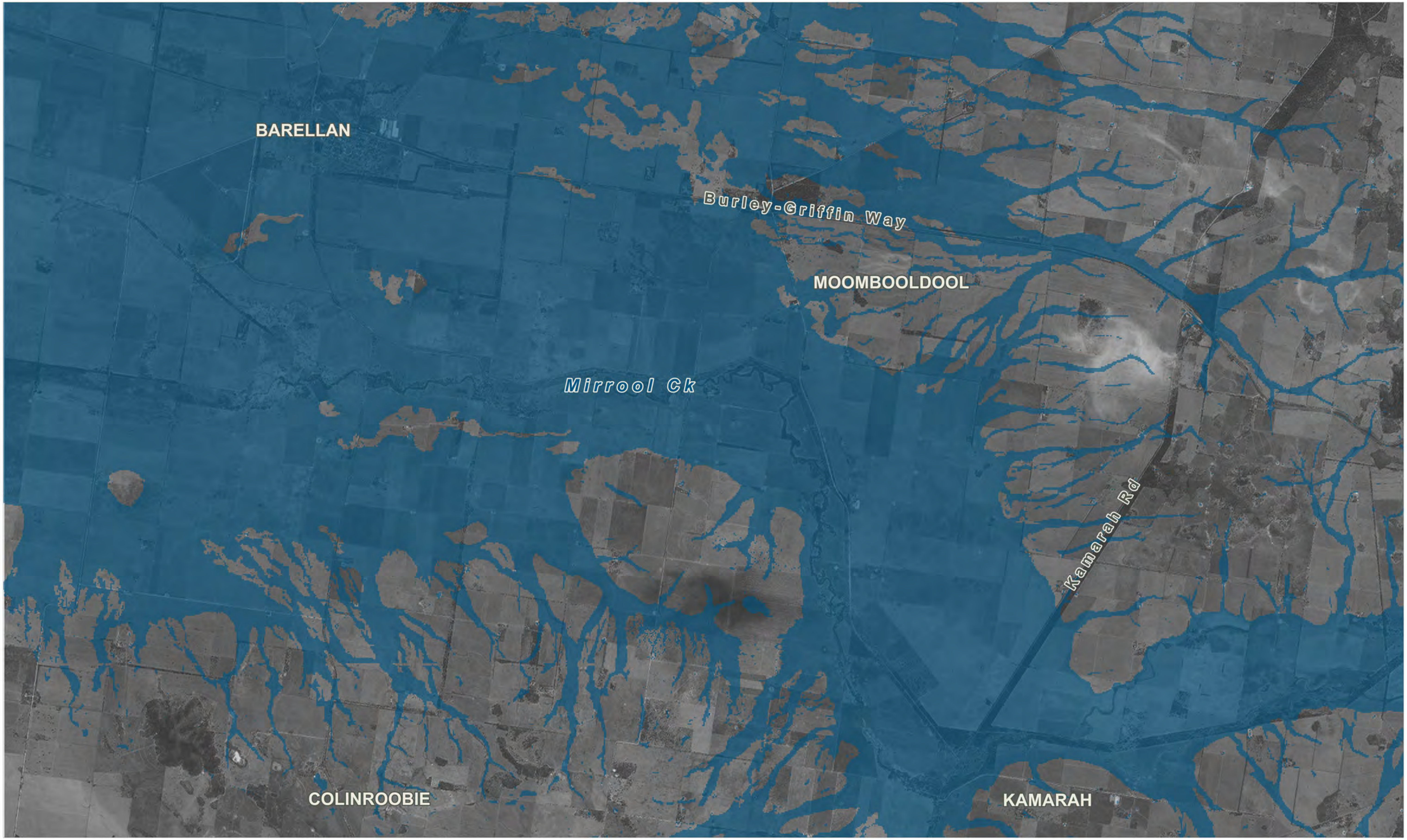
0 2 4km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\Mapping\DRG_A04_PMF_Hazard_Floodplain.WOR



LEGEND

FPA

Title:
Barellan Flood Study Flood Planning Area
Barellan Floodplain

Figure: A-5

Rev: A

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N

0 2 4km
Approx. Scale

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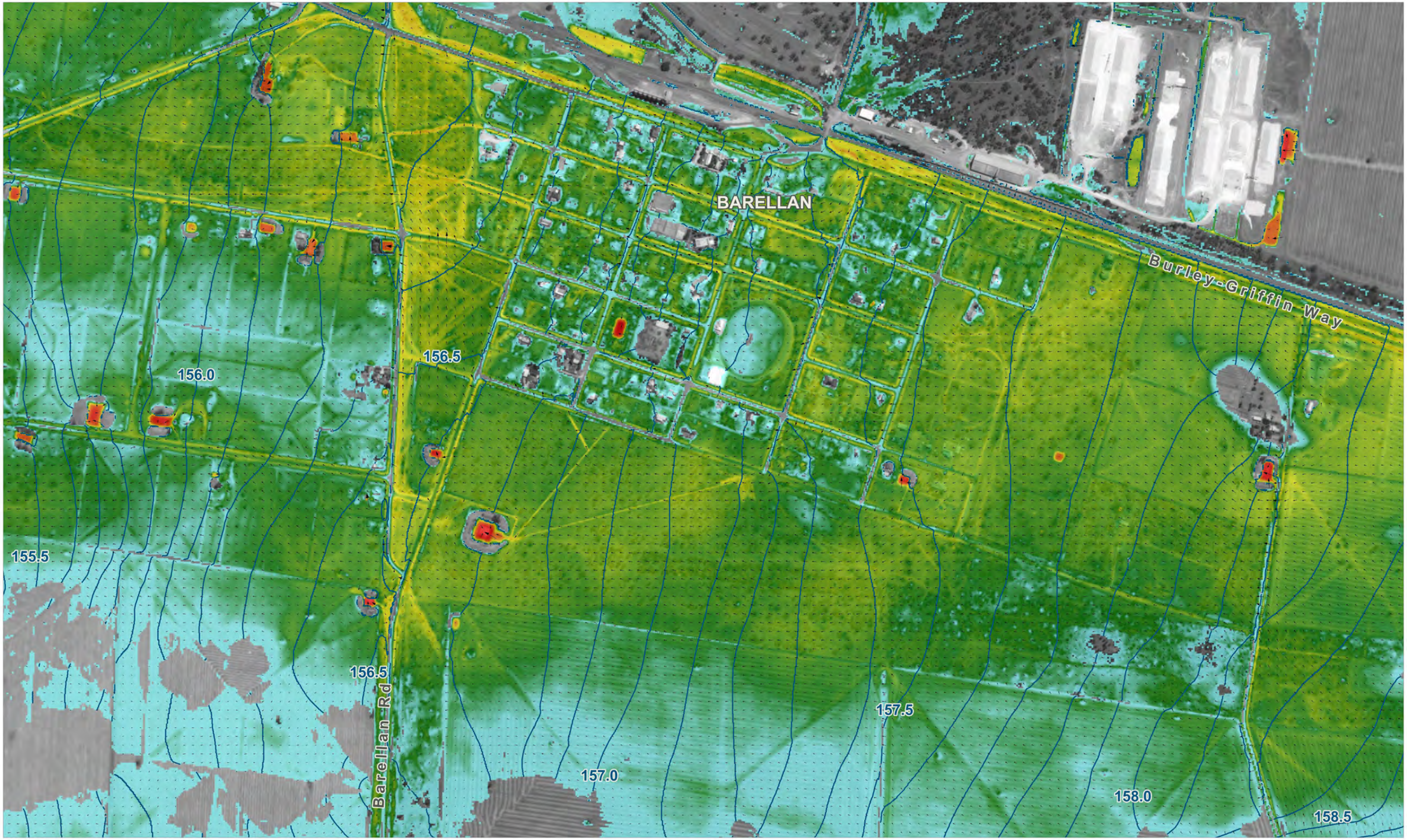

LEGEND

Peak Flood Depth (m)

- 0.1 (lower depths mapped as same colour)
- 0.2
- 0.5
- 1.0
- 2.0 (higher depths mapped as same colour)

Peak Flood Velocity (m/s)

Scale: 1mm = 0.125m/s @A3

- 0.125
- 0.25
- 0.50
- 0.75

1:5 Peak Flood Level Contours (m AHD)

Title:

Barellan Flood Study 1% AEP Modelled Peak Flood Depths, Velocities & Water Levels - Barellan Town

Figure: **A-6**

Rev: **A**

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N

0 200 400m

Approx. Scale

BMT WBM

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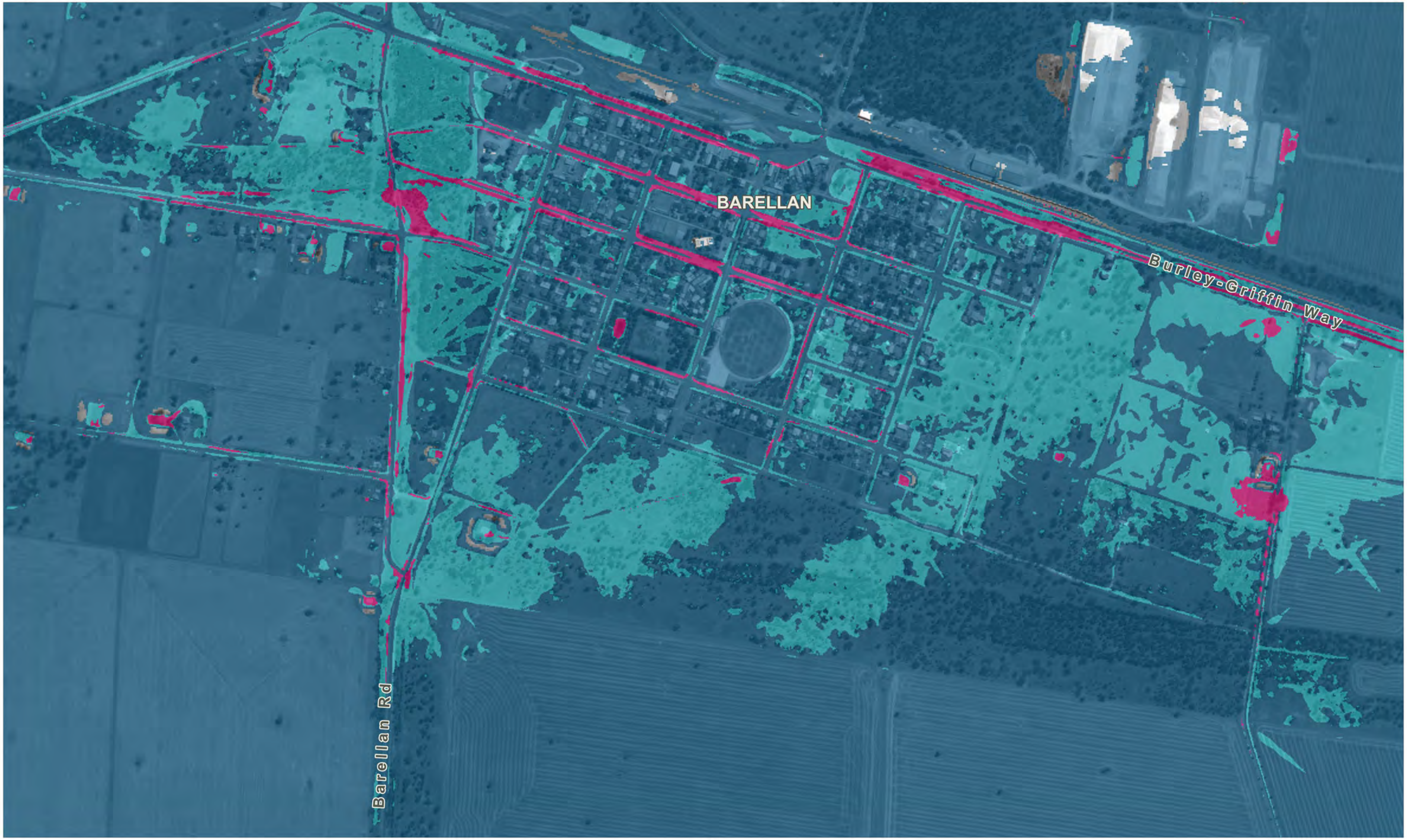

LEGEND

Hydraulic Category

- Flood Fringe - floodplain extent defined at the extreme flood event
- Flood Storage - velocity * depth < 0.1 and depth > 0.3 at the 1% AEP event
- Floodway - velocity * depth > 0.1 at the 1% AEP event

Title:
Barellan Flood Study Hydraulic Categorisation
Barellan Town

Figure: **A-7**

Rev: **A**

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Approx. Scale

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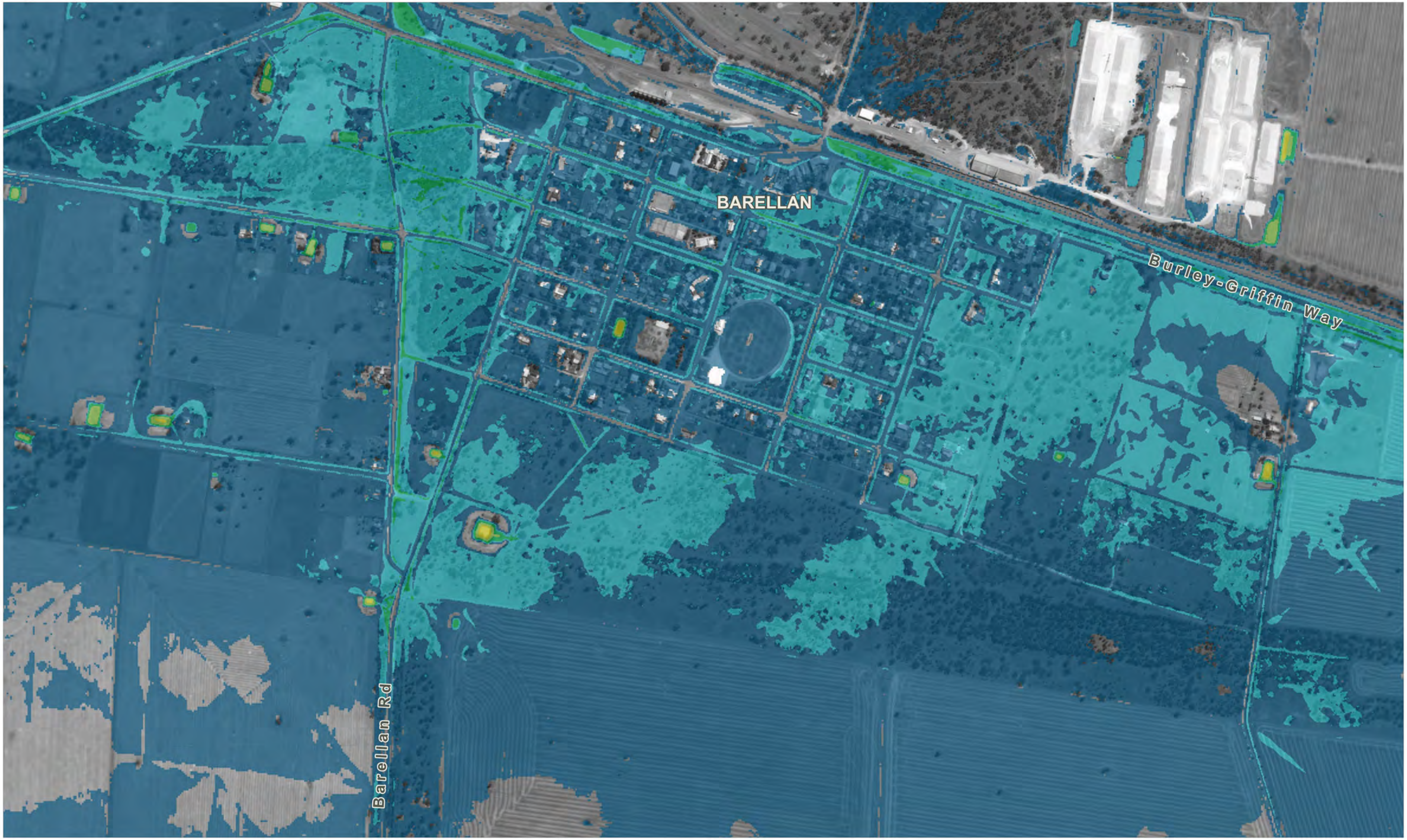

LEGEND

Hazard Classification

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

Title:

Barellan Flood Study 1% AEP Hazard Categorisation Barellan Town

Figure: **A-8**

Rev: **A**

N

0 200 400m

Approx. Scale

BMT WBM

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Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\Mapping\DRG_A08_1%AEP_Hazard_Town.WOR

LEGEND

Hazard Classification

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

Title:

Barellan Flood Study Extreme Flood Hazard Categorisation Barellan Town

Figure: A-9

Rev: A

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N

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Approx. Scale

BMT WBM

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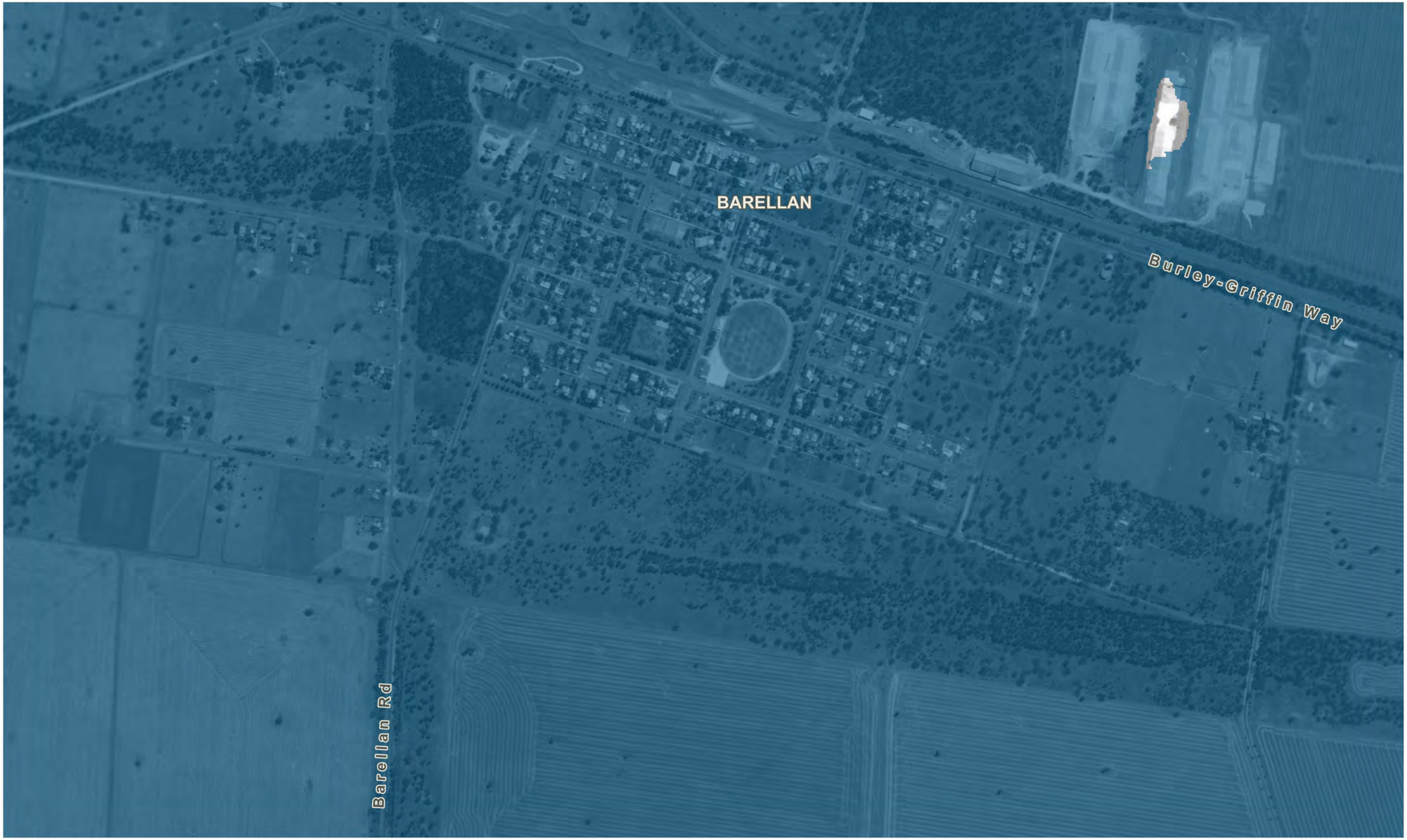

LEGEND

FPA

Title:
Barellan Flood Study Extreme Flood Planning Area
Barellan Town

Figure: A-10

Rev: A

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N

0 200 400m

Approx. Scale

BMT WBM

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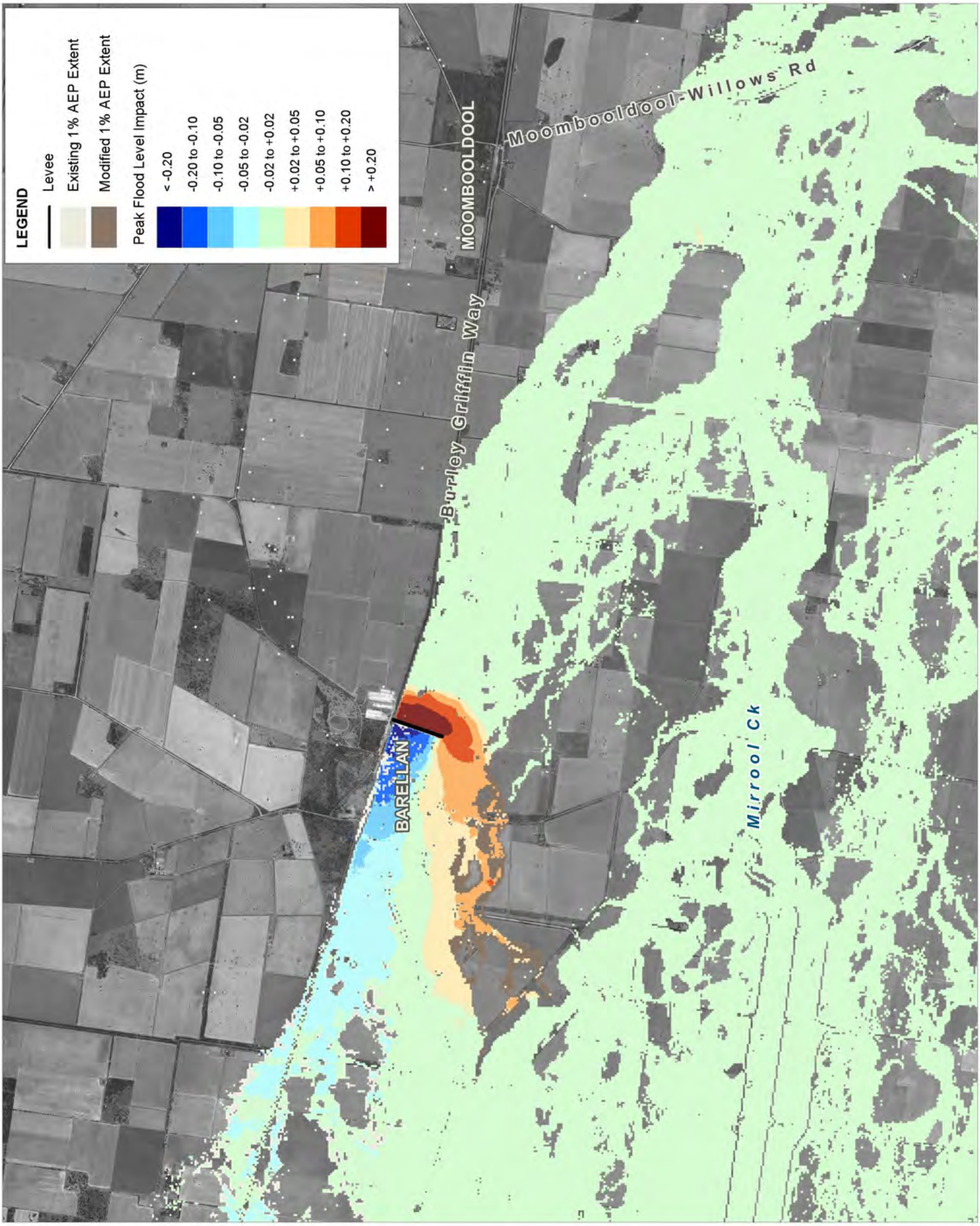
Appendix B. Preliminary Levee Alignment Options



Title:

Barellan FRMS&P Preliminary Option 1a
1% AEP Change in Peak Flood Level

Figure: **B-1**

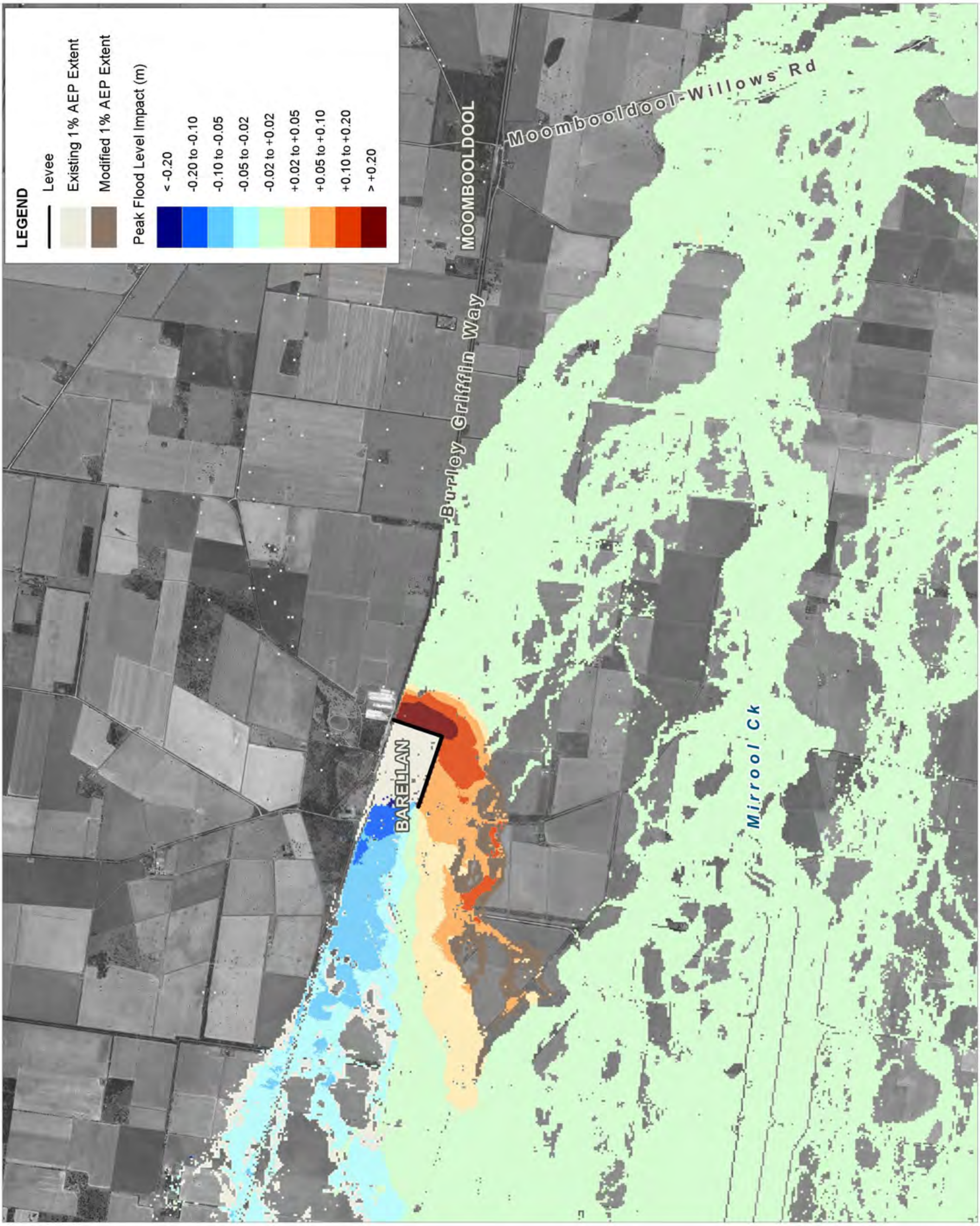
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B01_Levee_Prelim_Opt_01a.WOR



Title:

Barellan FRMS&P Preliminary Option 1b
1% AEP Change in Peak Flood Level

Figure: **B-2**

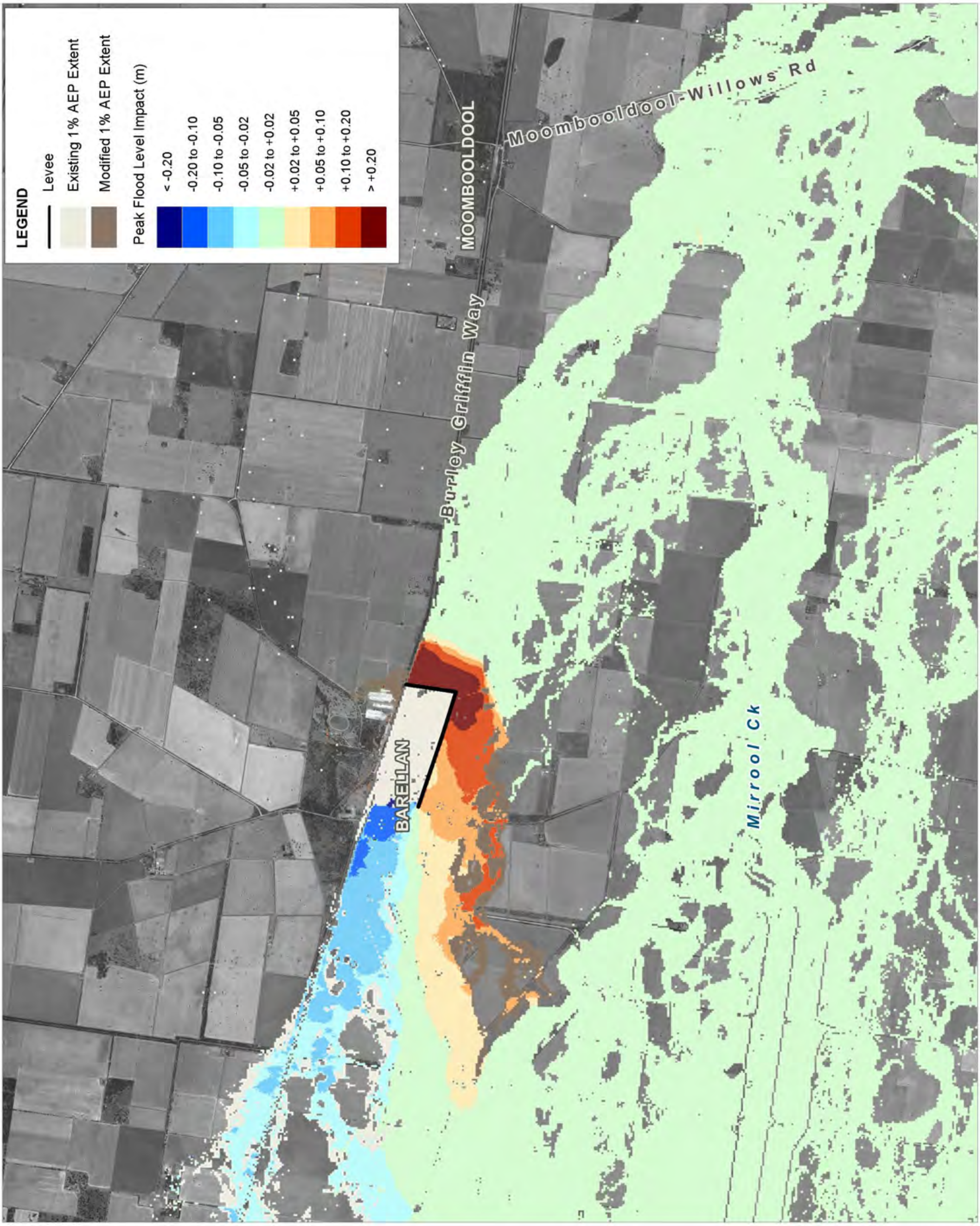
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B02_Levee_Prelim_Opt_01b.WOR



Title:

Barellan FRMS&P Preliminary Option 1c
1% AEP Change in Peak Flood Level

Figure: **B-3**

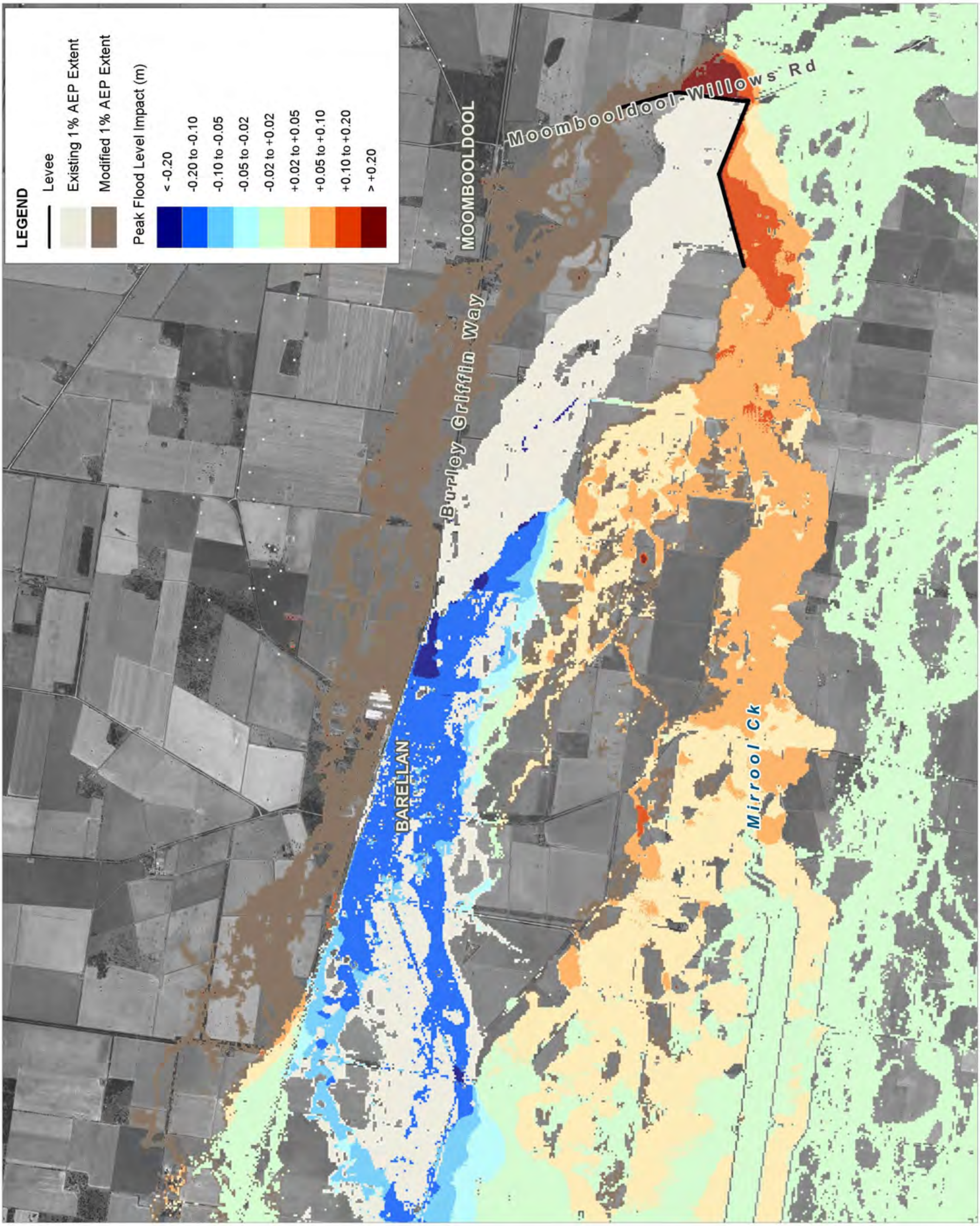
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B03_Levee_Prelim_Opt_01c.WOR



Title:

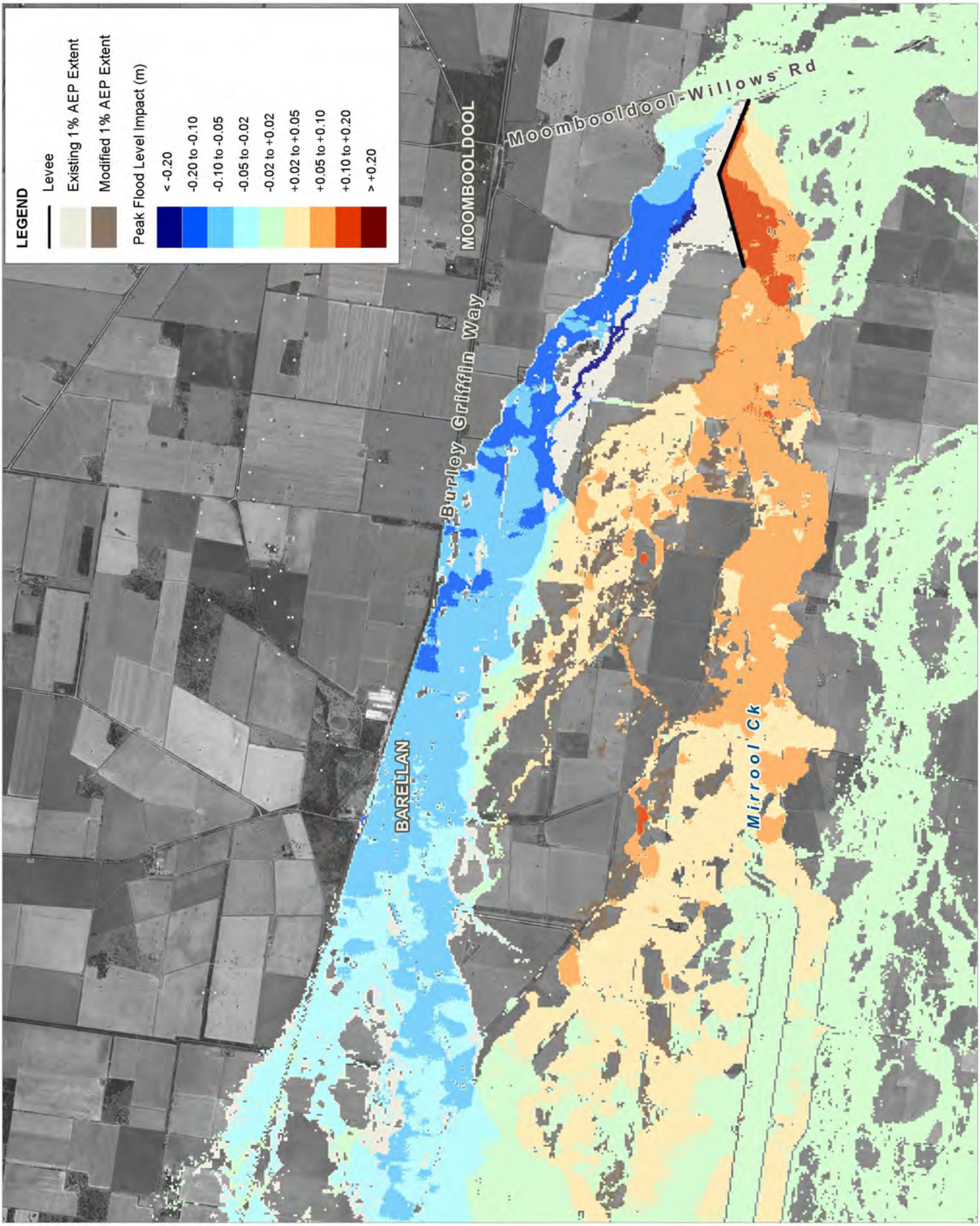
Barellan FRMS&P Preliminary Option 2a
1% AEP Change in Peak Flood Level

Figure: B-4

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B04_Levee_Prelim_Opt_02a.WOR



Title:

Barellan FRMS&P Preliminary Option 2b
1% AEP Change in Peak Flood Level

Figure: **B-5**

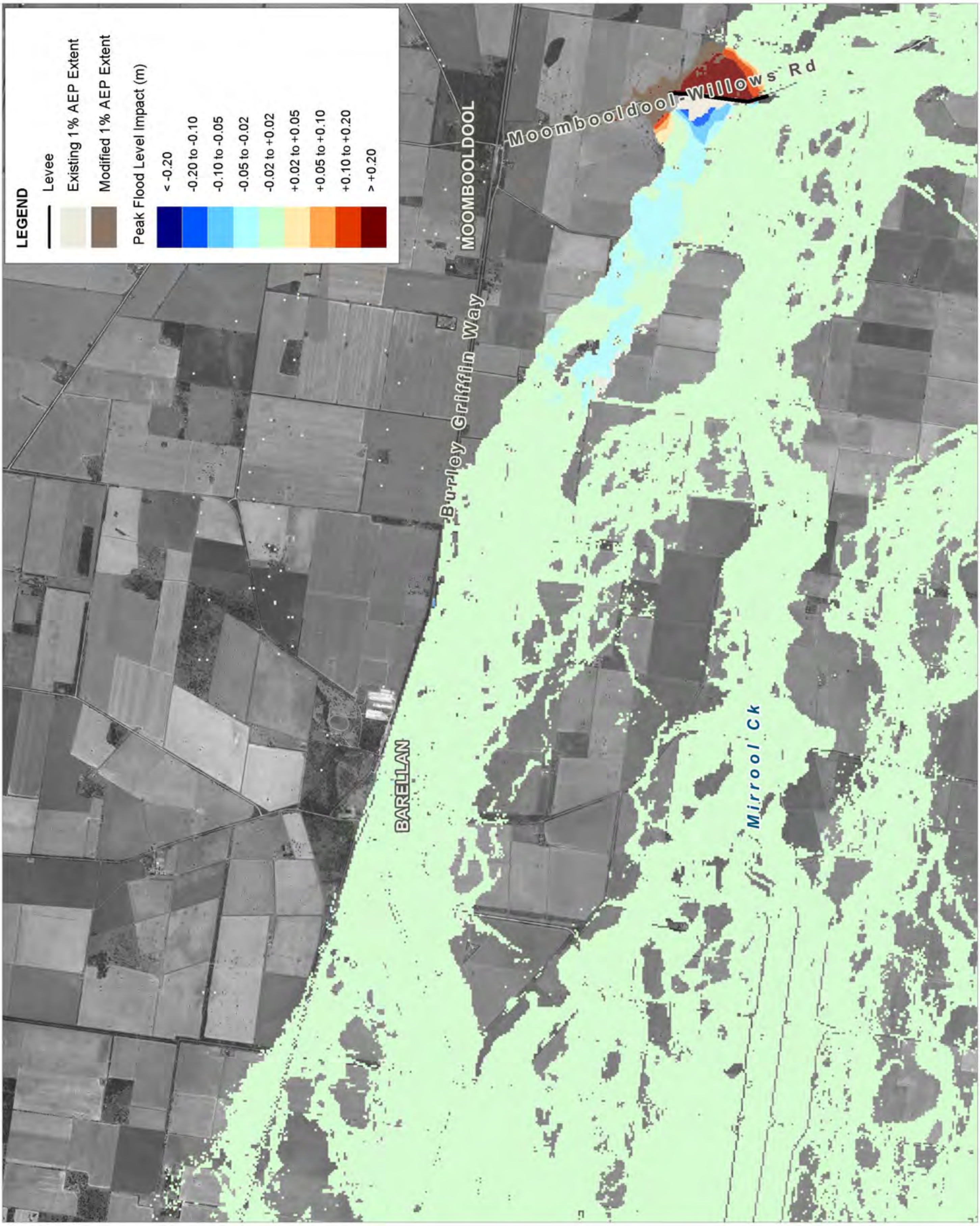
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B05_Levee_Prelim_Opt_02b.WOR



Title:

Barellan FRMS&P Preliminary Option 2c
1% AEP Change in Peak Flood Level

Figure: **B-6**

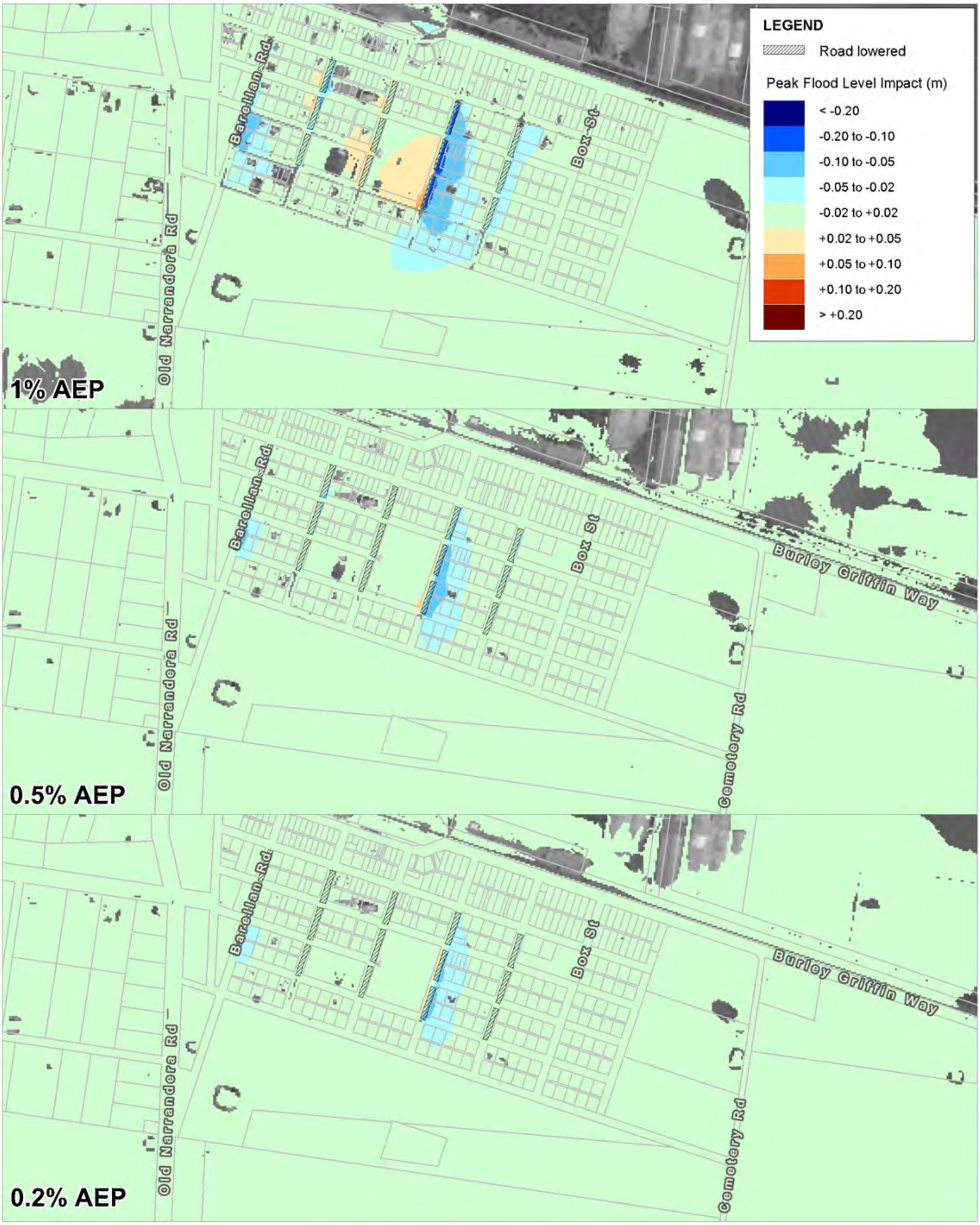
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B06_Levee_Prelim_Opt_02c.WOR



Title:

Barellan FRMS&P Preliminary Option - Lowering of Road Crests Change in Peak Flood Level

Figure: **B-7**

Rev: **A**

N

0 375 750m

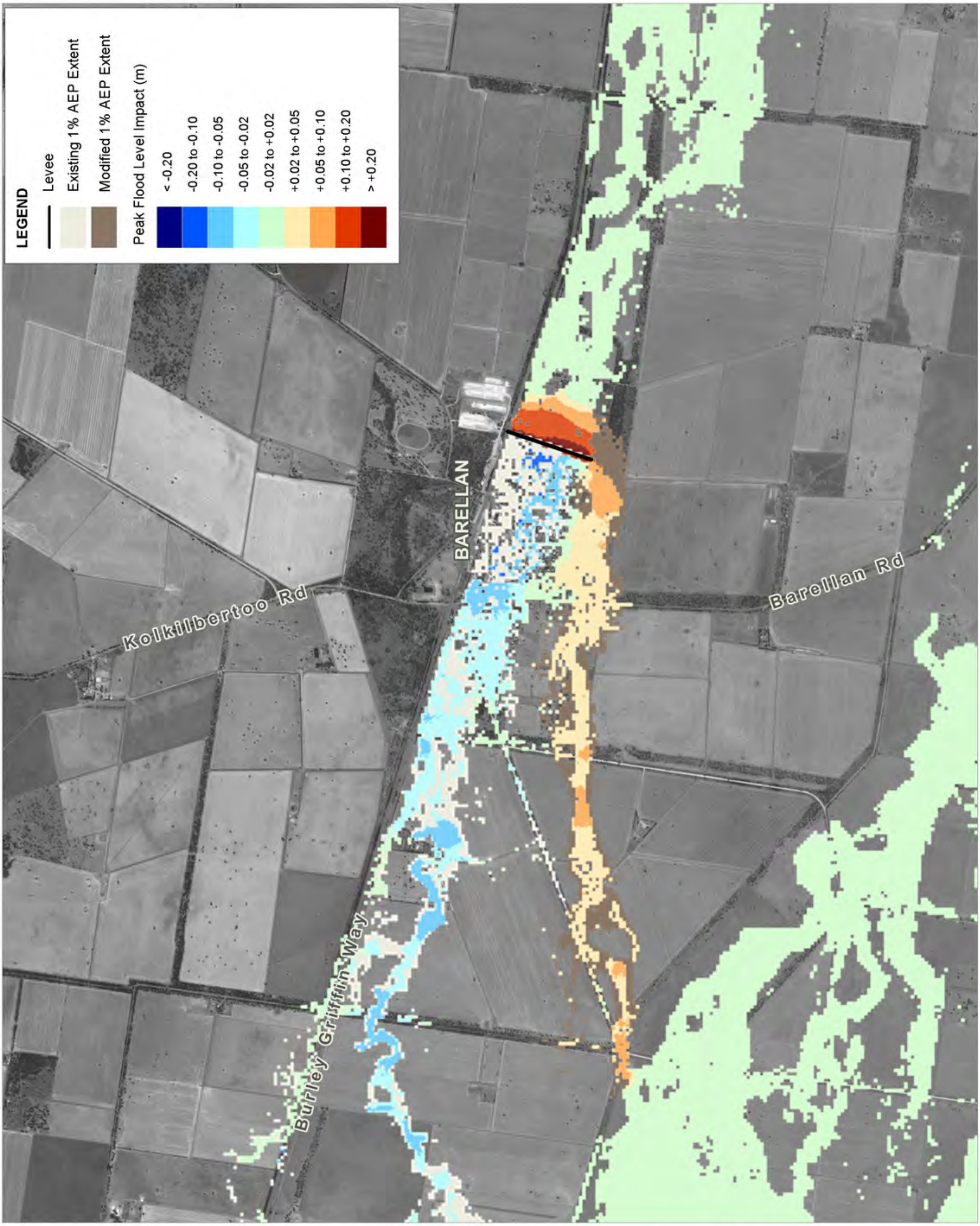
Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_B07_Lower_Roads_Opt_03b_03.WOR

Appendix C. Peak Flood Level Impacts Levee Option 1a



Title:

Barellan FRMS&P Levee Option 1a
2% AEP Change in Peak Flood Level

Figure: **C-1**

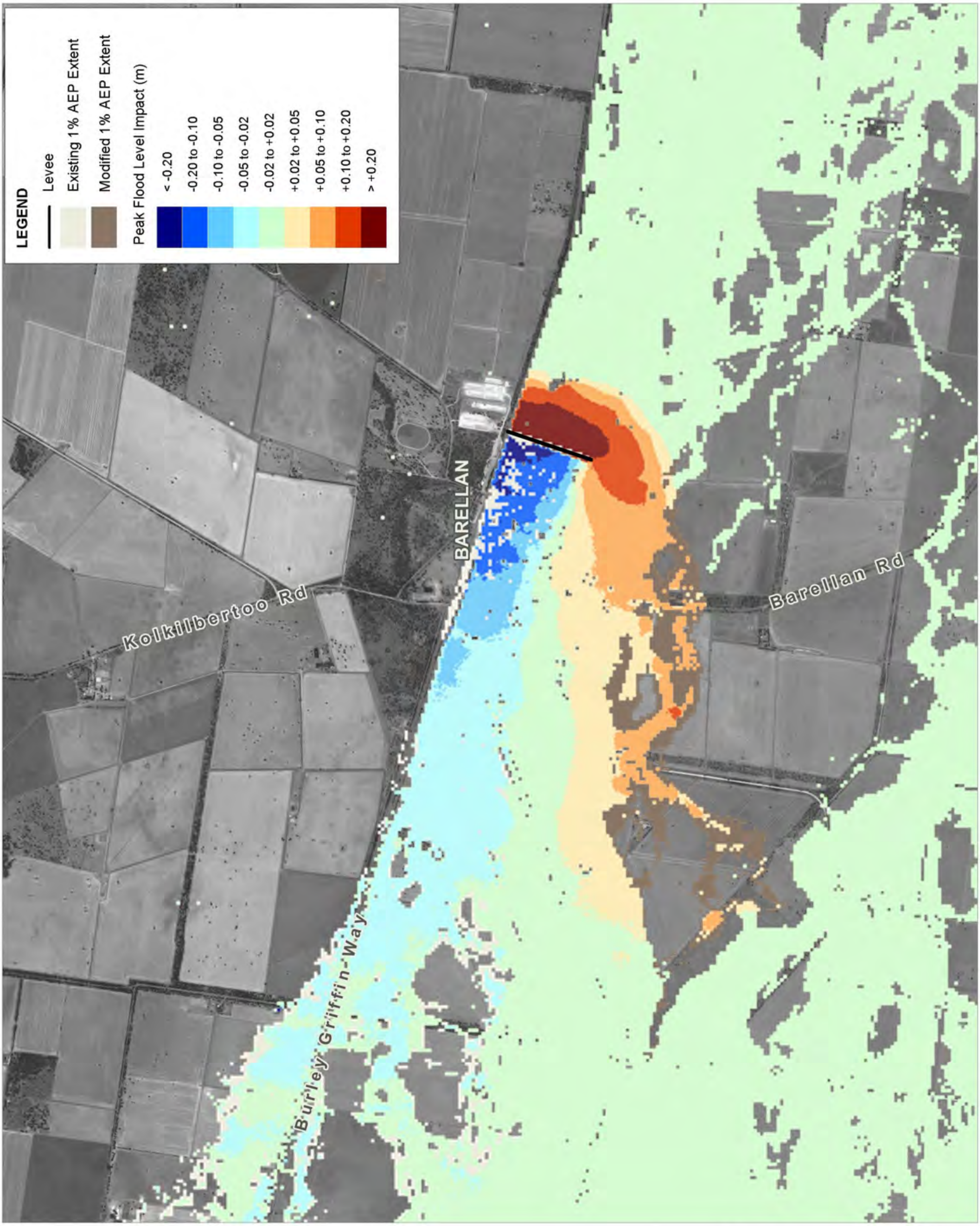
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_C01_170906_Levee_Opt_01a_50y.WOR



Title:

Barellan FRMS&P Levee Option 1a
1% AEP Change in Peak Flood Level

Figure: **C-2**

Rev: **A**

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N

0 0.75 1.5km

Approx. Scale

BMT WBM

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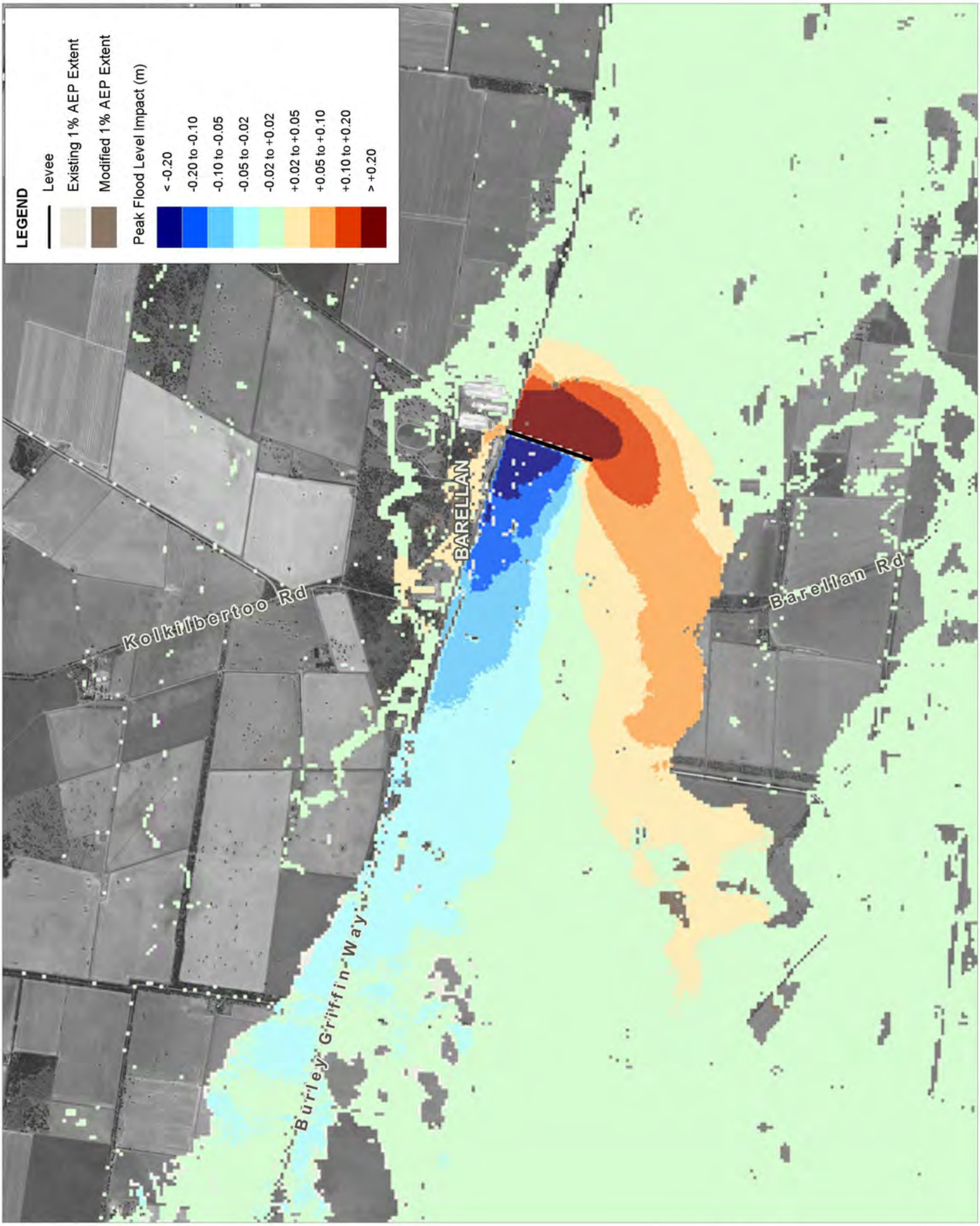
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_C02_170906_Levee_Opt_01a_100y.WOR



Title:

Barellan FRMS&P Levee Option 1a
0.5% AEP Change in Peak Flood Level

Figure: **C-3**

Rev: **A**

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N

0 0.75 1.5km
Approx. Scale

BMT WBM
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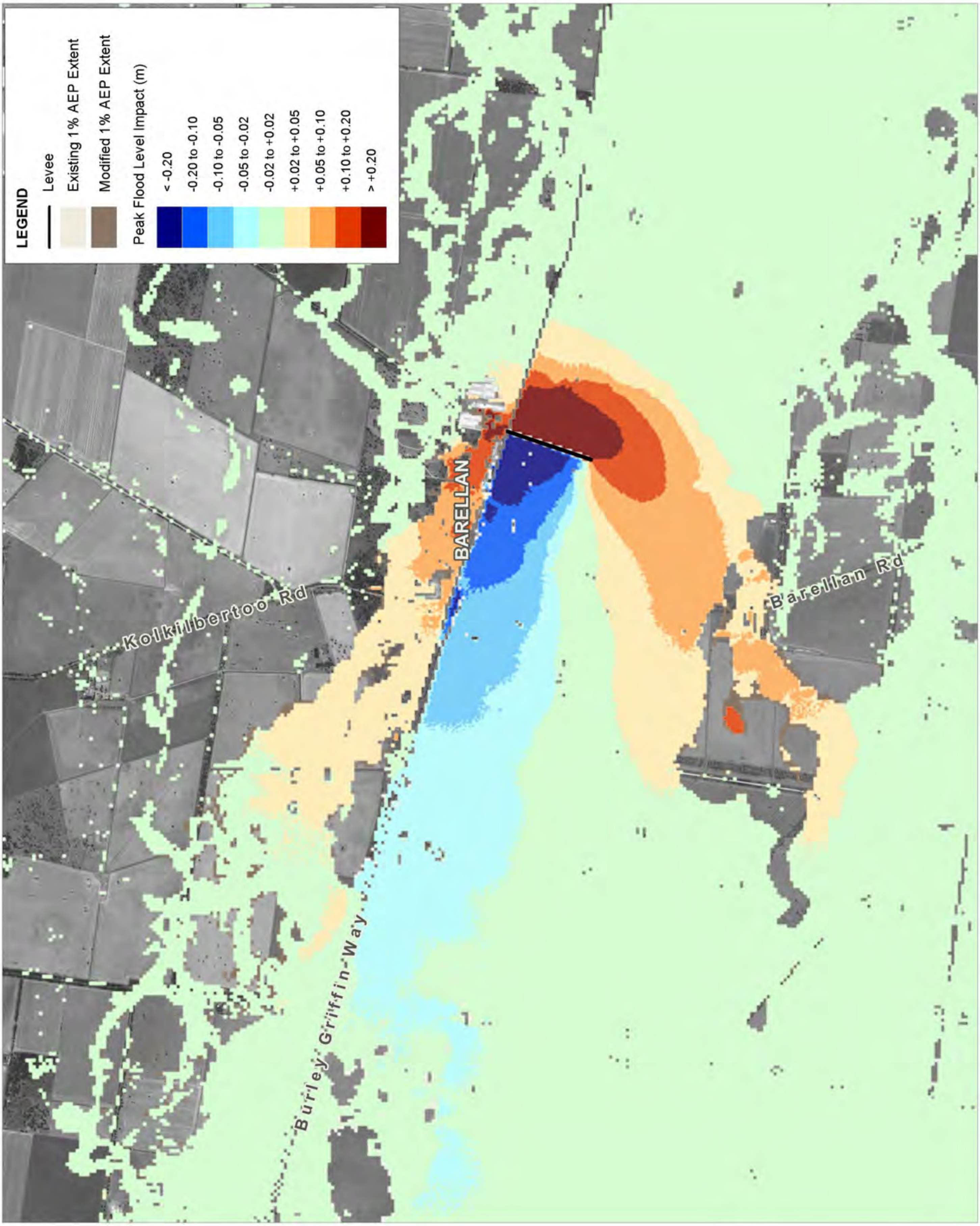
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_C03_170906_Levee_Opt_01a_200y.WOR



Title:

Barellan FRMS&P Levee Option 1a
0.2% AEP Change in Peak Flood Level

Figure: C-4

Rev: A

N

0 0.75 1.5km
Approx. Scale

BMT WBM
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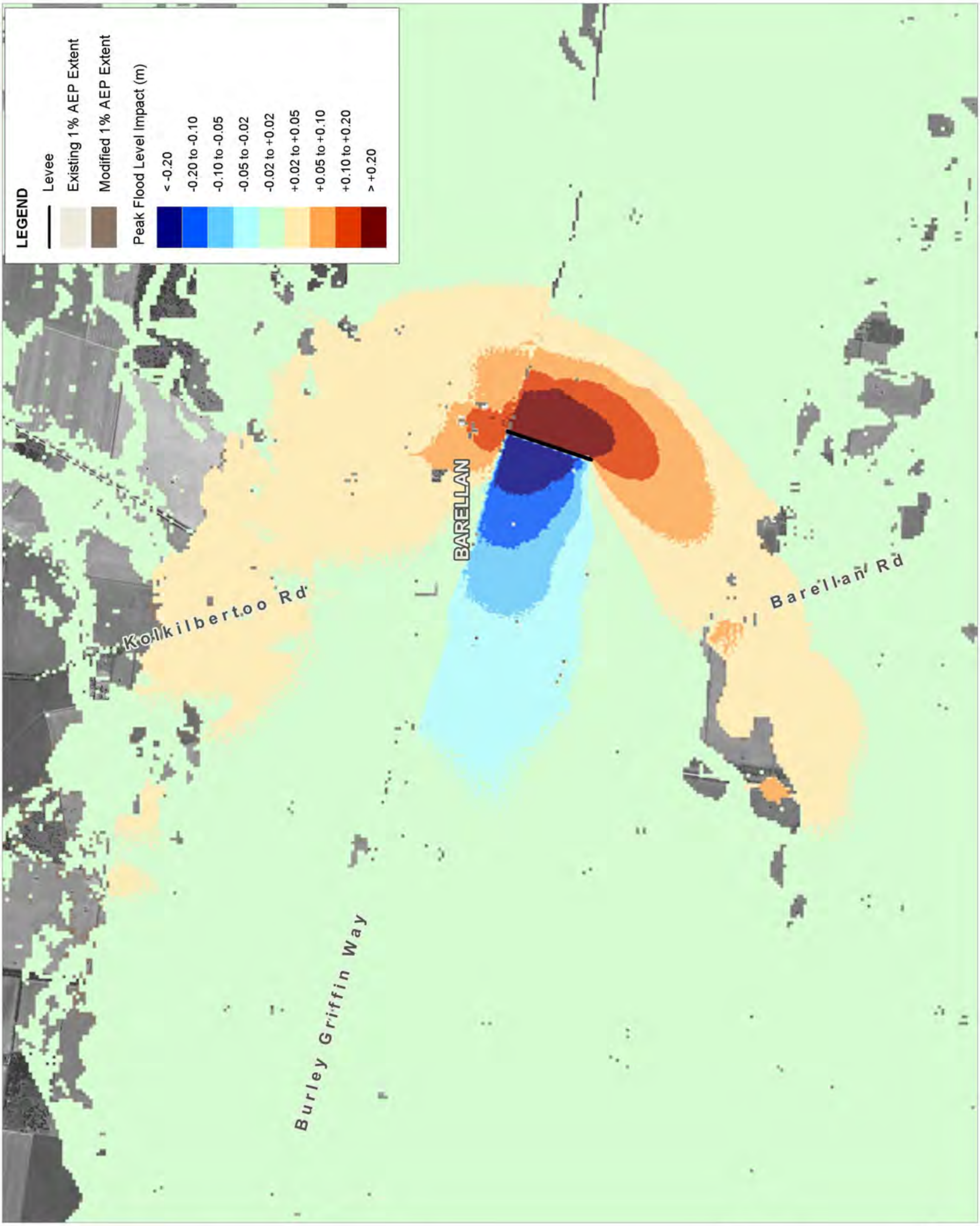
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_C04_170906_Levee_Opt_01a_500y.WOR



Title:

Barellan FRMS&P Levee Option 1a
Extreme Flood Event

Figure: **C-5**

Rev: **A**

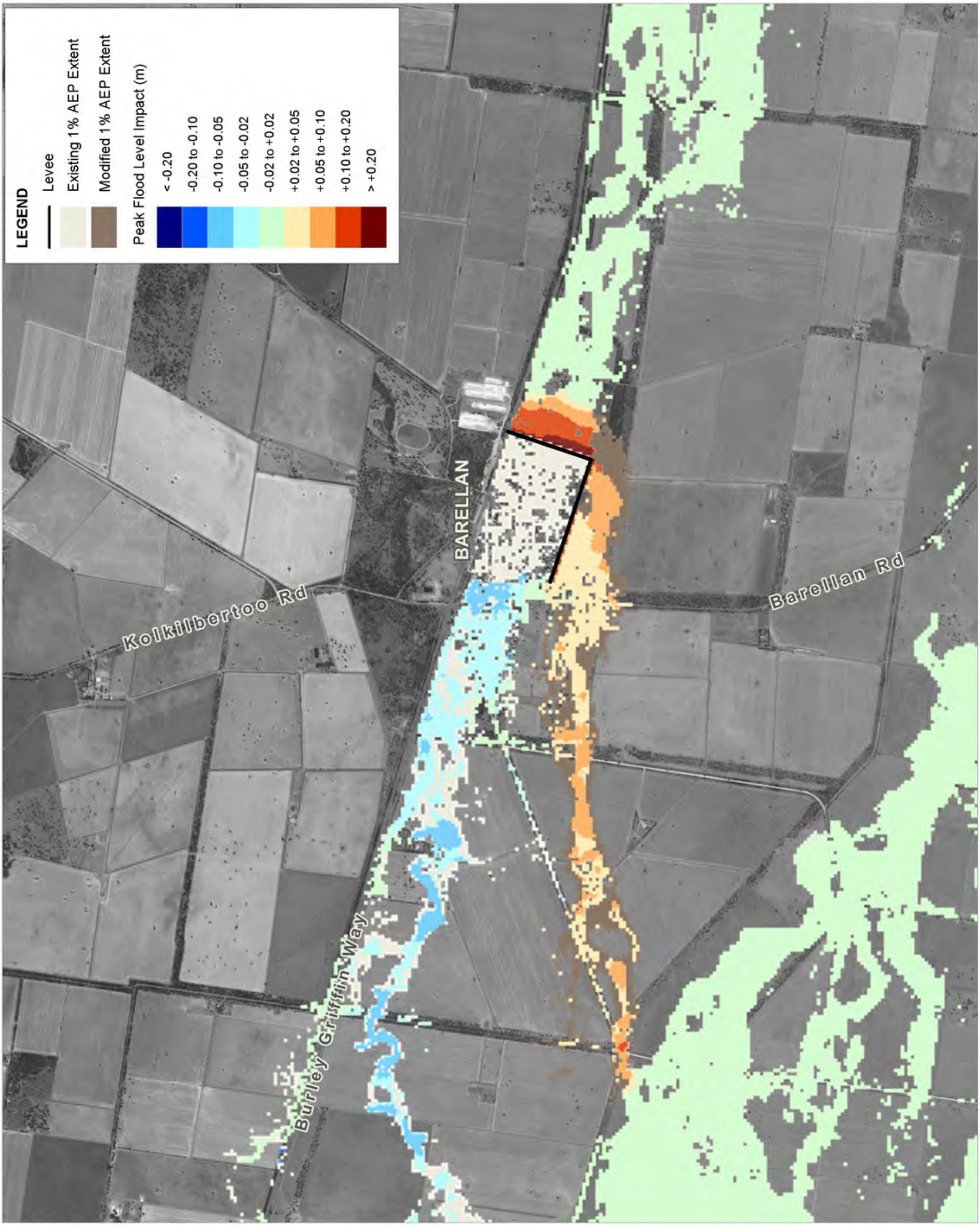
N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_C05_170906_Levee_Opt_01a_PMF.WOR

Appendix D. Peak Flood Level Impact Maps Levee Option 1b



Title:

Barellan FRMS&P Levee Option 1b
2% AEP Change in Peak Flood Level

Figure: **D-1**

Rev: **A**

N

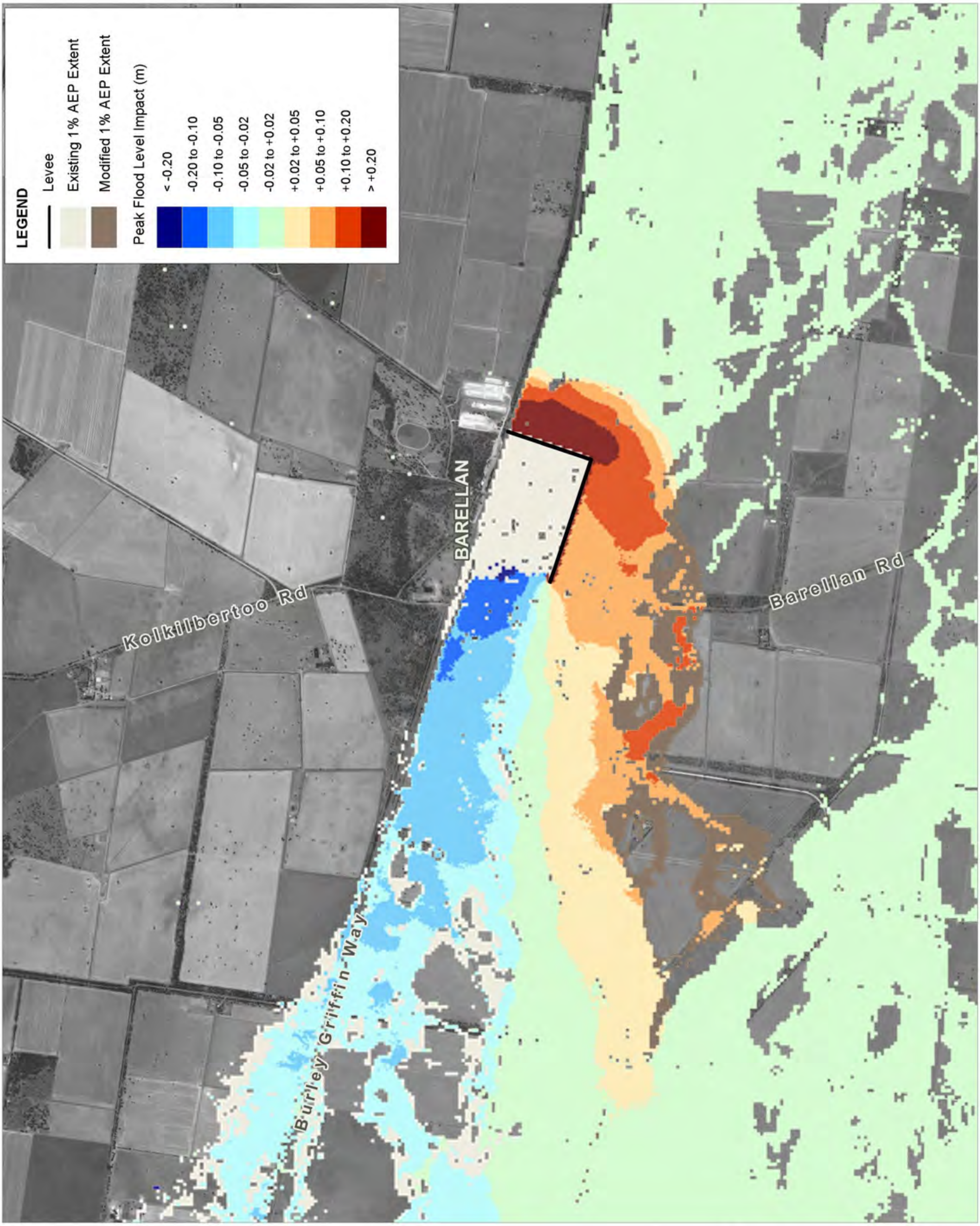
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_D01_170906_Levee_Opt_01b_50y.WOR



Title:

Barellan FRMS&P Levee Option 1b
1% AEP Change in Peak Flood Level

Figure: **D-2**

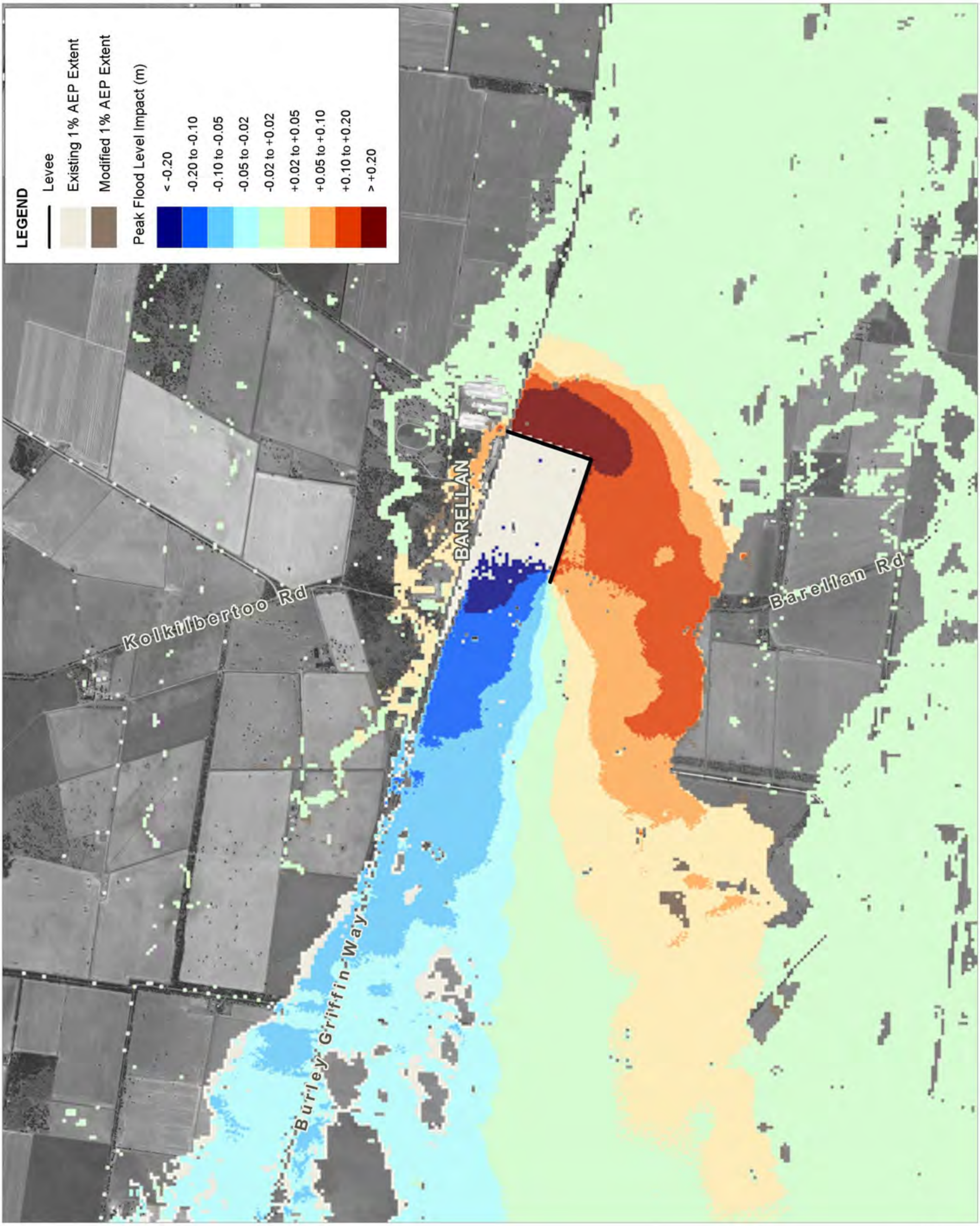
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_D02_170906_Levee_Opt_01b_100y.WOR



Title:

Barellan FRMS&P Levee Option 1b
0.5% AEP Change in Peak Flood Level

Figure: **D-3**

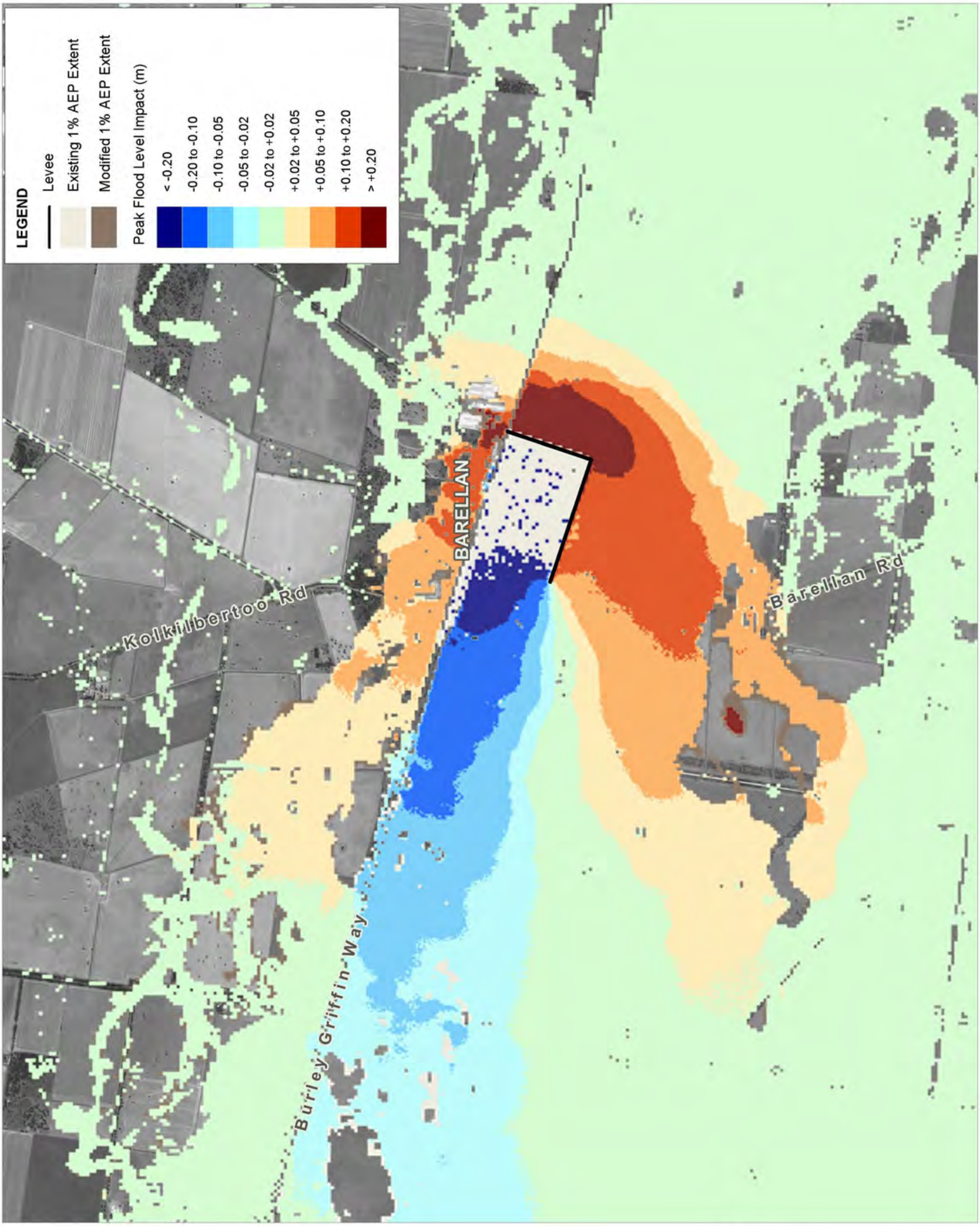
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_D03_170906_Levee_Opt_01b_200y.WOR



Title:

Barellan FRMS&P Levee Option 1b
0.2% AEP Change in Peak Flood Level

Figure: **D-4**

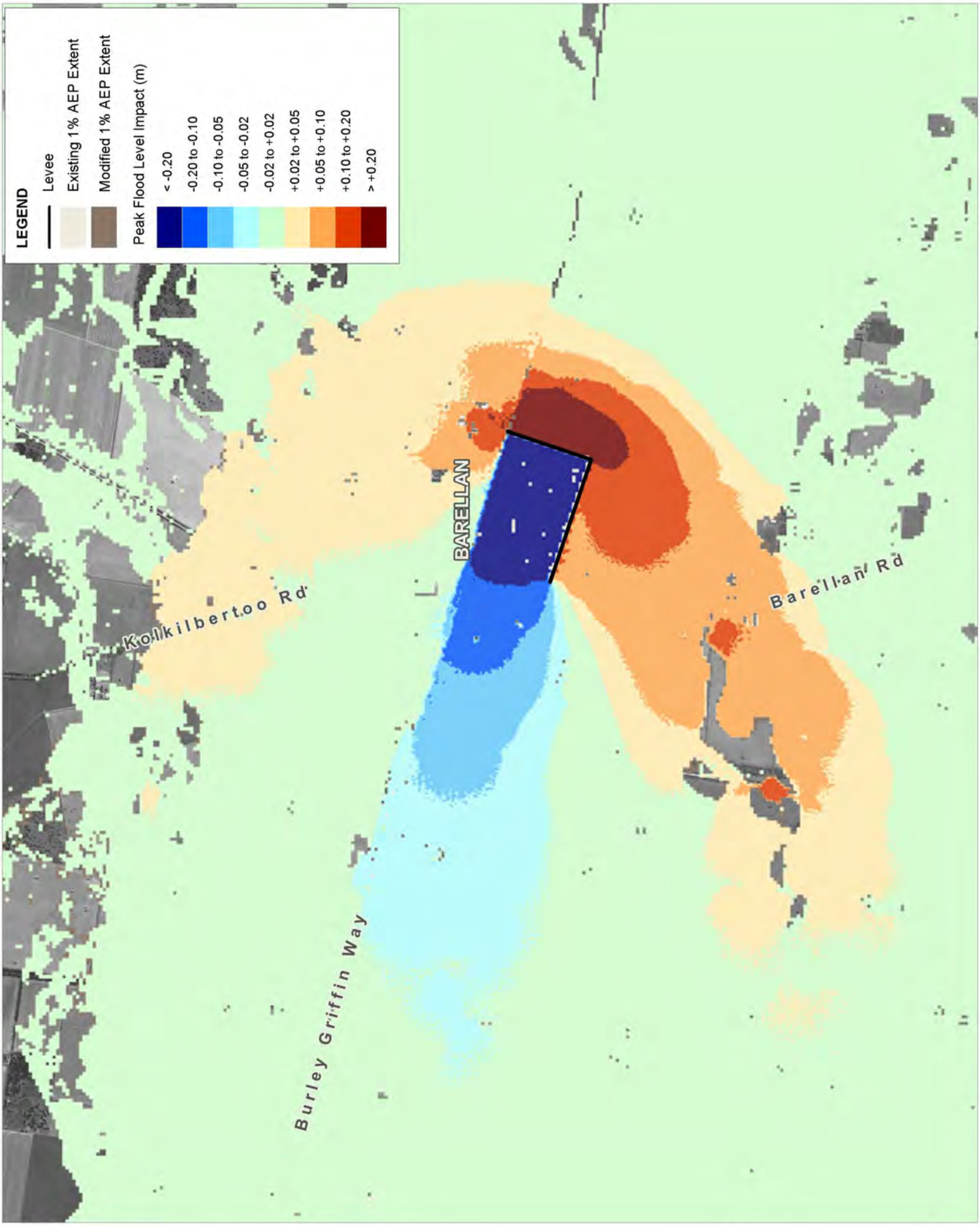
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_D04_170906_Levee_Opt_01b_500y.WOR



Title:

Barellan FRMS&P Levee Option 1b
Extreme Flood Event

Figure: **D-5**

Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
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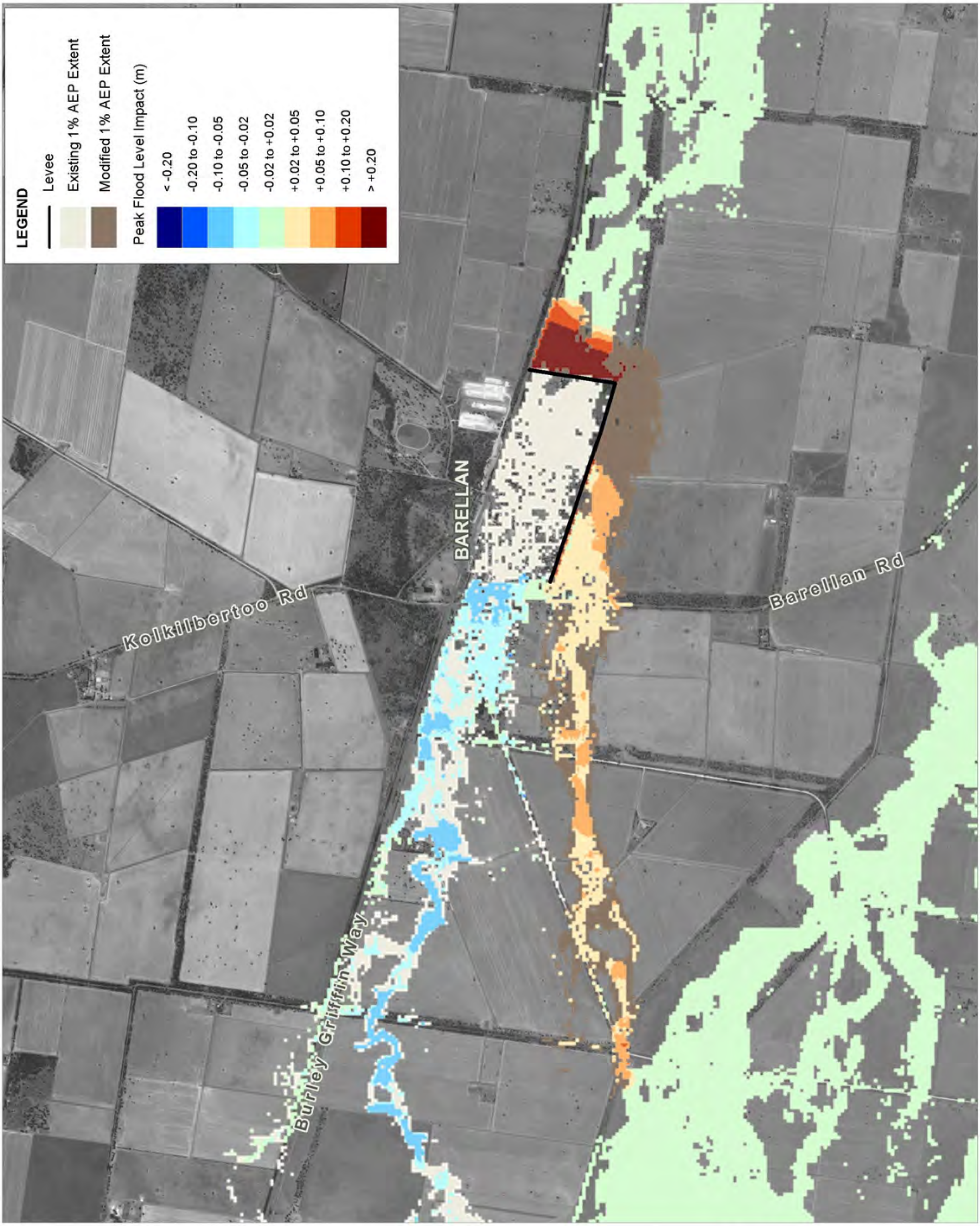
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_D05_170906_Levee_Opt_01b_PMF.WOR

Appendix E. Peak Flood Level Impact Maps Levee Option 1c



Title:

Barellan FRMS&P Levee Option 1d
2% AEP Change in Peak Flood Level

Figure: **E-1**

Rev: **A**

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N

0 0.75 1.5km
Approx. Scale

BMT WBM
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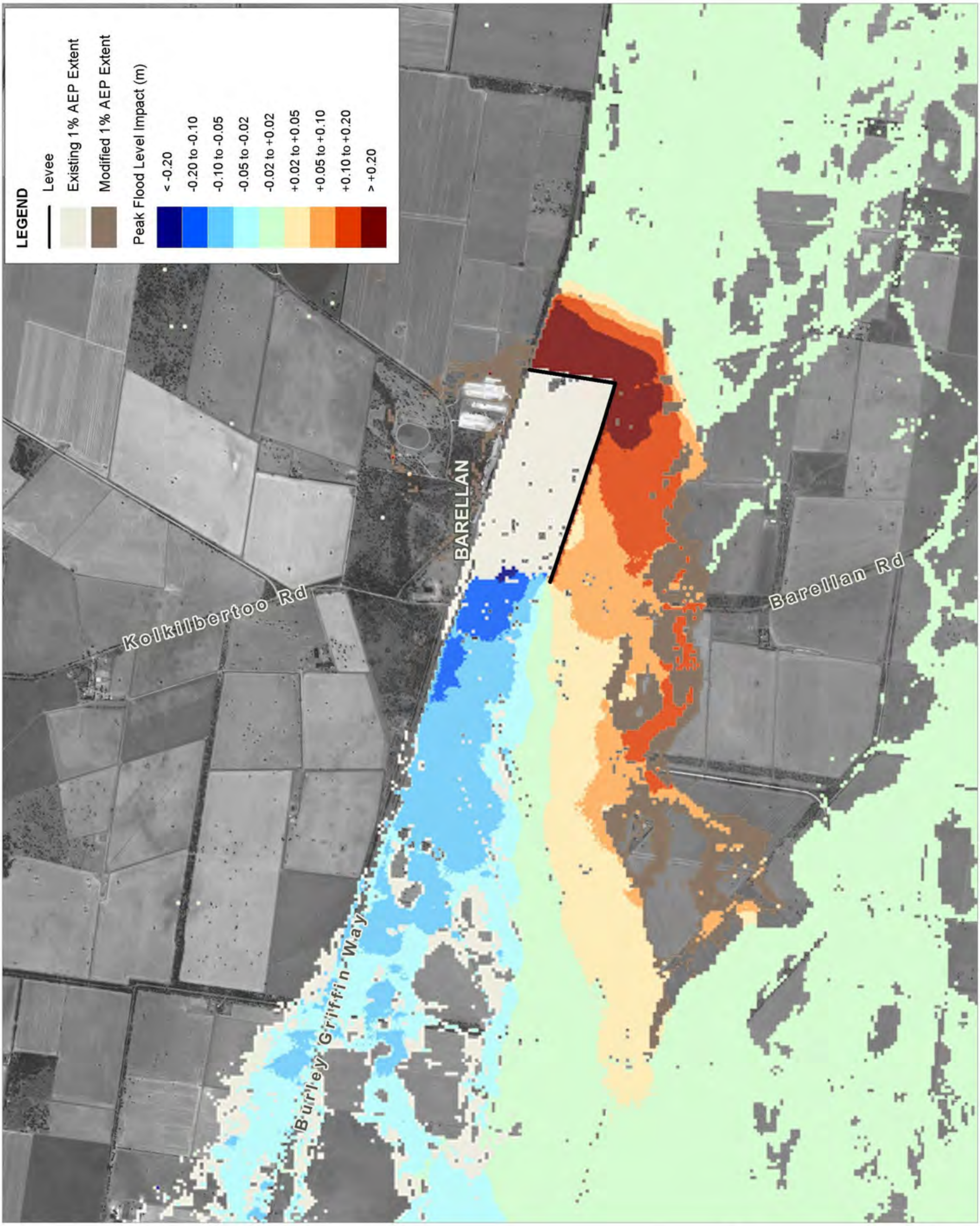
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_E01_170906_Levee_Opt_01c_50y.WOR



Title:

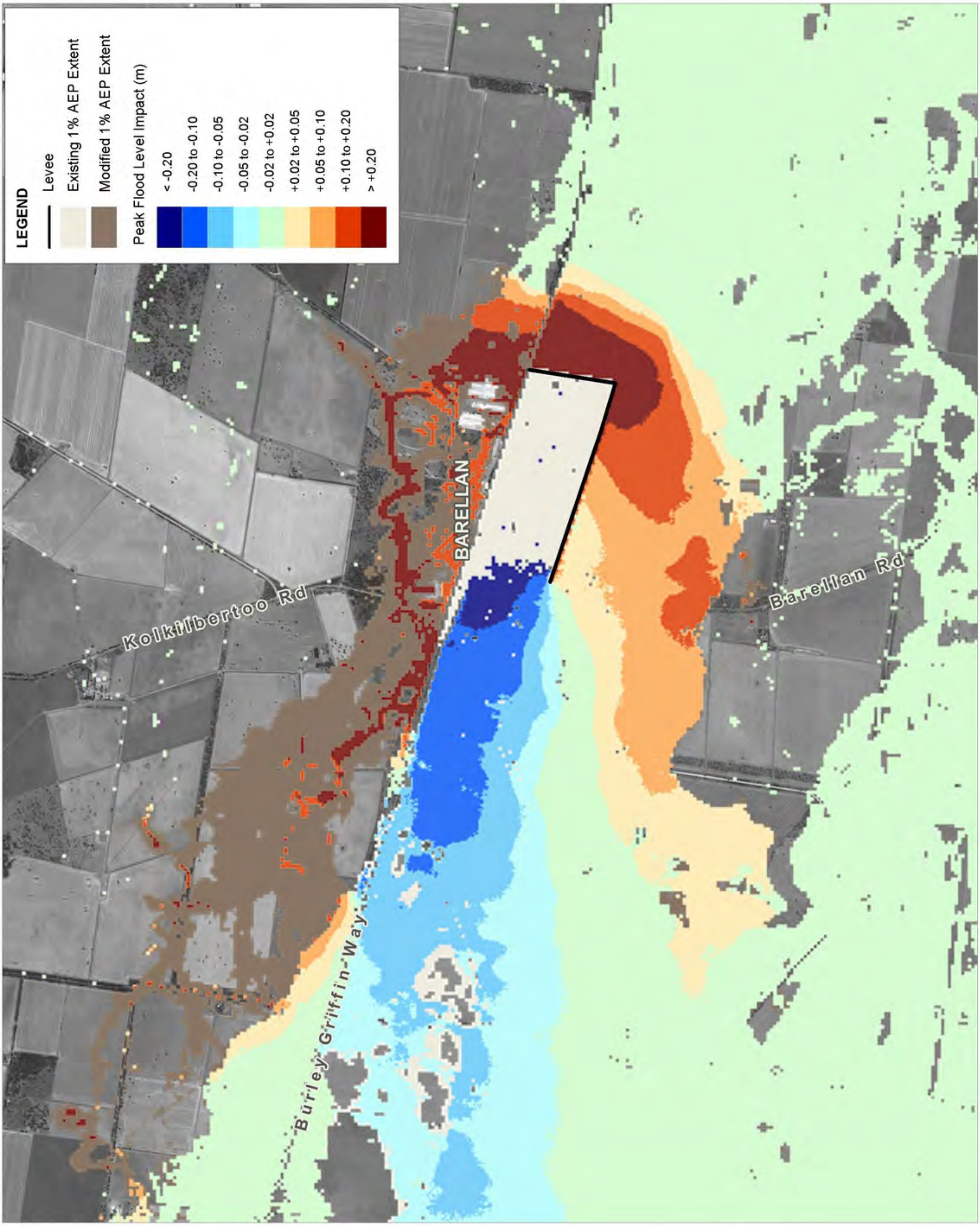
Barellan FRMS&P Levee Option 1d
1% AEP Change in Peak Flood Level

Figure: **E-2**

Rev: **A**

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_E02_170906_Levee_Opt_01c_100y.WOR



Title:

Barellan FRMS&P Levee Option 1d
0.5% AEP Change in Peak Flood Level

Figure: **E-3**

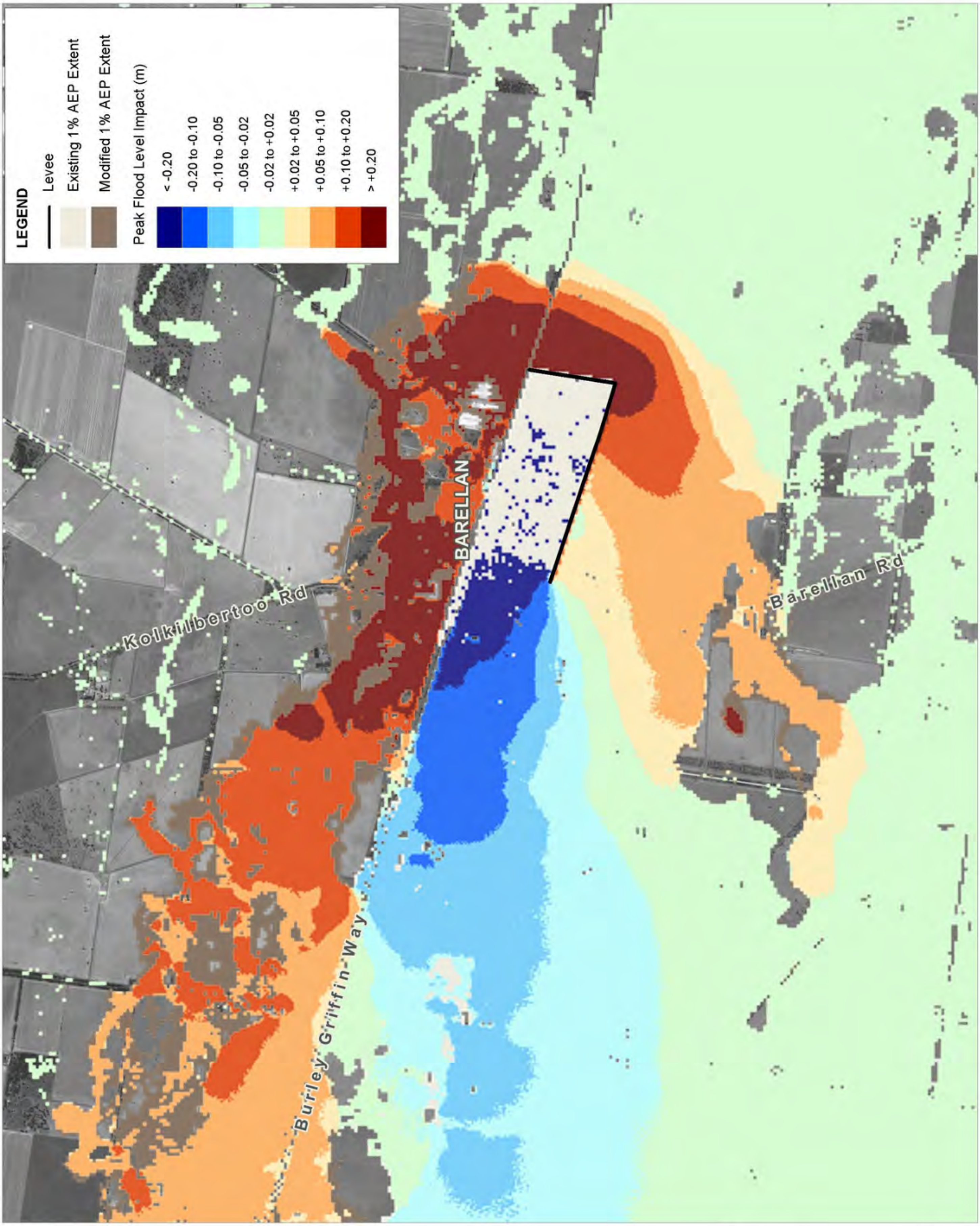
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_E03_170906_Levee_Opt_01c_200y.WOR



Title:

Barellan FRMS&P Levee Option 1d
0.2% AEP Change in Peak Flood Level

Figure: **E-4**

Rev: **A**

BMT WBM
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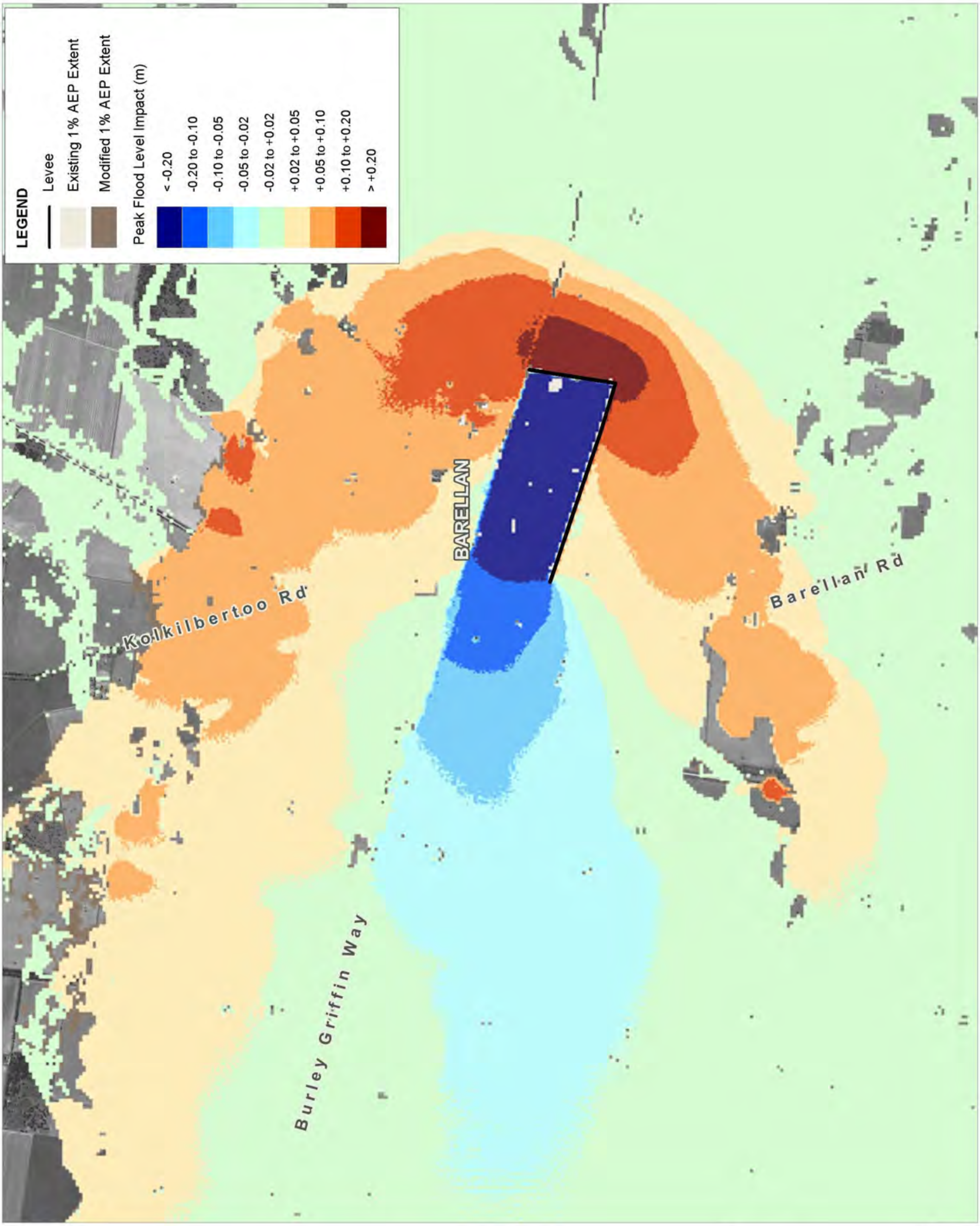
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_E04_170906_Levee_Opt_01c_500y.WOR



Title:

Barellan FRMS&P Levee Option 1d Extreme Flood Event

Figure: **E-5**

Rev: **A**

N

0 0.75 1.5km

Approx. Scale

BMT WBM

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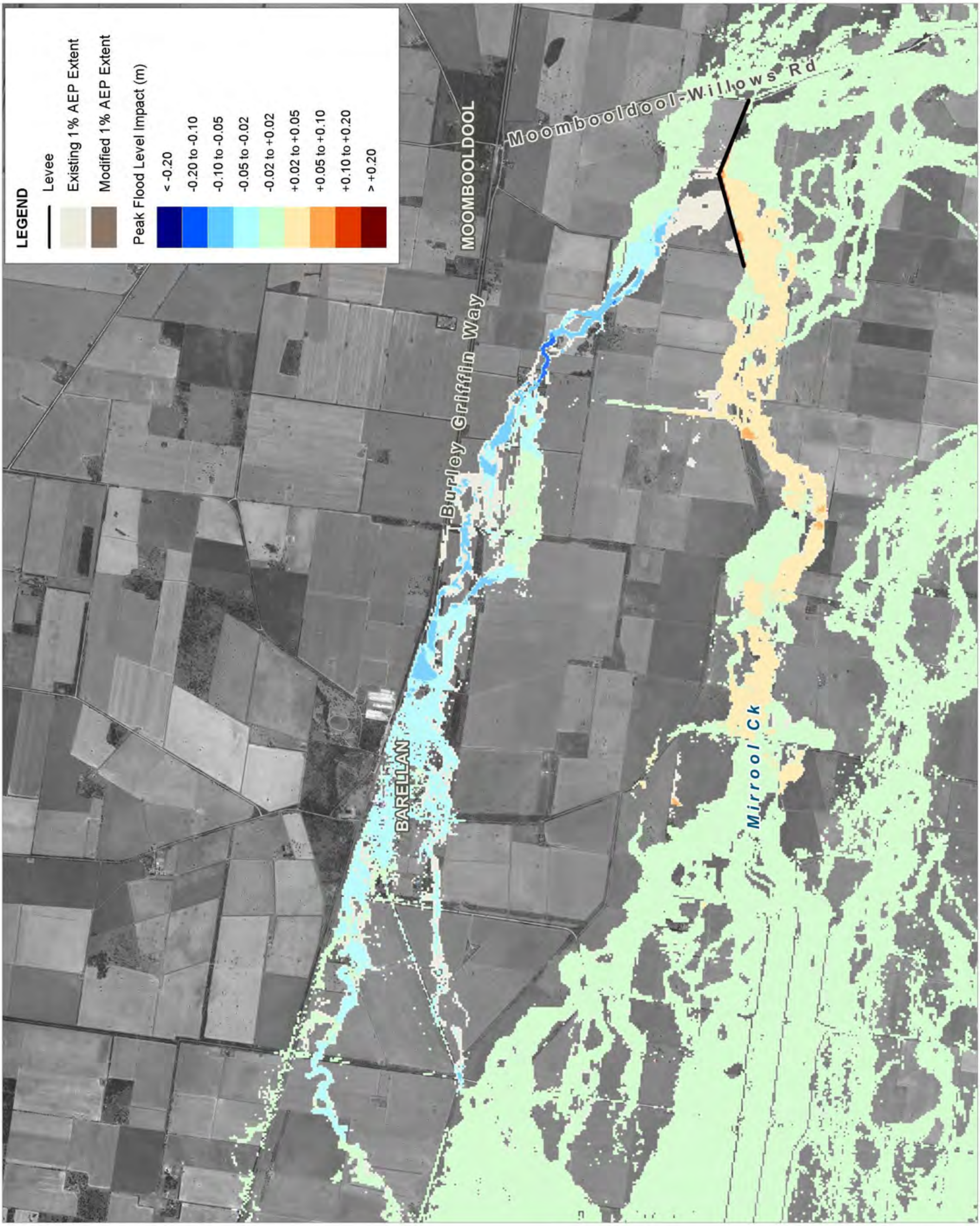
Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_E05_170906_Levee_Opt_01c_PMF.WOR

Appendix F. Peak Flood Level Impact Maps Levee Option 2b



Title:

Barellan FRMS&P Levee Option 2b
2% AEP Change in Peak Flood Level

Figure: **F-1**

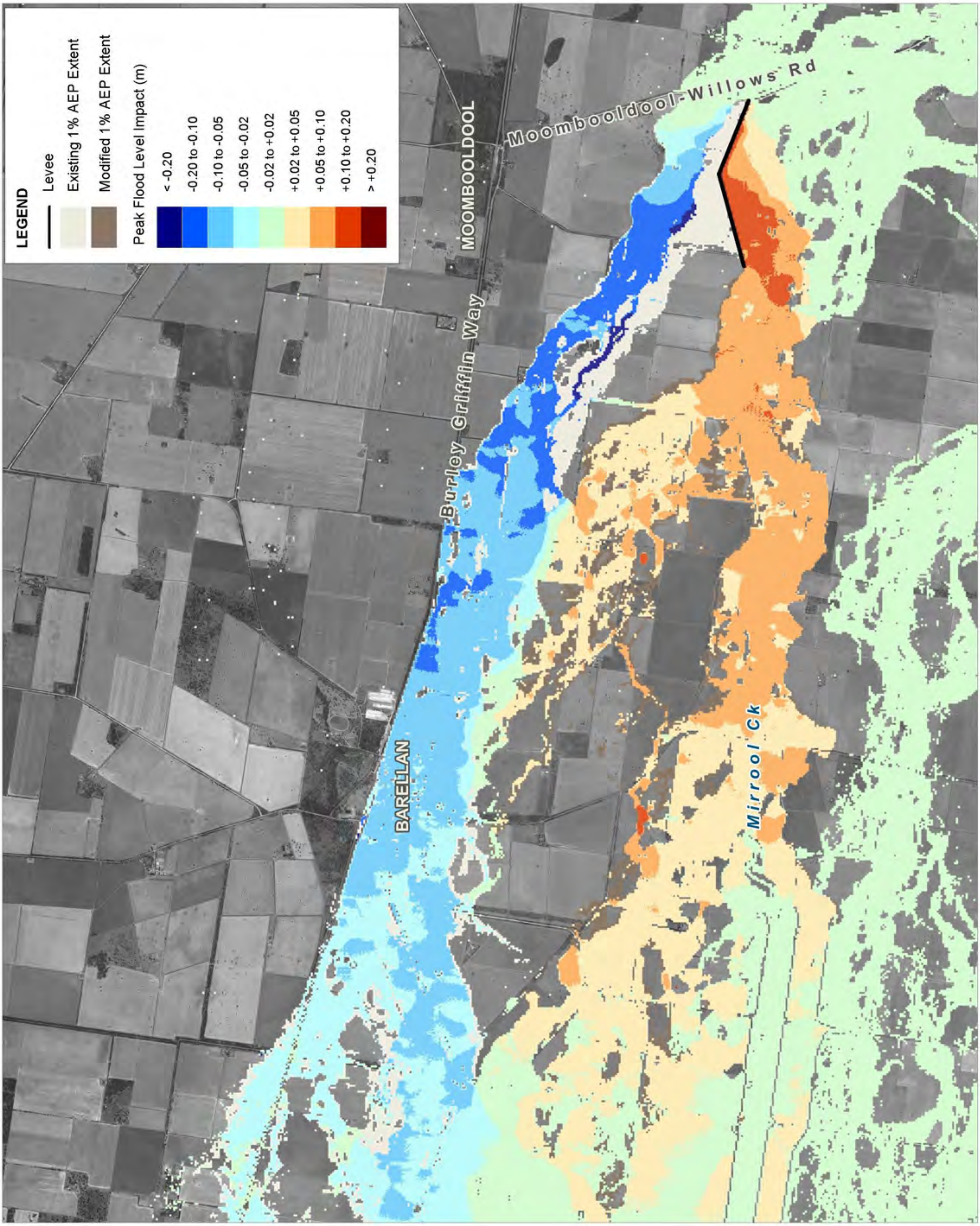
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_F01_170908_Levee_Opt_02b_50y.WOR



Title:

Barellan FRMS&P Levee Option 2b
1% AEP Change in Peak Flood Level

Figure: F-2

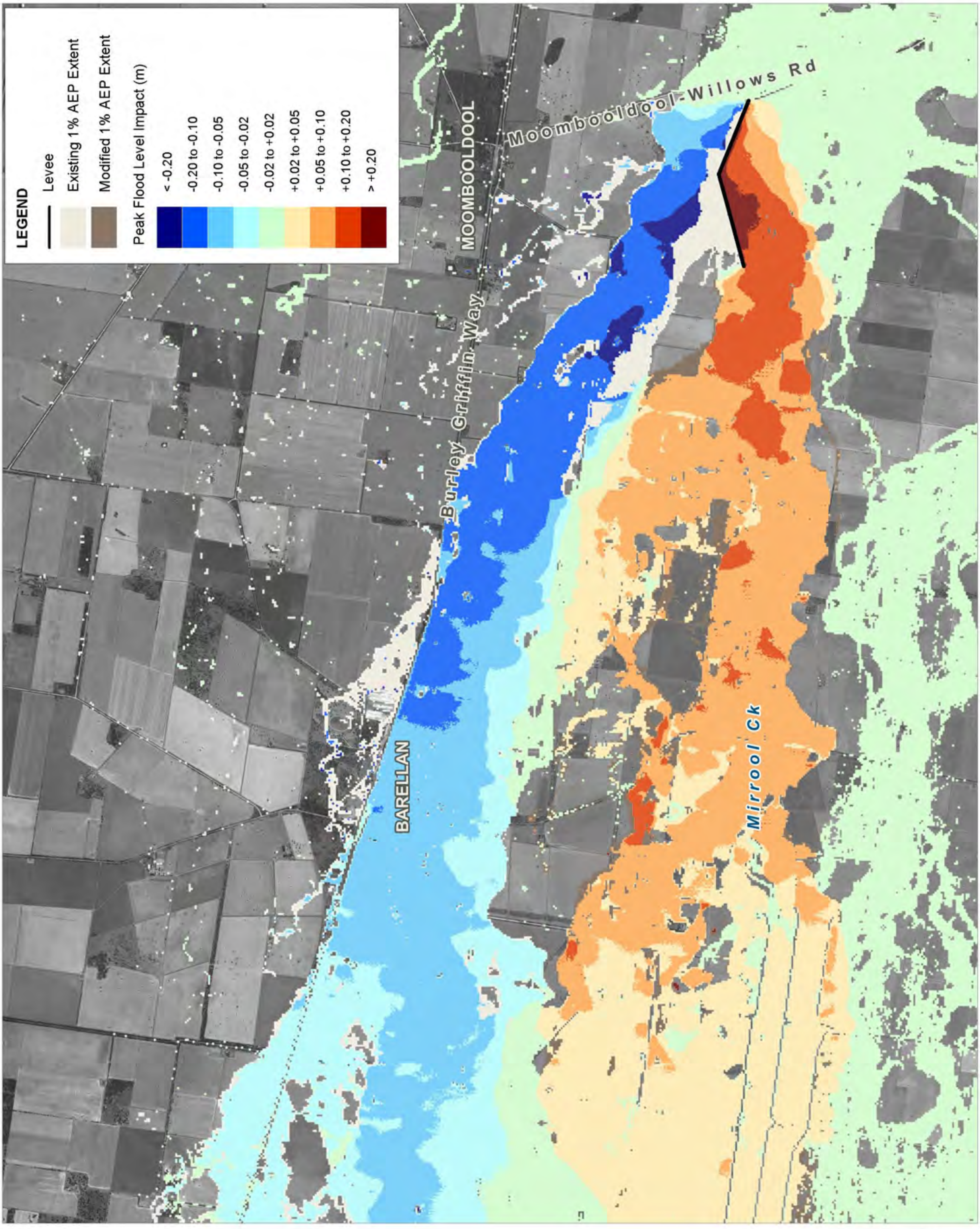
Rev: A

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_F02_170908_Levee_Opt_02b_100y.WOR



Title:

Barellan FRMS&P Levee Option 2b
0.5% AEP Change in Peak Flood Level

Figure: **F-3**

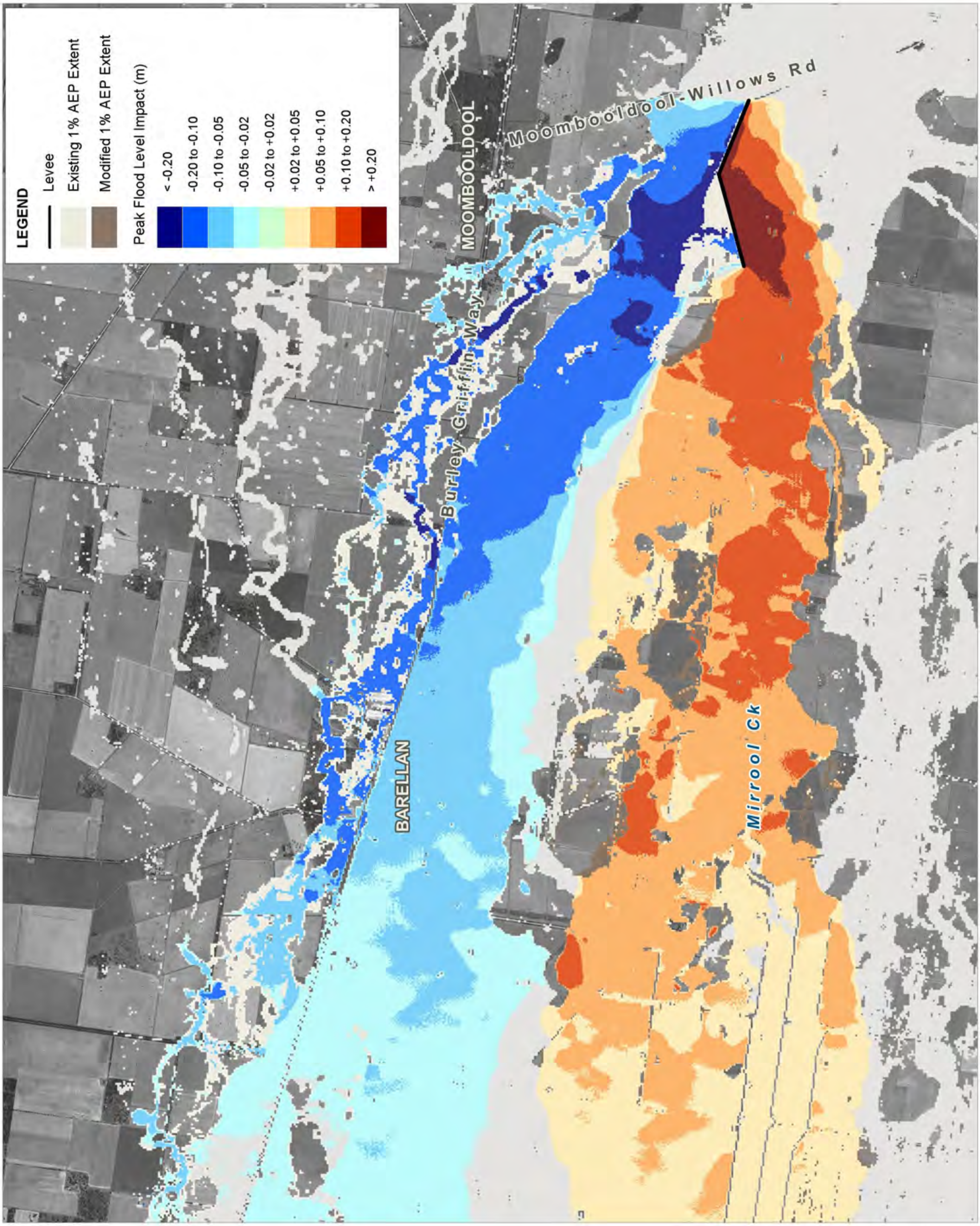
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_F03_170908_Levee_Opt_02b_200y.WOR



Title:
Barellan FRMS&P Levee Option 2b
0.2% AEP Change in Peak Flood Level

Figure: **F-4**

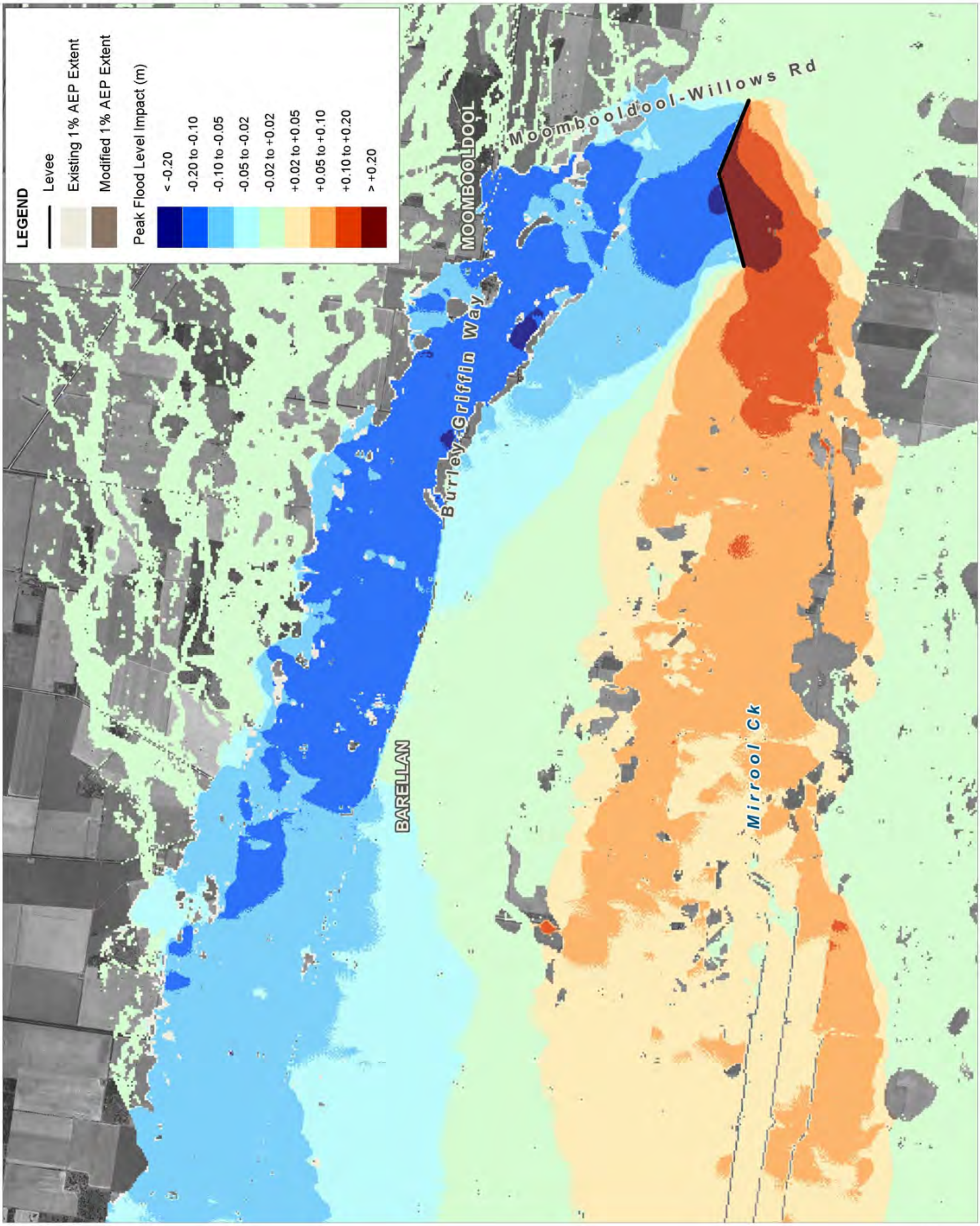
Rev: **A**

N

0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_F04_170908_Levee_Opt_02b_500y.WOR



Title:

Barellan FRMS&P Levee Option 2b
Extreme Flood Change in Peak Flood Level

Figure: **F-5**

Rev: **A**

N

0 1 2km
Approx. Scale

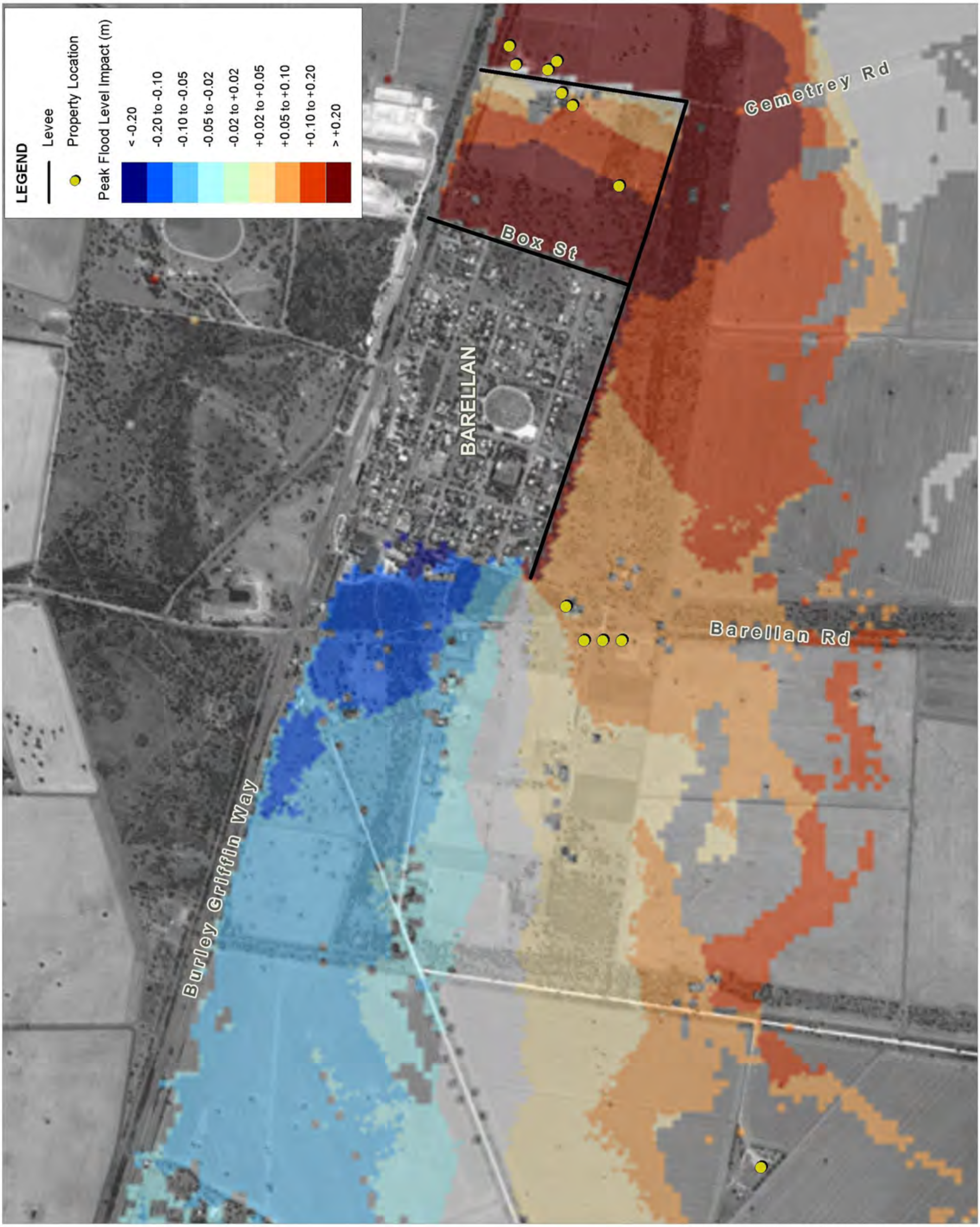
BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_F05_170908_Levee_Opt_02b_PMF.WOR

Appendix G. Capital Construction Cost Estimates

				OPTION 1A		OPTION 1B		OPTION 1C		OPTION 2B	
Parallel road alignment levee											
Item No.	**Item Description**	**Unit**	**Rate**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**
1	**Site Clearing**										
	Easement over Levee Footprint	ha	26,000	0.7	18,200	1.7	44,200	2.2	57,200	2.2	57,200
	Geotechnical Testing along levee route	Item	78,000	1	5,000	1	19,000	1	28,000	1	78,000
	Preliminaries (Site Establishment, Sediment Control, etc)	Item	156,000	1	24,000	1	29,000	1	32,000	1	156,000
	Clear and Grub along Route of Levee	m^2	1	7,219	7,219	17,204	17,204	22,462	22,462	21,688	21,688
	Strip and Store Topsoil (300 mm) for later spreading over levee batters	m^2	2	7,219	14,438	17,204	34,408	22,462	44,924	21,688	43,376
2	**Reinstating Surfaces (including levee construction)**										
	Roll and Compact Levee Foundation	m^2	5	7,805	39,025	18,557	92,785	24,181	120,905	23,290	116,451
	Supply and compact suitable impervious fill to form levee embankment	m^3	42	7,817	328,316	17,244	724,263	21,155	888,506	18,795	789,385
	Excavate from stockpile and spread topsoil over face of levee	m^2	1	7,805	7,805	18,557	18,557	24,181	24,181	23,290	23,290
	Grass seed levee batters	m^2	5	7,805	39,025	18,557	92,785	24,181	120,905	23,290	116,451
3	**Burley Griffin Way Tie-in**										
	Demolish, remove and dispose existing road	m^2	30	1,300	39,000	1,300	39,000	1,300	39,000	-	-
	Roll and Compact Levee Foundation	m^2	5	1,300	6,500	1,300	6,500	1,300	6,500	-	-
	Supply and compact suitable impervious fill to form levee embankment	m^3	42	1,148	48,195	1,148	48,195	1,148	48,195	-	-
	New 2 lane flexible pavement rural road (includes contingency)	m	2500	55	137,500	55	137,500	55	137,500	-	-
4	**External Mitigation Works**										
	House raising / property protection	property	50,000	3	150,000	9	450,000	7	350,000	2	100,000
	Sub-total				864,000		1,753,000		1,920,000		1,502,000
	Contingencies (30%)				218,000		485,000		535,000		451,000
	Sub-total				**1,082,000**		**2,238,000**		**2,455,000**		**1,953,000**
	Investigation and Design Costs (10%)				108,200		223,800		245,500		195,300
	Project Management (9%)				97,380		201,420		220,950		175,770
	Construction Management Costs (12%)				129,840		268,560		294,600		234,360
	Total				**1,417,000**		**2,932,000**		**3,216,000**		**2,558,000**
Road-topped levee											
Item No.	**Item Description**	**Unit**	**Rate**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**	**Quantity**	**Cost ($)**
1	**Site Clearing**										
	Easement over Road Embankment	ha	26,000	1.0	26,000	3.0	78,000	4.4	114,400	4.7	122,200
	Geotechnical Testing along embankment route	Item	26,000	1	13000	1	38000	1	54000	1	26,000
	Preliminaries (Site Establishment, Sediment Control, etc)	Item	10,400	1	27000	1	36000	1	42000	1	10,400
	Clear and Grub along Route of Embankment	m^2	1	9,701	9,701	22,599	22,599	25,518	25,518	47,410	47,410
	Strip and Store Topsoil (300 mm) for later spreading over levee batters	m^2	2	9,701	19,402	22,599	45,198	25,518	51,035	47,410	94,820
	Demolish, remove and dispose existing road	m^2	30	-	-	6,900	207,000	18,180	545,400	-	-
2	**Reinstating Surfaces (including levee construction)**										
	Roll and Compact Levee Foundation	m^2	5	9,352	46,758	21,953	109,767	28,295	141,473	26,871	134,356
	Supply and compact suitable impervious fill to form levee embankment	m^3	42	18,550	779,098	41,631	1,748,487	51,760	2,173,935	46,855	1,967,930
	Excavate from stockpile and spread topsoil over face of levee	m^2	1	9,352	9,352	21,953	21,953	28,295	28,295	26,871	26,871
	Grass seed levee batters	m^2	5	9,352	46,758	21,953	109,767	28,295	141,473	26,871	134,356
3	**Road works**										
	350 thick DGS40 sub-base or crushed sandstone compacted in max 200mm layers m	m^2	26	6,024	156,624	15,312	398,112	21,048	547,248	21,640	562,640
	150 thick DGB20 basecourse m	m^2	15	6,024	90,360	15,312	229,680	21,048	315,720	21,640	324,600
	Hot bitumous flush seal m	m^2	7	6,024	42,168	15,312	107,184	21,048	147,336	21,640	151,480
	40 thick AC10 overlay asphalt m	m^2	21	6,024	126,504	15,312	321,552	21,048	442,008	21,640	454,440
4	**Burley Griffin Way Tie-in**										
	Demolish, remove and dispose existing road	m^2	30	1,300	39,000	1,300	39,000	1,300	39,000	-	-
	Roll and Compact Levee Foundation	m^2	5	1,300	6,500	1,300	6,500	1,300	6,500	-	-
	Supply and compact suitable impervious fill to form levee embankment	m^3	42	1,148	48,195	1,148	48,195	1,148	48,195	-	-
	New 2 lane flexible pavement rural road (includes contingency)	m	2500	55	137,500	55	137,500	55	137,500	-	-
5	**External Mitigation Works**										
	House raising	property	50,000	3	150,000	9	450,000	7	350,000	2	100,000
	Sub-total				1,774,000		4,154,000		5,351,000		4,158,000
	Contingencies (30%)				491,000		1,205,000		1,564,000		1,247,000
	Sub-total				**2,265,000**		**5,359,000**		**6,915,000**		**5,405,000**
	Investigation and Design Costs (10%)				226,500		535,900		691,500		540,500
	Project Management (9%)				203,850		482,310		622,350		486,450
	Construction Management Costs (12%)				271,800		643,080		829,800		648,600
	Total				**2,967,000**		**7,020,000**		**9,059,000**		**7,081,000**

Caution: This information is provided as a guide only and costs may not be limited to those shown. All rates are estimates and are subject to inflation and general industry fluctuations.



Title:

Maximum Enveloped 1% AEP Impact - Levee Opt 1b and 1c Adversely Affected Properties

Figure: G-1

Rev: A

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Filepath : K:\N20551_Barellan_Flood_Study\MapInfo\Workspaces\FRMS\FIG_G01_171129_Levee_Impacted_Properties.WOR

Appendix H. Public Exhibition Submissions

B John Wright
72 Bendee Street
BARELLAN NSW 2665

8 February 2018

The General Manager
Narrandera Shire Council
141 East Street
NARRANDERA NSW 2700

RE: BARELLAN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN DRAFT REPORT

I have reviewed the subject documentation and inspected:

1 The town and adjacent areas to the east, south & west, and
2 Various areas along Mirrool Creek and within the catchment to the east of the town.

Accordingly, the following points are provided in summary:

1 LEVEE/DIVERSION BANK APPROACH

I believe this structure has major issues including:
- Nil grades along both Box Street & Cemetery Road therefore relying on 'head' for flow.
- Diversion of water onto neighbouring properties to the east, south & west of the town.
- Legal implications in relation to diversion of water.

2 NO LEVEE/DIVERSION BANK APPROACH

I believe the approach should be twofold and include works within:

MIROOL CREEK CATCHMENT

Works should be implemented along roads with the objective of keeping creek flood flows within or as near as possible to the creek. Works should be site specific and may include:
- Diverting flows along Holloway Road towards the creek.
- Increasing height of Mirrool Road to contain flows near creek.

- Addressing culvert function along Mumbledool Station or Willows Road (eg capacity, flow direction).

There should be significantly less impact in Barellan if flood flow is retained/controlled in this manner. A Committee of local and long term landholders and Council personnel should be established to address and prioritise works.

BARELLAN TOWN

The town has regular problems from poor drainage and associated maintenance in many areas including:
- Impacts on septic systems.
- Nuisance flooding.
- Mosquito breeding in ponded water..

These problems and any flooding impacts from the upstream catchment should be addressed via a combination of the following points which will promote water flow through the town:
- Causeways/ larger culverts across roads running north/south (an existing effective causeway is located between the netball courts and school).
- Replacement of small piped vehicle crossings into residential properties with causeways similar to those constructed at the 2 new 'Aged Care' homes at the south end of Bendee Street.
- Elimination of pedestrian crossings over tabledrains (ie they are unused & trip hazards).
- Improved shaping of some road tabledrains to a 'dish shape' (eg east end of Wilga Street).
- Construction of extra outlet channels at the west end of the town (eg Bendee Street).

Once again, priorities should be selected. An observation is there appears to be no problems with water flow where streets have kerb and gutter with no restrictions.

In conclusion, I have some SIGNATURES below from people who concur with my approach.

Please contact me on 0418 434516 if you wish to further discuss these issues or have any questions.

Yours faithfully

B J Wright

B J Wright
SENIOR SOIL CONSERVATIONIST (P.S.C. 1970)
T.R.E.E.S P/L.

SIGNATURES:

J. M. Jameson 71 Mulga St. Barellan

K G McGufficke 97 Bendee St Barellan

A. Hitchings 37 BENDEE St BARELLAN,

P V Allen 6 [illegible] KOOBA ST BARELLAN

Margaret Ohlsen 11 Old Narrandera Rd BARELLAN NSW

PAUL MONEY 37 TUBBS RD

PM Money BARELLAN

Barry Tubb Tubb RD Barellan

Peter Tubb 205 OLD N DRD BARELLAN

Zeita Smith ZEITA SMITH 17 CEMETERY RD BARELLAN.

N.C. FINDLAY. 76 BENDEE ST BARELLAN.

Chris Halden DUNTROON BARELLAN

Dianne Halden 5279 Barellan Rd Barellan

SIGNATURES:

JACK RAYMOND NASH

MIRIAM ROLLSTON

Chistie Smith

Matthew Smith

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Our Ref: DXW: L.N20551.001.docx

19 March 2018

B John Wright
72 Bendee Street
Barellan
NSW 2665

Dear John

RE: BARELLAN FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN DRAFT REPORT

Thank you for taking the time to provide a submission during the public exhibition of the Draft Barellan Floodplain Risk Management Study and Plan. Having reviewed your submission, BMT offers the following response.

1) Levee / Diversion Bank Approach

As you suggest, there is limited grade along the eastern alignments of the proposed levees. The flood waters would build on the upstream side of the levee, being discharged along the southern side of the Kurrajong Street alignment. This results in an upstream head of around 0.2 m being generated along the eastern alignment, as modelled within the levee assessment. This has been identified and as such the proposed levee crest is 0.2 m higher along the eastern alignment than it is at the eastern end of the southern alignment – as per Figure 8-2 and Figure 8-3 of the study report.

The proposed levee options do result in localised increases to modelled peak flood levels within the areas outside of the levee alignment. Although relatively minor, these flood level increases could potentially worsen flooding at a few existing properties. These impacts have been identified by the study and would be assessed in more detail during any subsequent levee option feasibility study, as recommended within the Draft Plan.

2) No Levee / Diversion Bank Approach

The suggested works along Holloway Road, Mirrool Road and Willows Road were assessed as part of the study. Whilst the nature of the works would likely assist in reducing the flood risk in Barellan, they do not eliminate the risk. Therefore, options remote from Barellan near Mirrool Creek did not compare favourably to those local to Barellan in the Cost-benefit analysis. The modelling of these remote options identified potential flood impacts through the resultant redistribution of flood flows. Also, such works would not afford Barellan protection from local catchment runoff between Barellan and Mirrool Creek, which was the source of the peak flood inundation within the town during the March 2012 event.

The suggested drainage improvement works within Barellan were assessed within the study. Whilst it is true that these works would help reduce flooding in Barellan, their impact on the major design flood events was not significant. Therefore, such options do not compare favourably within a Cost-benefit Analysis and their function is limited to addressing nuisance flooding rather than the overall flood risk emanating from the broader catchment. It is understood that the nuisance flooding within Barellan resulting from heavy rainfall is a significant problem for the residents. The local drainage works suggested can potentially improve the current situation. It is understood that Council are actively pursuing the potential for local drainage improvements and BMT has provided Council with data to assist them in their investigations.

We trust that the information provided above addresses your concerns and again thank you for your interest in the study and efforts in providing this submission.

Yours Faithfully
BMT

Daniel Williams
NSW Flood Lead

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Hammer, Fred

From: pkbourchier <pkbourchier@bigpond.com>
Sent: Saturday, 10 February 2018 2:56 PM
To: Council Email

Subject: Barellan Floodplan submission from Phil Bourchier.

Categories: Yellow Category

To the General Manager. Thanks for the opportunity to comment on the Barellan Floodplan. The planed bank down Box st then along the common in my opinion would need a 2nd containment bank on the south side of the common and then a floodway in the Narrandera rd and then containment banks through private land across to the Merribe rd. I can see a problem with the private land bit tho. It was put to the community session at the club 15th January that better drainage through the town was of little benefit. I still think with floodways in all the N/S roads in the town would be a massive help. In my mind both these plans would benefit the town but I think we could stop most of the flooding threat by doing more work upstream, some on the Willows & Mirrool rd's keeping the water in the creek. This would need to be back up with a drain/bank on the Holloway rd south from McDonald's rd back to the creek. That would mop up any water not held by the Willows/Mirrool rd's and any water flowing west off the Kamarah rise. Thanks again for the opportunity. Phil Bourchier Willanra Barellan. 0429 639439.

Sent from my Samsung Galaxy smartphone.

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Our Ref: DXW: L.N20551.002.docx

19 March 2018

Phil Bourchier
Willanra
Barellan
NSW 2665

Dear Phil

RE: BARELLAN FLOODPLAIN SUBMISSION

Thank you for taking the time to provide a submission during the public exhibition of the Draft Barellan Floodplain Risk Management Study and Plan. Having reviewed your submission, BMT offers the following response.

It is not essential that the proposed levee options incorporate a parallel containment bank to the south of the common. The resultant flood conditions during major flood events would be similar to those that currently exist, albeit with the localised increases in peak flood level identified within the study. However, should such works benefit the overall levee design options, then it is expected that this would be identified as future studies investigate the feasibility and design of a preferred levee option.

The suggested drainage improvement works within Barellan were assessed within the study. Whilst it is true that these works would help reduce flooding in Barellan, their impact on the major design flood events was not significant. Therefore, such options do not compare favourably within a Cost-benefit Analysis and their function is limited to addressing nuisance flooding rather than the overall flood risk emanating from the broader catchment. It is understood that the nuisance flooding within Barellan resulting from heavy rainfall is a significant problem for the residents. The local drainage works suggested can potentially improve the current situation. It is understood that Council are actively pursuing the potential for local drainage improvements and BMT has provided Council with data to assist them in their investigations.

The suggested works along Holloway Road, Mirrool Road and Willows Road were assessed as part of the study. Whilst the nature of the works would likely assist in reducing the flood risk in Barellan, they do not eliminate the risk. Therefore, options remote from Barellan near Mirrool Creek did not compare favourably to those local to Barellan in the Cost-benefit analysis. The modelling of these remote options identified potential flood impacts through the resultant redistribution of flood flows. Also, such works would not afford Barellan protection from local catchment runoff between Barellan and Mirrool Creek, which was the source of the peak flood inundation within the town during the March 2012 event.

We trust that the information provided above addresses your concerns and again thank you for your interest in the study and efforts in providing this submission.

Yours Faithfully
BMT

Daniel Williams

Daniel Williams
NSW Flood Lead