MURRUMBURRAH FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

NOVEMBER 2020

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Project **Murrumburrah Floodplain Risk Management Study and Plan**	**Project Number** **118099**
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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BCA	Building Code of Australia
DPIE	Department of Planning, Industry and Environment (formerly OEH)
GIS	Geographic Information System
LGA	Local Government Area
LiDAR	Light Detection and Ranging (airborne survey method)
m	metres
m^3/s	cubic metres per second
mAHD	metres above Australian Height Datum
MHL	Manly Hydraulics Laboratory
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SES	State Emergency Services
TUFLOW	Hydraulic Modelling software
WBNM	Watershed Bounded Network Model (Hydrologic modelling software)

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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 management responsibilities.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study
- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management Study
- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan
- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Murrumburrah Flood Study (Reference 1), the first stage of the management process was completed in December 2019. The Murrumburrah Floodplain Risk Management Study and Plan constitutes the second and third stage of the management process for the catchment. This study has been prepared by WMAwater for Hilltops Council and was undertaken to provide the basis for future management of flood liable lands within the study area.

This report has been prepared with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning, Industry and the Environment.

EXECUTIVE SUMMARY

STUDY OBJECTIVE

The NSW Government's Flood Policy provides for:

- *a framework to ensure the sustainable use of floodplain environments,*
- *solutions to flooding problems,*
- *a means of ensuring new development is compatible with the flood hazard.*

Implementation of the Policy requires a four stage approach, the first of which is preparation of a Flood Study to determine the nature and extent of the flood problem and has been completed. The main objective of the second and third stage, namely this Floodplain Risk Management Study and Plan is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximate costed recommendations in regards to flood risk mitigation in the catchment.

The Murrumburrah Flood Study provided information about existing flood risk in the Currawong Creek catchment, which is also known locally as Murrimboola Creek. Flood modelling tools were developed In the Flood Study that can be used by Council for decision-making about land-use planning, and in future studies such as the current Murrumburrah Floodplain Risk Management Study and Plan to assess the effectiveness of potential measures to reduce flood risk.

STUDY AREA

The study area is located within the Hilltops Council Local Government Area (LGA). The study area includes the twin towns of Murrumburrah and Harden and adjacent rural areas, comprising a total area of approximately 17 km^2. Currawong Creek is a significant feature of the towns, crossing the main street close to the central shopping strip. Other notable tributaries within the study area include Cunningham Plains Creek and Demondrille Creek. The total catchment area of Currawong Creek to just downstream of Murrumburrah weir is approximately (310 km^2). The upper catchment consists primarily of rural farmland.

There is a history of flooding both from Currawong Creek and from smaller local creeks through and adjacent to town. The most recent flood that caused major damage and loss was December 2010. The major flood of record is 1930, which caused widespread inundation of homes, destruction of buildings and infrastructure including the main Albury Street Bridge over Currawong Creek. This event was in the order of a 1% AEP event (that is, less than 1% chance of similar flooding occurring in any given year), or possibly rarer.

The Currawong Creek catchment upstream of Murrumburrah-Harden consists primarily of rural agricultural land with some small pockets of natural forested areas. The town of Murrumburrah\Harden itself consists of a mix of pervious and impervious surfaces with piped and overland flow drainage systems. The majority of streets in town have either concrete kerb/guttering or grass roadside swales.

The work undertaken in this study includes:

- preliminary investigation of the full range of floodplain management measures;
- detailed investigation of the key management measures;
- preliminary benefit cost analysis and scheduling the key management measures;
- community consultation; and
- preparation of a management plan outline the strategy for managing the floodplain within the floodplain at Murrumburrah-Harden.

COMMUNITY CONSULTATION

During the Flood Study questionnaire was distributed in December 2018, 41 responses were received of which 24 respondents had observed some sort of flooding, 8 respondents indicating that their property was directly affected and 7 respondents indicated that damage had been caused to their property due to flooding.

SUMMARY OF FLOOD STUDY MODELLING

Computer models of the study area were established and calibrated against historical flood data (October 1993, December 2010, March 2012 and September 2016 events). Qualitative observations from the February 1930 flood event, which is the largest flood on record for the major creeks, were also used to validate the modelled flood behaviour.

Mapping of design flood behaviour, as well as mapping outputs derived from the modelling for use in Councils planning activities were provided as well as information relevant for road overtopping risk and flood emergency response.

SUMMARY OF FLOODPLAIN RISK MANAGEMENT STUDY (FRMS) INVESTIGATIONS

Flood damage in Murrumburrah is primarily attributed to external damages (landscaping, fencing, sheds, etc.) in events up to the 1% AEP, with 33 properties being affected by damages in that event (of which 15 above floor level). In the PMF event, there are 277 properties affected by direct flood damages, with 196 flooded above floor level. The average annual damage is estimated to be approximately $57,000.

The majority of flood damages in Murrumburrah are concentrated in the following locations:

- Residences and commercial/community buildings near the Albury Street bridge across Currawong Creek, on Iris Street and Albury Street;
- Residences on Short Street near Whitton Lane, where there is a local sag point created by the railway embankment;
- Along the main drainage line through town that runs through the bowling club, the public school, and into an open channel between Ward Street and Iris Street;
- Residences and commercial building on overland flow paths between Albury Street and the railway line near Whitton Lane and Redbank Street; and
- The commercial precinct on Neill Street between Station Street and East Street, where it backs onto a sag point in Whitton Lane.

Investigation of management measures for the FRMS focussed on these locations. Generally the flood risk is relatively low and therefore construction of major flood mitigation works generally is not warranted.

However there are several planning and educational / awareness measures that can be implemented at relatively low cost that are likely to produce significant benefits for a relatively low cost.

RECOMMENDED FLOODPLAIN RISK MANAGEMENT PLAN (FRMP) MEASURES

All investigated measures were assessed using a multi-criteria framework to identify recommended measures and rank them in terms of effectiveness and priority. The outcomes of the FRMS and measures recommended for implementation in the FRMP are summarised in Section 1 of this report. Section 1 of this report comprises the Floodplain Risk Management Plan that Council will commit to implementing for this catchment once this report is adopted by Council.

1. MURRUMBURRAH FLOODPLAIN RISK MANAGEMENT PLAN

1.1. Introduction

The Murrumburrah Floodplain Risk Management Plan has been prepared for Hilltops Council in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 2) and:

- *Is based on a comprehensive and detailed evaluation of factors that affect and are affected by the use of flood prone land;*
- *Represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land; and*
- *Provides a long-term path for the future development of the community.*

The Murrumburrah Floodplain Risk Management Plan covers the Currawong Creek and Cunningham Plains catchments, which are located in the South West Slopes area of NSW, approximately 125 km north-west of Canberra. The study area includes the twin towns of Murrumburrah and Harden and adjacent rural areas (see Figure 1). The catchment lies within the Local Government Area (LGA) of Hilltops Council.

Flooding in the twin towns can occur from local rainfall within town, or from rainfall over the upstream catchment leading to flooding on Currawong Creek and Cunningham Plains Creek. No detailed local catchment flood study has previously been undertaken in the area until completion of the Murrumburrah Flood Study in December 2019 (Reference 1). This flood study provided information about existing flood risk in the catchment based on flood modelling tools. The models were calibrated using observations from historical floods, and used to estimate the impacts of flooding for a range of standardised "design" flood probabilities. This modelling was completed in accordance with the guidelines in Australian Rainfall and Runoff (Reference 3).

Previous management plans in 1987 only briefly considering flooding within Harden and Murrumburrah within the context of the greater Murrumbidgee catchment (Reference 4).

Hilltops Council is responsible for managing development in accordance with flood risk, as per the NSW Floodplain Development Manual (Reference 2). This study will provide Council with relevant flood information for strategic planning and development assessment.

1.2. Scope of Flood Study (Reference 1)

The Flood Study defined design flood behaviour for the 5%, 2%, 1%, 0.5% and 0.2% Annual Exceedance Probability (AEP) design storms and the Probable Maximum Flood (PMF) in the twin towns of Murrumburrah and Harden. The report documented the data, methodology and outputs from the flood modelling exercise, including the following specific tasks:

- the collection and collation of existing information relevant to the study which includes the data already held by Council as well as other information, such as rainfall data;
- the preparation of hydrologic and hydraulic models capable of defining the flood

behaviour for the study area for a wide range of design flood probabilities;
- undertaking sensitivity analysis; and
- the interpretation and presentation of model results to describe and categorise flood behaviour and hazard for a range of design storm events for the existing catchment conditions.

A discussion of the AEP terminology and a glossary of other flood-related terms are provided in Section 10.

1.3. Management Measures Considered

A matrix of possible management measures was prepared and evaluated in this Floodplain Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer to Section 5.2) including flood mitigation dams and voluntary purchase of all flood liable buildings. The use of on-site stormwater detention as a flood mitigation measure, as opposed to its use for mitigating the effects of urbanisation was also eliminated.

The full range of measures was evaluated and the outcomes are summarised in Table 1. Table 2 details the matrix scoring system and Table 3 provides the matrix results which ranks the management measures considered.

Community opinion on the full range of options has been canvassed during the public exhibition period.

Table 1: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
	FLOOD MODIFICATION:	
LEVEES AND FILLING (Section 5.3.1)	Prevent or reduce the frequency of flooding of protected areas.	• Levees are suitable on large river systems where they can protect a number of buildings. • May cause local drainage problems and be unacceptable to the community due to restriction of waterfront access and views. • Levees will still be overtopped in major flood events and for this reason flood planning controls will still apply to areas protected by levees. • There are no suitable sites.
TEMPORARY FLOOD BARRIERS (Section 5.3.3)	Prevent entry of floodwaters	• In a catchment such as Currawong Creek with a short warning time this measure is not practical.
CHANNEL DIVERSION / FLOODWAYS (Section 5.3.5)	To channel floodwaters away from affected areas and so reduce flood levels.	• The creation of flow diversions can provide an effective means of diverting floodwaters away from affected areas and thus reducing flood levels. • There are no practical areas where a new floodway could be created due to existing development. • Improvements are recommended to the overland flow swale at the rear of the Harden nursery to reduce flood damages to adjacent properties.

MEASURE	PURPOSE	COMMENT
CHANNEL MODIFICATIONS (Section 5.3.4)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by straightening of the channel, widening or removal of vegetation along the banks. • However, such measures can often increase flood risk downstream. • These measures are costly to undertake and generally require ongoing maintenance, have significant environmental impacts, are not an ecologically sustainable measure and are thus rarely used. • There are no practical areas where this measure could be undertaken due to existing development.
MAJOR STRUCTURE MODIFICATION (Section 5.3.2)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by removal of significant hydraulic restrictions such as narrow culverts or low level bridges or even minimising the potential for blockage. • However, such measures can often increase flood risk downstream. • The larger measures (widen culverts or replace a bridge) are generally costly to undertake. Reducing the potential for blockage through regular maintenance is supported. • No location was identified which would provide a significant reduction in above floor inundation upstream. • However, modifications to the Neill Street causeway may provide other environmental and access benefits
DRAINAGE NETWORK UPGRADES (Section 5.3.6)	To increase pipe or culvert capacity	• Can be expensive and may only be effective for smaller flood events • Upgrades are recommended for further investigation at Whitton Lane near Short Street, across the railway line.
DRAINAGE MAINTENANCE (Section 5.3.7)	Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure and may involve removing unwanted vegetation and other debris.	• Is an ongoing management responsibility for Council. • Increased frequency of maintenance is recommended at Whitton Lane and the Aurville Road crossing at Cunningham Plains Creek.
FLOOD MITIGATION DAMS, RETARDING BASINS (Section 5.3.8)	Reduce the peak flow from the catchment by increasing the volume of flood storage in the catchment.	• The size of storages required to make a difference need to be very large, making them impractical on environmental, social and economic grounds. • No suitable sites were identified in this study
ON-SITE DETENTION (Section 5.3.8)	Decrease effects of increased urbanisation.	• On-site detention or retarding basins are not necessary based on current levels of development pressure, but may be required if development is significantly intensified in urban areas.
	RESPONSE MODIFICATION:	
FLOOD WARNING (Section 5.4.1)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	• Relatively short warning time makes it impossible to provide a fail-safe warning system. • Any system will provide some additional warning. • Costs of a catchment-specific system are not currently

MEASURE	PURPOSE	COMMENT
		justified, but should be reviewed periodically as new technology becomes available.
FLOOD EMERGENCY PLANNING (Section 5.4.2)	Effective planning for emergency response is a vital way of reducing risk to life and property.	• The cost to undertake this measure is small and will provide a high benefit/cost ratio. • A range of measures are provided and supported.
COMMUNITY FLOOD EDUCATION (Section 5.4.3)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	• A cheap and effective method but requires continued effort from the community. • Possible approaches are provided.
IMPROVED FLOOD ACCESS, ROAD CLOSURES AND NOTIFICATIONS (Section 5.4.4)	To ensure safe and reliable access during times of flood and to reduce the risk to life of vehicles entering flood waters.	• The nature of the existing flood risk at key road crossings was investigated. • Elimination of the flood hazard is not possible. • Installation of flood warning signs and depth indicators at Aurville Road on Cunningham Plains Creek is recommended. • The Albury Street Bridge should be closed to traffic when water is within 0.5m of the underside of the bridge.
	PROPERTY MODIFICATION:	
VOLUNTARY HOUSE RAISING (Section 5.5.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	• All flood damages will not be prevented and only suitable for non-brick buildings on piers. • Costs approximately $80,000 per house but can vary considerably. • Only suitable for a small number of houses (generally with floor levels first inundated in the 10% AEP (1 in 10 year)) or smaller events and not attractive to all residents. • Not recommended for widespread adoption
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (Section 5.5.2)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	• High cost per property. • Applicable for isolated, high hazard properties in flood liable areas. • No suitable houses were identified.
FLOOD PROOFING (Section 5.5.3)	Prevent flooding of existing buildings by sealing all the entry points.	• Generally only suitable for brick, slab on ground buildings. • Less viable for residential buildings but should be considered for non-residential buildings of slab on ground construction. • Council should investigate the feasibility of flood proofing works for the rear of the Museum (School of Arts Building)
LAND USE ZONING (Section 5.5.4)	Reduce potential hazard and losses from flooding by appropriate land use planning.	• Well-established processes are in place for dealing with land-use in flood hazard areas. • Current land-use zoning is being reviewed by Council, and areas of potential change have been investigated in this study to identify the flooding constraints.
FLOOD PLANNING LEVELS (Section 5.5.5)	Provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.	• Flood planning levels for a range of activities should be included in the DCP.

MEASURE	PURPOSE	COMMENT
FLOOD PLANNING AREA (Section 5.5.6)	It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk.	• A flood planning area has been developed for Murrumburrah-Harden.
CHANGES TO PLANNING POLICY (Section 5.5.7)	Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages.	• There is currently no flood DCP or floodplain management policy in the study area. • Council should develop flood-related development controls as a high priority, in conjunction with the development of the Hilltops Council LEP.
MODIFICATION TO S10.7 CERTIFICATES (Section 5.5.8)	S10.7 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	• Council should to review flood related information on Section 10.7 certificates to bring it in line with the findings of the Flood Study and this FRMS&P.
	OTHER MANAGEMENT MEASURES	
FLOOD INSURANCE (Section 5.6)	To spread the risk of individual financial loss across the whole community through insuring against flood damage.	• Does not reduce damage, but spreads the cost. • These issues are outside the scope of this present study. • Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages. • Individuals should be aware that there is a range of flood insurance products available for residential property, and that the available coverage varies significantly with different insurance providers.

1.3.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method for using the time value of money to compare the reduction in flood damages (benefit) with the capital and ongoing cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was developed for the catchment, allowing B/C estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

1.3.2. Management Matrix

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- technical feasibility (design considerations, construction constraints, long-term performance);
- community acceptance and social impacts;
- economic merits (capital and recurring costs versus reduction in flood damages);
- financial feasibility to fund the measure;
- environmental and ecological benefits;
- impacts on the State Emergency Services;
- political and/or administrative issues;
- long-term performance given the likely impacts of climate change,
- risk to life.

The colour coded scoring system for the above criteria is provided in Table 2 and largely relates to the impacts in a 1% AEP event. Table 3 indicates the weighting assigned to each measure, however these may be adjusted in the light of community consultations and local conditions.

Table 2: Colour Coded Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefitted	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight forward	straight forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrati ve Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

Table 3: Matrix of Management Measures Investigated in Study

Option	Section in Study	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental / Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)
Update S10.7 certificate information	5.5.8		3	3	2	3	3			1	3		18	1
Planning policy updates (LEP and DCP)	5.5.7		3	3	1	3	3	1	1	-1	3	1	18	1
Flood education and awareness	5.4.3		3	3	3	1	2		2		1	2	17	3
Overland flow path improvement near Harden nursery	5.3.5	3	2	3	3	1	2		1		2		17	3
Flood planning mapping	5.5.5 / 5.5.6			1	2	3	3		1	2	3	1	16	5
SES review flood emergency planning	5.4.2		2	1	3	3	3		1		1	1	15	6
Changes to land use zones must consider potential flooding implications	5.5.4			2	2	3	3	1		-2	3	1	13	7
Flood warning signs and depth indicators	5.4.4			3	2	1	3		1	-1	1	2	12	8
Investigate Sewage Treatment Plant Upgrades	5.5.9	2	1	2	3	1	1	1			1		12	8
Drainage network upgrades	5.3.6	2	2	1	2	1				-1	3		10	10
Creek and drainage maintenance	5.3.7	1	2	2	3		1	1			-1		9	11
Flood proofing by property owner	5.5.3	3	2	1	1	1	-1						7	12
Neill Street Causeway modification	5.3.2			1	1		1	1			1		5	13
Flood warning and response	5.4.1		3	-3	2	1	-2		2	-2	1	1	3	14
Temporary flood barriers	5.3.3	1	1	-2	1	-1	1			-2	1		0	15
On site detention policy	5.3.8		2	-1	-1		-1			-1	2		0	15
Voluntary house purchase	5.5.2		2		-1	-1	-3			-2	2	1	-2	17
Flood retarding basins / dams	5.3.8	2	2	-1	1	-3	-3			-2	1	1	-2	17
Modifications to major bridges / culverts	5.3.2	2	1	-2		-1	-3			-2	2		-3	19
Voluntary house raising	5.5.1		2	-2	-1	-1	-3			-2	2	1	-4	20
Levees and Filling	5.3.1	2	2	-3	-1	-2	-3	-2		-2	2		-7	21
Flow diversions and channel capacity increases	5.3.4 / 5.3.5	1	1	-2		-2	-3	-2		-2	1		-8	22

1.4. Floodplain Risk Management Measures in Plan

The recommended measures are described in Table 4 and shown on Figure 2. Implementation priorities may vary depending on funding availability, agency agreement, responsibility etc.

Table 4: Recommended Management Measures in Plan

Option	Section in Study	Priority	Responsibility	Costing	Timeframe to Implement	Rank (Total)
Update S10.7 certificate information	5.5.8	High	Council	Low	Short	1
Update LEP and DCP to include flood planning controls	5.5.7	High	Council	Low	Short	1
Develop flood awareness program	5.4.3	High	Council / SES	Medium	Medium	3
Flow path improvement works near Harden nursery	5.3.5	High	Council	Low	Short	3
Incorporate updated flood planning area mapping into Council planning systems	5.5.5 / 5.5.6	High	Council	Low	Short	5
SES review flood emergency management	5.4.2	Medium	Council / SES	Low	Short	6
Changes to land use zones must consider potential flooding implications	5.5.4	Medium	Council	Low	Medium	7
Install warnings and depth indicators at Aurville Road. Close Albury Street Bridge to traffic when flooding nears bridge deck.	5.4.4	Medium	Council / SES	Low	Short	8
Investigate feasibility of modifying ponds or levee construction to reduce inundation frequency	5.5.9	Medium	Council	Medium	Medium	8
Liaise with Railcorp to upgrade rail cross-drainage at Whitton Lane.	5.3.6	Medium	Council	Medium	Medium	10
Continue creek and drainage maintenance, increase frequency at Whitton Lane and Aurville Road	5.3.7	Medium	Council	Medium	Long	11
Flood proofing by property owner. May be suitable for Museum (School of Arts building)	5.5.3	Low	Landowner	Low	Long	12
Neill Street causeway modification may improve environmental outcomes such as fish passage and reduced erosion, without significantly affecting flood behaviour	5.3.2	Low	Council	Medium	Medium	13
Flood warning - Currently subject to technical limitations and not cost effective. Review in future as available technology and costs change.	5.4.1	Low	Council / SES / BoM	High	Long	14
Install temporary flood barriers	5.3.3	Low	Council / Property owner	Low	Medium	15
Consider whether on site detention policy is required in LGA	5.3.8	Low	Council	Medium	Long	15

Notes:

- *Costing*: Low < $40K Medium $40K to $100K High > $100K
- *Timeframe*: Short <2 years Medium 2 to 4 year Long > 4 years

2. BACKGROUND

2.1. General

This Study has been prepared by WMAwater on behalf of Hilltops Council. The Study is composed of two parts:

1. The Murrumburrah Floodplain Risk Management Study; and
2. The Murrumburrah Floodplain Risk Management Plan.

This document details both the above components (abbreviated to FRMS&P). This FRMS&P follows on from the Murrumburrah Flood Study (Reference 1) undertaken by WMAwater and completed in December 2019, which defined the design flood behaviour in the study area under existing conditions.

The main objective of this FRMS&P is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximately costed recommendations in regards to flood risk mitigation in the catchment.

Council requires consideration of a range of management options to effectively manage existing, future and continuing flood risks in the catchment. The outcomes from FRMS&P will also assist the SES in updating the Local Flood Plan for the catchment. The FRMS&P is to be undertaken in accordance with the guidelines provided in the NSW Floodplain Development Manual (Reference 2).

The study area covers approximately 17 km^2 around the town centre of Harden and Murrumburrah, with the total catchment area draining to the Cunningham Creek stream gauge at Harden comprising some 901 km^2. Creeks within the study area include Currawong Creek, Cunningham Plains Creek, Demondrille Creek and various small unnamed ephemeral creeks. These creeks are all tributaries of the Murrumbidgee catchment within the Murray-Darling Basin. Currawong Creek, which is also known locally as Murrimboola Creek, is a significant feature of the twin towns of Murrumburrah and Harden. It is referred to as Currawong Creek for the remainder of this report.

The catchment generally flows from north to south, with Cunningham Plains Creek running west to the confluence with Currawong Creek. Numerous farm dams are located along Cunningham Plains Creek. Currawong Creek runs south-west through the middle of the study area. The total catchment area of Currawong Creek to just downstream of Murrumburrah weir is approximately 310 km^2. Currawong Creek is generally confined to a relatively-well defined valley both upstream and downstream of the main township. Elevations in the upper part of the main township (to the south-east) reach approximately 440 mAHD (mapping of the topography from LiDAR aerial survey is shown in Figure 3). The topography within the study area is generally moderately sloping, with typical grades of approximately 3% within town.

Flooding in the area was previously investigated in the 1987 Murrumbidgee River Floodplain Management Study undertaken by Sinclair Knight Mertz and Partners (Reference 4). Mapping was undertaken by the Water Resources Commission circa 1987 to define the extent of inundation of flooding from Currawong (Murrimboola) Creek. The present Flood Study (Reference 1) updates the 1987 studies to provide more detailed investigation of flood behaviour in Murrumburrah and incorporates recent flood events and current best practice floodplain management guidelines.

The land use within the catchment consists primarily of rural agricultural land, and low or medium density residential development in town. A sewerage treatment plant is located near the confluence of Currawong Creek and Demondrille Creek, towards the downstream end of the study area. The Main South railway line and Burley Griffin Way (B94) pass through the town, crossing creeks and tributaries in several places, with the raised railway and road embankments forming a notable feature of the floodplain at some locations. Neil Street crosses Currawong Creek at Murrumburrah weir, providing a second option for crossing the creek during times of low-flow. However this road crossing is typically inundated even after relatively minor rainfall.

Drainage elements within the catchment include natural creek channels, kerbs and gutters and larger structures such as culverts through road and rail embankments. These drainage elements are primarily owned by Hilltops Council, the NSW Roads and Maritime Authority or State Rail.

2.1.1. Main South Railway Line and Burley Griffin Way (B94)

The main south railway line crosses Cunningham Plains Creek just upstream of the main township of Harden, with the raised railway embankment forming a significant barrier to mainstream flooding and overland flows in some locations. The railway line passes over Currawong Creek just upstream of the confluence with Cunningham Plains Creek. It was noted in the historical newspaper account that during the 1930 flood event the arched culverts at this location acted as a significant choke point to flows from the upstream catchment (Reference 5). Hence the hydraulic constriction due to the culverts and raised rail embankment may have mitigated the effects of the flood on downstream businesses and properties in Murrumburrah and Harden.

East of town, numerous culverts passing underneath the Burley Griffin Way (B94) road embankment allow for the exchange of flows between the portion of the Cunningham Plains Creek catchment to the south of the road and the main creek channel. Burley Griffin Way also crosses Currawong Creek at Murrumburrah.

2.1.2. Notable Catchment Features in Murrumburrah and Harden

Currawong Creek: Currawong Creek is joined by Cunningham Plains Creek before passing through the centre of Murrumburrah and Harden.

Properties in low lying areas, relative to the creek, are vulnerable to inundation. During the February 1930 event properties on Neill Street, Iris Street, Albury Street and Bathurst Street were inundated due to flooding of Currawong Creek.

The arched railway culverts under the railway line have been observed to act as a constriction point for flows from the upstream catchment during large floods, such as the 1930 flood. The main bridge through town was destroyed in the February 1930 event and the Bathurst Street footbridge was inundated and destroyed in the December 2010 flood. These observations suggest that significant and destructive velocities may occur in the creek during large flood events. Newspaper accounts of the February 1930 flood also suggest that a light traffic bridge at Bathurst Street was inundated. It is considered likely that this ‘light traffic bridge’ mentioned in the article was similar in location and design to the footbridge that was destroyed in the December 2010 flood.

Unnamed Creek between Ward Street and Iris Street (runs parallel to Albury Street and Neil Street): The piped drainage system upstream of the intersection of Ward Street and Neill Street discharges into an unnamed creek. This unnamed creek passes under several roads before discharging into Currawong Creek. It is considered likely that during intense local rainfall events flooding of this creek may occur, potentially resulting in the inundation of properties which back onto the creek.

2.2. Historical Flooding

Flooding in Murrumburrah and Harden can occur when intense local rainfall generates runoff exceeding the capacity of drainage channels and creeks, producing overbank flow or overland flooding. Flooding in some areas may be exacerbated by the blockage of hydraulic structures and the presence of obstructions to overland flow paths.

Notable Currawong Creek flood events occurred in February 1930, October 1993, December 2010 and September 2016. The February 1930 and December 2010 events in particular were major floods that caused significant inundation, damage and loss. Many businesses and properties were identified as flood affected in the written historical account of the “great 1930 flood” and some of these historic structures were again inundated in the December 2010 event. Historical flood events have resulted in damage to both residential and commercial properties, many of which are currently standing. Mainstream flooding of Currawong Creek has previously resulted in the destruction of the road bridge at Albury Street (Burley Griffin Way) and a footbridge at Bathurst Street. These structures have subsequently been replaced and rebuilt.

Records of historical flooding were obtained from resident responses to the community consultation as part of the Murrumburrah Flood Study (Reference 1). A selection of photographs obtained from this community consultation process is shown in Photo 1 to Photo 6.

Photo 1: Massey's Store – February 1930

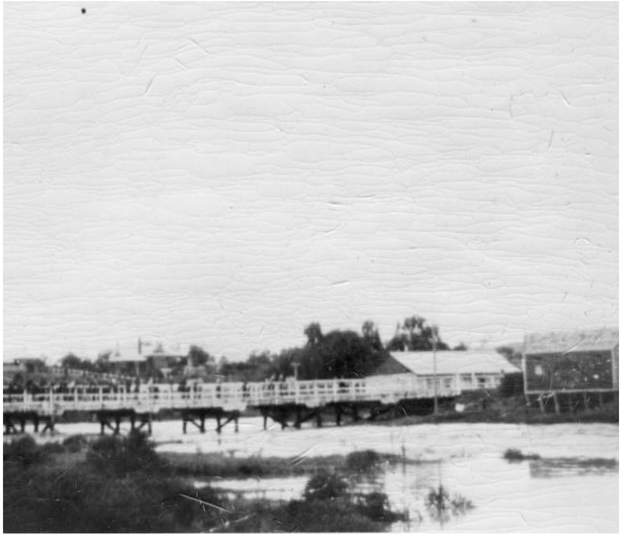


Photo 2: Albury St Bridge - February 1930

Photo 3: Buthurst St Footbridge – October 1993

Photo 4: Murrumburrah Institute/ Museum – December 2010

Photo 5: Currawong Creek – September 2016

Photo 6: Creek at Roberts Park – Year Unknown

2.3. Previous Flood Studies

The following is a summary of previous flood investigations completed in the area.

2.3.1. Map of Flood Inundation for Murrimboola and Currawong Creeks

Public Works prepared mapping of estimated flood extents for Murrimboola and Currawong Creeks in 1987 but WMAwater was unable to obtain a copy of this mapping.

2.3.2. NSW Inland Rivers Flood Plain Management Study – Murrumbidgee Valley Summary Report (Sinclair Knight and Partners, 1987)

This study (Reference 4) examined the flood impact and investigation of management options across the Murrumbidgee Valley. The study makes brief mention of Murrimboola Creek and identifies Murrumburrah as a town on a Murrumbidgee tributary which is subject to flooding. The study makes the assertion that Murrumburrah does not have serious flood problems relative to other population centres within the Murrumbidgee Valley, suggesting that minor structural works could provide an adequate level of flood protection.

2.3.3. Murrumbidgee Flood Data Collection in 2010

In 2010 WMAwater was involved in the collection of post-flood data on behalf of the NSW SES following the December 2010 Murrumbidgee River flood event. Several flood marks from Currawong Creek flooding were collected. A report was produced summarising the location and relevant details of flood marks collected during this exercise.

2.3.4. Murrumburrah Flood Study (Reference 1)

This report provided the first detailed assessment of the existing flood problem in the study area. The first stage involved data collection including:

- All available topographic and structural data was collected including Light Detection and Ranging (LiDAR) survey of the study area and its immediate surroundings. Supplementary detail survey for the creek channels with in-bank channel and weir cross-sections for dam embankments collected by CPC Surveyors between 4/03/2019 and 19/03/2019. Data for hydraulic structures was supplied by Council based on field measurements and field survey.
- Building floor levels are required in order to undertake an assessment of potential flood damage. Floor level survey was undertaken for 35 properties by CPC Surveyors on based on either historical flooding observations or vicinity to Currawong Creek. Floor levels for other properties potentially affected by flooding were compiled by using LiDAR to estimate ground levels at each building and adding a height-above-ground estimate for floor level heights above ground. These height-above-ground estimates were determined via visual inspection using techniques such as counting the number of bricks or steps from ground level to floor level, or other approximation methods – this technique provides a sufficient level of accuracy for undertaking flood damages. Google StreetView, in conjunction with photographs taken during a site visit, was used to estimate the height of the floor above

ground. In total, 378 floor level estimates were made using this method.

- A database of stormwater pits and pipes was provided by Hilltops Council and updated where data was missing.
- In order to calibrate and validate the models, data from historical events are required. Notable flood events were identified via an analysis of the historical records, community observations and recorded stream gauge data. Information suitable for model calibration/validation was available from the October 1993, December 2010, March 2012 and September 2016 flood events. Flood mark data was collected through a data collection exercise completed by WMAwater following the December 2010 event. Qualitative flooding observations were collected during the community consultation process.
- The community consultation process indicated that four respondents could identify a flood mark and several residents provided photos indicating the extent of flooding in the study area.
- Qualitative observations of flood levels were collected from newspaper accounts of the February 1930 flood event and the community consultation process. In some cases the locations of potentially useful flooding observations from newspaper accounts of the 1930 flood event were unable to be established and in some cases the precise location of flooding observations were unclear.
- Records of flood and stormwater related calls to the SES in Harden from 2015 to 2019 were analysed and these provide a qualitative indication of locations where local stormwater and overland flow has caused problems in the study area.
- Historical stream gauge data were available from Cunningham Creek downstream of Harden (410092) from 1976 to 1980, 1986 to 1988 and 2011 to present. Recordings at this gauge station were discontinued in 1988 and the station was re-established in 2011 providing approximately 14 years of recorded data. The gauge captured continuous water level data for the September 2016 flood event, however the February 1930, October 1993 and December 2010 event are outside the period of record. It is likely that larger flood events have occurred on Cunningham Creek outside the period of record.
- Flood Frequency Analysis (FFA) uses the record of past flooding at a site to determine design event discharge. FFA is generally preferable to the design event method of rainfall-runoff modelling however could not be undertaken due to the limited length and quality of the observed gauge record and the relatively low quality of the rating curve.
- All daily and continuous (pluviometer) rainfall gauges within 50 km of Harden were analysed for each of the significant recent events (1993, 2010, 2012, 2016) with the rainfall totals used to create rainfall isohyets for the entire catchment. A comparison of the burst intensity of these historical rainfall events with the design rainfall IFD was also undertaken.
- A questionnaire was distributed to residents in the study area to obtain information about historical flooding. 41 responses were received and of those that responded, 24 respondents had observed some sort of flooding within the catchment, with 8 respondents indicating that their property was directly affected. 7 respondents indicated that damage had been caused to their property due to flooding. In total approximately 5% of residents responded to the distributed questionnaire. This is a relatively low response rate and may be indicative of a low awareness of flooding for many residents within the study area. The following issues were raised in the responses:
    - Some residents were concerned about the flood damage to their home and

properties.

- Residents in town identified flow paths through their properties which generally form when runoff exceeds the capacity of the drainage network resulting in overland flow.
- Some residents suggested that erosion and sedimentation processes are a significant feature of the local creek systems. These processes may result in changes to the morphology of the creek system following major flood events.
- A resident described flooding of Currawong Creek as typically short in duration. This observation is consistent with the relatively small catchment area of Currawong Creek, in comparison to larger western NSW rivers such as the Murrumbidgee.

In the second stage a WBNM hydrologic computer model and a TUFLOW hydraulic computer model were established based on the above data. A hydrologic model estimates the amount of runoff that flows from a catchment for a given amount of rainfall, and the timing of this runoff flow. A hydraulic modelling represents the simulation of how floodwaters move through across the terrain and estimates the flood levels, depths, velocities and extents across the floodplain. The hydraulic model can simulate floodwater both within the creek banks, and when it breaks out and flows overland, including flows through structures (such as bridges and culverts), over roads and around buildings.

The hydrologic model covered the entire catchment but the TUFLOW hydraulic model only encompassed the study area, comprising the twin township of Murrumburrah/ Harden from just upstream of the arched railway culverts on Currawong Creek to downstream of the sewage treatment plant near the confluence of Currawong Creek with Demondrille Creek. The eastern and western boundaries extend from Harden Racecourse (Cunningham Plains Creek) to the crossing of Demondrille Creek on Burley Griffin Way (B94). The total area included in the model covers 16.5 km^2.

The third stage involved calibrating both models to the available historical flood data collected in the first stage, namely the floods of:

- October 1993;
- December 2010;
- March 2012; and
- September 2016.

Calibration was undertaken to demonstrate that the WBNM and TUFLOW modelling system can accurately match historical flood levels.

In the fourth stage the models were used to determine design flood levels ranging from small frequent events to much larger more infrequent events. These flood levels can be used for setting flood planning levels such as the minimum floor level of a new house or the level of a new garage floor. ARR 2016 guidelines for design flood modelling were adopted for this study, including the use of ARR 2016 design information for the 5%, 2%, 1%, 0.5%, 0.2% AEP events and in addition the Probable Maximum Flood (PMF). Sensitivity analysis was also undertaken to evaluate the effects of changing key model parameters. The Flood Study report provides detailed information and results.

In the final stage of the study a flood damages assessment was undertaken and this is discussed further in Section 3 of this report.

3. ECONOMIC IMPACTS OF FLOODING

3.1. Introduction

The quantification of flood damages is an important part of the floodplain risk management process. It helps identify where the financial impacts of flooding will occur, whether the benefits from various flood mitigation measures will outweigh the costs to implement those measures, and to prioritise which measures will be most cost-effective.

While flood damage assessment does not include all impacts or costs associated with flooding, it provides a basis for assessing the economic loss due to flooding, and also a non-subjective means of assessing the merit of flood mitigation works such as detention basins, levees, drainage enhancements, etc. By quantifying flood damages for a range of design events, appropriate management measures can be evaluated in terms of their benefits (reduction in flood damage) versus the cost of implementation.

The cost of flood damage and disruption to a community depends on a number of factors which include:

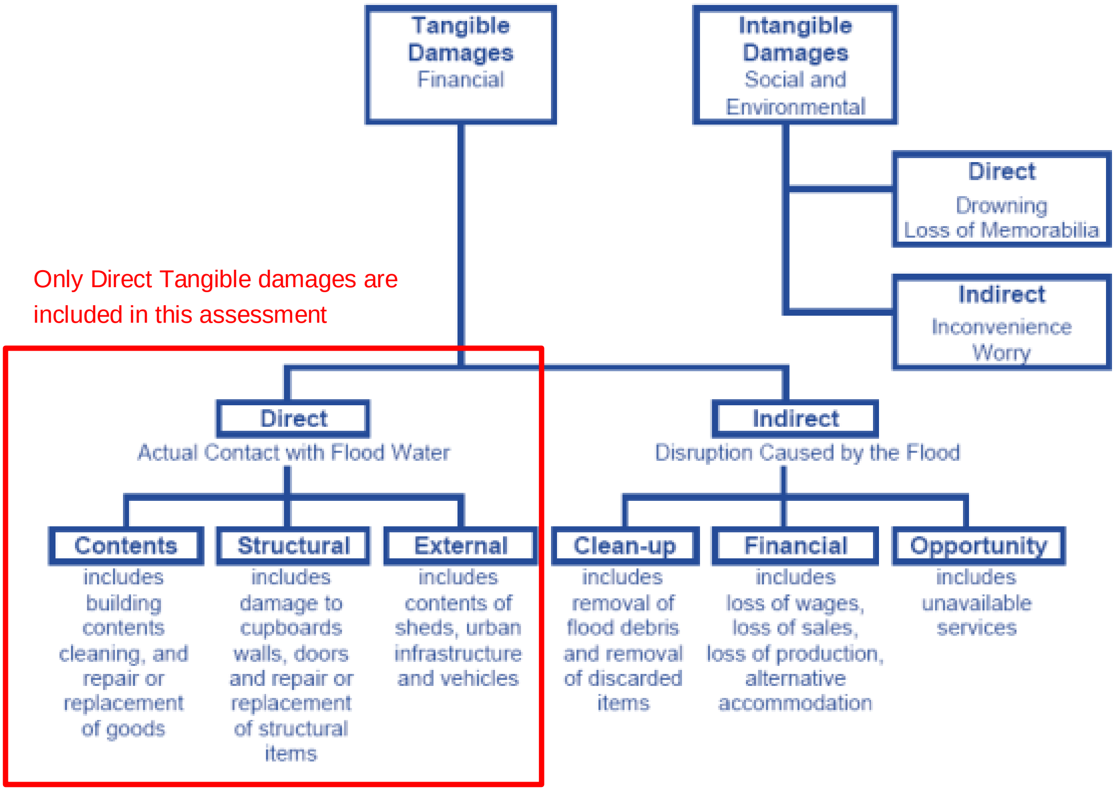
- Flood magnitude (depth, velocity and duration);
- Type of structures at risk and their susceptibility to damage;
- Nature of the development at risk (residential, commercial, industrial);
- Physical factors such as failure of services (e.g. utilities), flood borne debris, sedimentation, etc.;
- Awareness and readiness of the community to flooding;
- Effective warning times; and
- Availability of evacuation plans

The potential damage associated with a particular flood event can be divided into a number of components, which are grouped into two major categories;

- Tangible damages – financial costs of flooding quantified in monetary terms;
- Intangible damages – social costs of flooding reflected in increased levels of mental stress, loss of sentimental items, inconvenience to people, injury or loss of life, etc.

Intangible damages are difficult to measure and impossible to meaningfully quantify in dollar terms. For this reason, the following damage assessment focuses on tangible damages only. Tangible damages can be further sub-divided into two categories, direct and indirect damages, as illustrated in Diagram 1.

Diagram 1: Types of flood damages



The total likely damages in any given flood event is difficult to quantify, given the variable nature of flooding and the property and content values of houses affected. Nonetheless, flood damages are estimated to obtain an indication of the magnitude of the flood problem and compare the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of a mitigation option in relation to current damages, or to an alternative option, can assist in the decision making process.

3.2. Approach

Flood damage estimation procedures have been formulated using data collected following real flood events. Information collected includes identification of properties flooded, the extent of flooding, depth of flooding experienced, flooding mechanism etc. This information can then be used to guide and calibrate models used to calculate flood damages for a particular area. One of the most thoroughly studied flood damage assessments was that undertaken at Nyngan, following the flood in 1990.

The estimation of flood damage is focussed on residential and community buildings in the study area using guidelines issued by the NSW Government (Reference 6) and recognised damage assessment methodologies. The most common approach to assess flood damage data is in the form of flood-damage curves for a range of property types, i.e. residential, commercial, public property, public utilities etc. These relate flood damage to depth of flooding above a threshold level (usually floor level). The estimation of damage is based upon a flood level relative to the floor level of a property.

This section provides a summary of how flood damages were estimated and more detailed is provided in the Murrumburrah Flood Study (Reference 1).

3.2.1. Property Database

A property database was assembled using available aerial imagery and cadastre information for the study area. A total of 413 properties were included in the assessment. Detail survey was obtained for 41 floor levels of buildings close to the main creeks or where previous flooding had occurred. For the other 372 buildings, floor levels were estimated using the LiDAR data to estimate ground levels, and adding a height-above-ground estimate for floor level heights.

This estimation method is less accurate than detail survey, but is considered suitable for two reasons. Firstly, the estimation of property damage due to flooding is inherently difficult to estimate, given the large variation in building types, their contents, the duration of flooding and other factors, and so the accuracy of floor heights should be in line with the accuracy and applicability of the flood damage curves. Secondly, the economic damages assessment is only intended to be used as an estimate of the catchment-wide flood affectation and not on a per-property basis.

Flood levels were assigned to each property based on the modelled flood surface at the building. The database was used to determine the number and extent of properties inundated above protection level for the range of flood events modelled (5%, 2%, 1%, 0.5%, 0.2% AEP and the PMF). No freeboard was included in these estimates. It was assumed that negligible flood damages would occur in a 20% AEP flood.

3.2.2. Residential Damage

Flood damage of residential buildings was calculated using a residential damage spreadsheet based on a template developed by the NSW Department of Environment, Climate Change and Water (DECCW, now DPIE) in 2007. This includes a representative stage-damage curve derived for a typical house on a floodplain to estimate structural, contents and external damage. The amount of damage is based on the flood inundation depth for a given flood event. For the purposes of damages calculations, the AEP of the PMF event for the Currawong Creek was assumed to be 1 in 10^7.

Vehicle damage has been excluded from this assessment. Significant damage can be attributed to vehicles, but these damages are difficult to quantify due to the mobility of the vehicles and the ability to remove them from the path of flood waters. The damages associated with vehicles can be highly variable depending on the time of day, flood warning times, and other factors.

3.2.3. Non-residential Building Damage

There are several shops and community facilities impacted by flooding in Murrumburrah. Damages to these facilities were estimated using commercial damages curves, with an assumed typical floor area of 250 m^2, based on the average floor area of the survey buildings.

3.3. Estimated Tangible Flood Damages

The typical way to express flood damage for a range of flood events is by calculating the Annual Average Damage (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. The AAD value is determined by multiplying the damages that can occur in a given flood by the probability of that flood actually occurring in a given year, and then summing across a range of floods. This method allows smaller floods, which occur more frequently to be given a greater weighting than the larger catastrophic floods. The AAD for the existing case then provides a benchmark by which to assess the merit of flood management options.

A summary of the tangible flood damages is provided in Table 5. Additional details of the assumptions and methodology used to derive these estimates are provided in the Flood Study report (Reference 1). There is a large difference in the average tangible damages per property between the frequent and rare flood events. This is reflective of the rarer floods, the PMF in particular, having a far wider flood extent than the frequent events, and with much greater depths of inundation at buildings. There is estimated to be 19 properties affected above floor in the 1% AEP event. There are a larger number of properties with shallow overland flow in the vicinity of the building, resulting in potential external damages for a wide range of events. In the PMF event a large number of properties are affected, including 207 with above floor flooding. A map of the above floor affectation is shown Figure 4.

Table 5: Estimated Tangible Flood Damages for Murrumburrah

Flood Event	No. Properties Affected[1]	No. Properties Flooded Above Floor Level	Total Damages for Event[2]	Average Damage Per Flood Affected Property[2]	% Contribution to AAD
20% AEP	-	-	-	-	-
5% AEP	23	5	$455,100	$47,340	19.9%
2% AEP	28	9	$712,100	$58,343	30.6%
1% AEP	33	15	$1,340,100	$88,015	17.9%
0.5% AEP	38	20	$1,672,700	$98,466	13.2%
0.2% AEP	44	22	$2,052,300	$101,148	9.8%
PMF	277	196	$26,910,800	$209,141	8.7%
Average Annual Damages (AAD)			**$57,200**		

1 - Floodwaters greater than 0.1 m in the vicinity of the building

2 - Rounded to the nearest $100

3.4. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, injury, loss of life, loss of sentimental items, etc. It is not possible to put monetary values on these intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to significantly more than tangible damages) and depend on a range of factors such as size of flood, the individuals affected and community preparedness and resilience. However, it is still important that the consideration of intangible damages is included when assessing the impacts of flooding on a community.

Post flood damage surveys have linked flooding to stress, ill-health and trauma for residents. For example, the loss of memorabilia, pets, important documents and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition, flooding may affect personal relationships and lead to stress in domestic and work situations. The actual flood event, resulting property damage, risk to life for the individuals or their family and the clean-up process can also add to the stress. In addition to the stress caused during an event, many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage and loss. The extent of stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event, there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths, the higher the risk becomes. However, there will always be localised areas of high risk where flows may be concentrated around buildings or other structures within low hazard areas. The intangible damages for Murrumburrah may be substantial, due to the lack of warning time expected for a typical flood event.

3.5. Critical Infrastructure and Vulnerable Properties

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise;

- clean-up costs;
- erosion and siltation;
- drain cleanout and maintenance;
- removing fallen trees;
- inundation of Council buildings;
- direct damage to roads, bridges and culverts;
- removing vehicles washed away;
- assistance to ratepayers;
- increases in insurance premiums;
- closures of streets;
- loss of working life of road pavements; and
- operational costs in the lead up to and during flood events.

Schools, child care, aged care and medical facilities are generally identified as vulnerable properties. Flooding to schools and similar institutions would have different impacts depending on the time of day, weekends and school holidays etc. Obviously outside school hours there may be nil risk to life issues. However it is important that all these facilities have knowledge of the potential flood risk and if required a prepared flood management plan. Murrumburrah Public School is affected by overland flow flooding from the small unnamed creek within town. This flow path does not affect buildings apart from the Covered Outdoor Learning Area (COLA), so the direct damage to buildings is unlikely, but there may be damage to the grounds from flooding, and the school should be aware of the risks that may arise to students during heavy rainfall.

3.6. Summary

33 properties are affected by damages in the 1% AEP (of which 15 above floor level). 23 properties are affected in the 5% AEP event, (of which 5 above floor level). In smaller flood events such as the 5% AEP event, the majority of damages are structural and contents damages to commercial buildings. In a 1% AEP event, damages are roughly equal between commercial and residential properties, with a higher proportion of losses from structural and contents damage than from external, below floor or indirect damages. In the PMF event, there are 277 properties affected by direct flood damages, with 196 flooded above floor level, of which 137 are residential properties. The average annual damage is estimated to be approximately $57,000.

The majority of flood damages in Murrumburrah are concentrated in the following locations:

- Residences and commercial/community buildings near the Albury Street bridge across Currawong Creek, on Iris Street and Albury Street;
- Residences on Short Street near Whitton Lane, where there is a local sag point created by the railway embankment;
- Along the main drainage line through town that runs through the bowling club, the public school, and into an open channel between Ward Street and Iris Street;
- Residences and commercial building on overland flow paths between Albury Street and the railway line near Whitton Lane and Redbank Street; and
- The commercial precinct on Neill Street between Station Street and East Street, where it backs onto a sag point in Whitton Lane.

The above areas should be the focus of flood risk management measures investigated at the, as well as locations where there will potentially be risk to life such as inundated road crossing or public spaces.

While these flood damage estimates are indicative only, they are useful in the evaluation of flood management options, aimed at reducing flood damage estimates while being economically viable to implement. Values for specific locations may need to be revised in more detail if they are critical for determining the funding for the viability of specific flood mitigation measures.

4. CURRENT PLANNING INSTRUMENTS AND LEGISLATION

4.1. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is a uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia. The goals of the BCA are to enable the achievement and maintenance of acceptable standards of structural sufficiency, safety, health and amenity for the benefit of the community now and in the future.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event. The Standard provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event. Flood hazard areas are identified by the relevant State/Territory or Local Government authority.

The BCA is produced and maintained by the Australian Building Codes Board (ABCB), and given legal effect through the *Building Act 1975, which in turn is* given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

4.2. State Provisions

4.2.1. EP&A Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

4.2.2. Ministerial Direction 4.3

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The objectives of Direction 4.3 are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Various clauses within Direction 4.3 provide additional legislation in regards to development on the floodplain. This includes restrictions that do not allow for development in the floodway, flood impacts on adjoining properties, and development intensification within the flood planning area.

4.2.3. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and
- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (Reference 2) relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits approach based on floodplain management. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk.

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required to address issues particular to a rural floodplain.

4.2.4. 2020 NSW Flood Prone Land Package

In June 2020, the NSW Government exhibited proposed policy updates titled the *Flood Prone Land Package*[1] which provides advice to councils on considering flooding in land use planning and consists of:

- a proposed amendment to schedule 4, section 7A of the Environmental Planning and Assessment Regulation 2000,
- a revised planning circular,
- a revised local planning direction regarding flooding issued under section 9.1 of the Environmental Planning and Assessment Act 1979,
- revised Local Environmental Plan flood clauses, and
- a new guideline: Considering Flooding in Land Use Planning (2020).

The revised planning circular (not yet gazetted at the time of writing this report) would supersede Planning Circular PS 07-003, which is currently in force (see following section). The direction has been revised to remove the need to obtain exceptional circumstances to apply flood-related residential development controls above the 1% Annual Exceedance Probability (AEP) flood event. This is reflected by changes to the standard LEP instrument clauses and implementation of planning certificate notifications. These changes will need to be implemented in the future Hilltops LEP if the proposed policy changes are gazetted.

The primary changes arising from this planning circular are that Councils would be required to distinguish between different categories of flood affectation on Section 10.7 planning certificates

[1] https://www.planningportal.nsw.gov.au/flood-prone-land-package Accessed 16 September 2020

as follows:

- Clause 7A(1)1 of the Regulation has been amended to require councils to include a notation on section 10.7 certificates if flood-related development controls relating to the Flood Planning Area apply to the land.
- Clause 7A(2)1 of the Regulation now requires councils to include a notation on section 10.7 planning certificates if flood-related development controls apply to sensitive, vulnerable, or critical uses, hazardous industries, hazardous storage establishments, or where risk to life considerations apply outside the Flood Planning Area.
- Clause 7A(3)1 of the Regulation is a new requirement in planning certificates. It requires councils to include a notation to advise whether there is a need to consider the impact of development against an established regional evacuation strategy or flood-related state emergency sub-plan, within the Regional Evacuation Consideration area (if the information is available).
- If flood-related development controls only relate to regional flood evacuation considerations, the notation under clause 7A(3) should be 'Yes'. Answers to 7A(1) and 7A(2) should not change.

This document provides the required information to distinguish between these categories of flood affectation, by providing differing Land Use Planning Categories (see Section 6.2) and associated mapping:

- Areas designated FPCC1/2/3 will require a notation as per Clause 7A(1)1 relating to being within the Flood Planning Area.
- Areas FPCC4 will require a notation as per Clause 7A(2)1 relating to controls on sensitive, vulnerable or critical uses.
- Areas designated "Extra FPCC 3 due to isolation" will require a notation as per Clause 7A(3)1 relating to the need to consider the regional evacuation strategy.

4.2.5. Planning Circular PS 07-003

Planning Circular PS 07-003 provides advice on a package of changes concerning flood-related development controls for land above the 1% AEP flood and up to the PMF.

Councils can make an application to the DPIE for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in the LEP, as per Planning Circular PS 07-003. This can be useful for areas where there are significant increases in flood risk associated with increased flood magnitude above the 1% AEP event. Some Councils, where this is an issue, choose to prohibit sensitive land uses below the PMF.

4.2.6. Section 10.7 (formerly Section 149) Planning Certificates

Section 10.7 Planning Certificates are issued in accordance with the EP&A Act 1979. They contain information on how a property may be used and the restrictions on development. A person may request a Section 10.7 certificate to obtain information about his or her own property but generally a Section 10.7 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919 requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Most councils' Planning Certificates are issued under Section 10.7 (2) and 10.7 (5) of the EP&A Act 1979. A separate request can be made for a Section 10.7 (2) Certificate which confirms whether complying development may be carried out under the State Environmental Planning Policy 2008 (Exempt and Complying Development). Information to be disclosed on a Section 10.7 (2) Planning Certificate is specified under the Environmental Planning and Assessment Regulation 2000 (Schedule 4) and includes the following where relevant:

- names of relevant planning controls i.e. SEPPs, LEPs, REPs, DCPs;
- declared state significant developments;
- zoning and land uses under the planning control;
- critical habitat;
- heritage information;
- land reserved for acquisition;
- coastal protection;
- mine subsidence;
- road widening and road realignment;
- council and other public authority policies on hazard risk restrictions (including flooding);
- Section 94 contributions plans.

4.3. Local Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments are used as tools to locate new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use LEPs and DCPs to control development on flood prone land.

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to.

Harden's Council's LEP 2011 was adopted in 2011 and applies to all land in Harden.

A DCP is supplementary to the LEP and State Environmental Planning Policies (SEPPs). A DCP specifies detailed guidelines and environmental standards for new development, which need to be considered in preparing a Development Application. The DCP generally provides a layered approach – some parts are relevant to all development, some to specific types of development, and some to specific land. Hilltops Council has DCPs for the former Council areas of Young and Boorowa, but there is no DCP for the former Harden Shire Council area, or currently in force for the town of Murrumburrah-Harden.

4.4. Local Strategic Planning Documents

Hilltops Council is currently undertaking major review of the strategic land use planning approach to meet requirements of the area for the next twenty years. This review is a staged process[2], which has already involved the development of several high level background and scoping studies, including:

- *Hilltops Council Economic Growth and Land Use Strategy – Preliminary Findings Report* (Reference 10)
- *Hilltops Council Economic Growth and Land Use Strategy – Strategic Directions and Recommendations Report* (Reference 11)
- *Hilltops Freight and Transport Study – Final Report* (Reference 12)
- *Hilltops Rural and Residential Study – Exhibition Report* (Reference 13)
- *Hilltops 2040 Local Strategic Planning Statement* (LSPS, Reference 14).

References 10 and 11 provide high level context about the local economy, demographics, growth requirements and development pressures in each of the urban areas of the Hilltops LGA.

Reference 11 contains some specific zoning recommendations about the business/commercial precincts in Murrumburrah-Harden. Reference 13 contains a more specific review of the zoning in the LGA, as well as discussion about potential residential growth areas and associated rezoning on the outskirts of Murrumburrah-Harden. The flood risk constraints related to these zoning considerations are discussed in Section 5.5.4 of this report.

Reference 12 identifies key freight and transport routes and upgrade requirements throughout the LGA. Some of these routes service Murrumburrah-Harden, and the flood constraints related to these routes are discussed in Section 5.4.4 of this report.

The Hilltops 2040 LSPS (Reference 14) provides the strategic directions for how, what and where land use and infrastructure will be allocated, planned and managed to achieve the objectives of Hilltops communities over the next 20 years. It is a strategic document, enacting State, Regional and Local strategies through land use and infrastructure planning and management, and includes consideration of natural hazards and constraints including flooding and riparian management.

The LSPS will inform future development of the Hilltops Local Environment Plan (LEP) and Hilltops Development Control Plan (DCP) from late 2020 onwards. The recommendations in this report are structured so that flood risk and floodplain management for Murrumburrah-Harden can be appropriately incorporated into the strategic planning framework. The LSPS already notes that *"Recommendations from the Murrumburrah Flood Study and Floodplain Risk Management Study for the town of Harden Murrumburrah are to be included and considered in future Local Environmental Plans and Development Control Plans."*

[2] https://hilltops.nsw.gov.au/Services/Building,-Planning-and-Transport/Strategic-Planning.aspx

5. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS identifies and assesses potential risk management measures which could be put in place to manage flood risk and reduce flood damages. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the study area.

5.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 2) separates risk management measures into three broad categories.

- **Flood modification measures** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

- **Response modification measures** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better 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.

- **Property modification measures** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

Table 6: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	House raising	Flood warning
Temporary defences	Voluntary purchase	Flood emergency management
Channel construction	Flood proofing	Community awareness
Channel modification	Land use zoning	Improved evacuation access
Major structure modification	Flood planning levels	Flood plan / recovery plan
Drainage network modification	Flood planning area	
Drainage maintenance	Changes to planning policy	
Retarding basins	Modification to S10.7 Certificate	
	Flood Insurance	

Table 6 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for the study area and have not been considered.

5.2. Measures Not Considered Further

It was apparent after a preliminary assessment that a number of risk management measures would not achieve an appropriate balance between the level of flood mitigation and social, environmental and economic impacts and were therefore not worthy of further consideration. These measures are summarised in Table 7.

Table 7: Risk Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	**Social Effect**	**Environmental Impact**	**Cost to Implement**	**Benefit/ Cost Ratio**
FLOOD MODIFICATION MEASURES					
Flood mitigation dams	Yes	Nil	Very High	Very High	Low
On site stormwater detention	Minor	Minor	Nil	High per property	Low
PROPERTY MODIFICATION MEASURES					
Voluntary purchase of all buildings inundated in the PMF	Nil	High	Nil	High per building	Probably Low

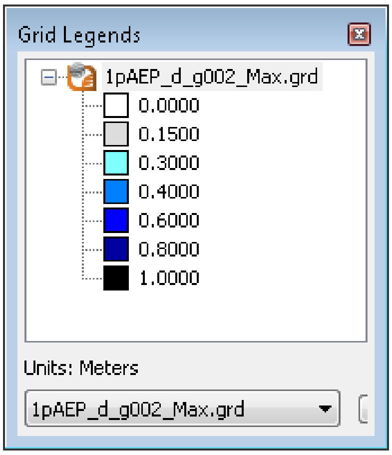
Flood mitigation dams within the catchment are not viable on economic, social and environmental grounds for reducing flood levels in the catchment. Construction of retarding basins (say up to 50,000 m^3) and the use of OSD or retention systems are increasingly being used in developing catchment areas, notably in newly developed urban residential areas. These measures are appropriate for use in controlling flooding in small rural catchments or to mitigate the effects of increased runoff caused by development but there are no sites available that would result in a significant impact on flood levels within the main creek system.

Voluntary purchase of all flood liable buildings is not viable due to the extremely high cost and likely adverse social impact.

5.3. Flood Modification Measures Considered

WMAwater reviewed areas where there is existing flood risk to life or property with a view to identifying whether there are structural measures that could feasibly mitigate that risk. The review included consideration of the flow behaviour, topography, and existing infrastructure.

For several options discussed below a diagram is provided that shows the 1% AEP peak flood depths at the location of interest. The legend is the same for each of these diagrams and is shown below, with very shallow depths (less than 0.15 m) indicated by transparent/grey colouring, and darker blue colours indicating deeper depths, up to black for depths greater than 1.0 m.



5.3.1. Levees and Filling

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban and rural areas and in overland flow situations where they usually take the form of smaller bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. Management of the local drainage from behind a levee is a major design challenge for these structures.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another the design requires consideration of hydraulic modelling so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind.

Table 8 provides a summary of the key issues to be considered with levee construction.

Table 8: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
“Environmentally Sensitive Measure”	A well-designed vegetated earthen embankment set back far enough from the riverbank to retain floodplain access, and that does not interrupt local drainage, can have minimal environmental impact providing that the natural wetland hydrology is not affected. However, in many urban locations it is hard to meet all these criteria.
Can protect a large number of buildings.	This is most likely to be the case in an urbanised area
Can provide a high level of protection	At many locations this is not possible due to the large height difference between the design events.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. In addition there is ongoing weekly or monthly maintenance (grass cutting, vegetation trimming). The annual cost of inspections for erosion or failure (of say flood gates) will generally be small (say less than $10,000 per annum per levee). However this amount can vary considerably depending upon the complexity and size of the structure.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy overlooking a creek system because of the visual attraction and a high embankment (typically 1 m or higher) will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5 m to 1 m should be added to the design flood level of the levee (level of protection afforded by the levee) to account for wave action, slumping of the levee or other local effects.
High acquisition and construction cost	The cost to import fill, compact and construct an earthen levee is dependent on the availability of good quality fill and the associated transport costs, these will vary depending upon the locality. However, generally it is the land take and associated costs (possible services re-location and access) which add considerably to the cost.
Low benefit cost ratio	Whilst the levee system may protect a number of buildings from being inundated in a (say) 1% AEP event it is likely to have a low benefit cost ratio unless the levee can include buildings inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP event). Typically these frequently inundated buildings are not concentrated in an area that can readily be protected by a levee.
Local runoff from within the “protected area” or upstream may cause inundation.	The ponding of local runoff from within the “protected area” may produce levels similar to that from the creek itself. In some places local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure.
May create a false sense of security.	Unless the levee system is constructed to above the PMF level it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA in August 2005).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless

	the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the creek system.	Access to the creek system for recreational activities requiring easy access, or access to existing bridges, will be restricted. This usually requires expensive re-design of entry points.
Increase in flood levels elsewhere	Levees by their very nature prevent inundation of part of the floodplain. The floodwaters that previously entered the protected area must now travel elsewhere and in so doing increase flows and flood levels elsewhere. The increase in level depends upon whether the area to be leveed was a flood storage area with no or little cross flow or the area was an area of active flow, termed a floodway.
Tying the levee into high ground	Unless the levee is a ring levee it usually needs to tie into high ground. This is likely to be a significant issue as it may require raising roads or significantly extending the levee alignment.

SPECIFIC OPTION ASSESSED – Levee behind Albury Street Business District

Diagram 2: Indicative Location of Potential Levee

A significant proportion of the damage in the December 2010 flood occurred in the commercial area between Albury Street and Currawong Creek, with flow rising out of Currawong Creek and inundating the lower floors of businesses that back onto the creek. Modelling was undertaken to determine whether a levee between the creek and the back of these properties could mitigate flood damages up to a certain designated flood event (Diagram 2).

Photo 7: Indicative Levee Location behind Metalcraft Shop

Several of the general issues discussed above are particularly relevant and limit the feasibility of a levee at this location, including:

- Land requirements, as the footprint of an earthen levee can be large once batters are accounted for. There may not be sufficient space between the properties and the creek banks, especially if existing riparian vegetation is retained (see Photo 7 and Photo 8);
- Construction and maintenance issues – the existing ground under the levee may not be of suitable quality to provide a footing. If a wall is used to minimize the footprint, then it needs to be appropriately engineered and interface with the rest of the levee;
- Local drainage – Levees can create nuisance flooding behind the levee which is not easily addressed without compromising the levee performance;
- Visual amenity – Residents and businesses often object to levees, particularly if they obstruct a view of the creek;
- Access – Providing access across the levee to the Bathurst St footbridge would present considerable challenges;
- Cost Effectiveness – To be cost effective, the levee generally needs to prevent flooding in frequent events or for a large number of properties;
- Adverse Flood Impacts – The levee would exclude water from one area, and can exacerbate flooding in other areas.

Photo 8: Indicative Levee Location behind Museum

Two indicative levee alignments were modelled – one extending from Albury Street around to high ground in the west as indicated in Diagram 2, and another shorter levee only extending from Albury Street to the northern end of the Bathurst Street footbridge. The first alignment was found to exacerbate flooding for events overtopping the levee. If the levee was set to protect against the 5% AEP event for example, then in the 1% AEP event flood levels would be significantly increased in the western area behind the levee, due to water overtopping on the eastern side and being obstructed from flowing out over the levee at the western side. Figure A1 shows the change in flood levels produced for the 1% AEP event for the first alignment, with a levee height of 1.5 m above existing ground levels.

The second alignment was found to reduce peak flood levels slightly for the affected buildings, but only within a limited area, and the depth reduction would not be enough to significantly reduce flood damages to the buildings. As shown in Figure A2, a 1.5m high levee using the second alignment would only reduce peak flood depths in the 1% AEP event by approximately 0.1 m.

Furthermore, both levee alignments were found to exacerbate flooding by increasing peak flood levels for affected properties on the eastern side of the creek, including properties on Iris Street north of the Albury Street Bridge (as shown on Figure A1 and Figure A2).

Given the relatively poor performance of a levee at this location for reducing flood damages, and the significant limitations outlined above, this option is not considered feasible.

SUMMARY AND RECOMMENDATIONS

In an urban environment it is difficult to construct a levee that provides protection and at the same time does not affect access and/or views or re-distributes floodwaters onto adjoining properties. Potential levee alignments were investigated but found to be not viable.

5.3.2. Major Structure Modification

DESCRIPTION

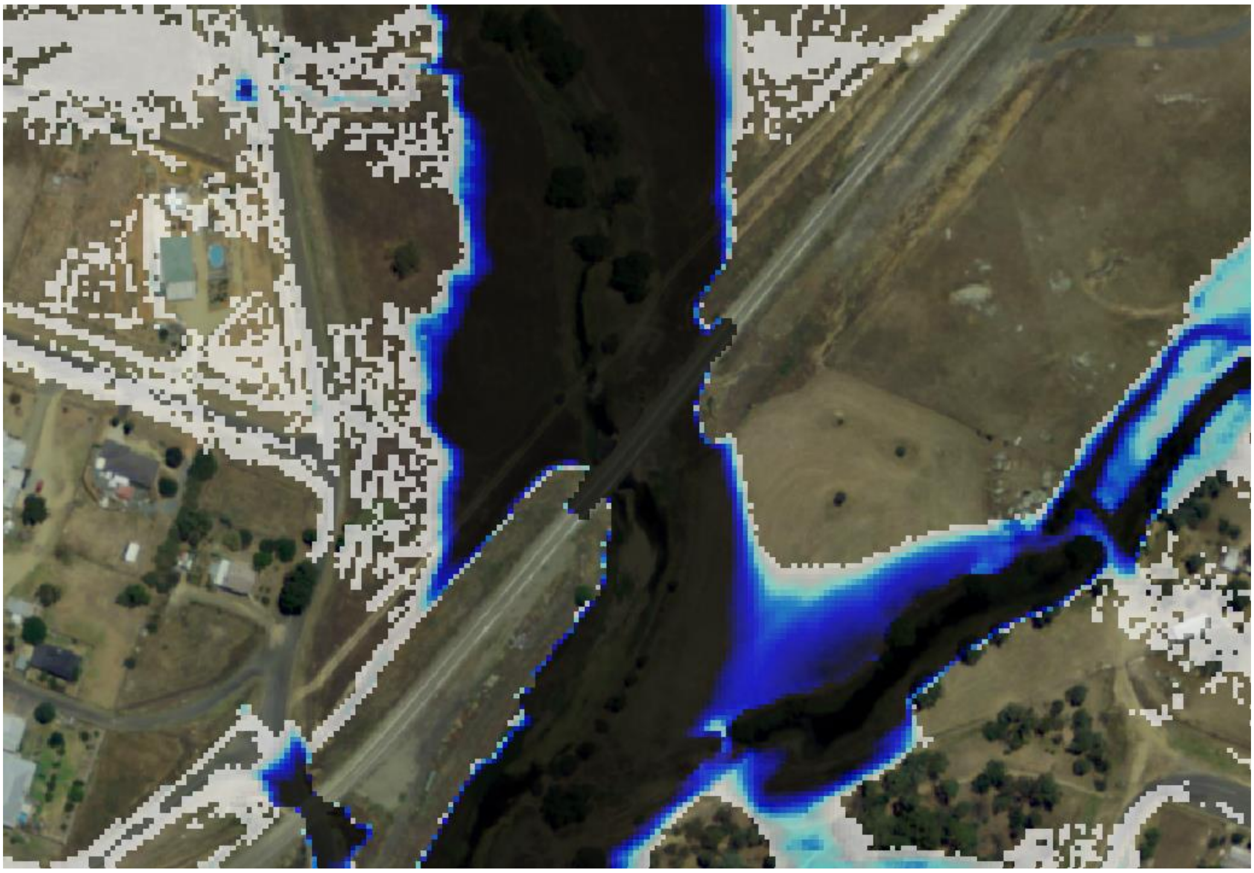
Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased (and vice versa). Generally the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by increasing the size of a culvert, widening a bridge or raising the deck level.

DISCUSSION

Increasing bridge or culvert capacity under road crossings will reduce food levels upstream. However as flood levels are reduced upstream there is less temporary floodplain storage upstream and thus a slight increase in peak flow downstream. Reducing the structure capacity will increase flood level upstream and possibly reduce them downstream.

SPECIFIC OPTION ASSESSED – Limit Flow Capacity at Railway Embankment

Diagram 3: Currawong Creek Constriction at Railway Arch Bridge



The blockage sensitivity assessment for the Flood Study indicated that major blockage of the Railway Arch Bridge at Currawong Creek (Diagram 3) would reduce flood levels through Roberts Park and around Iris Street and Albury Street.

Modelling was undertaken to assess whether an intentional obstruction of the bridge capacity, for example by closing one of the brick arches, would produce benefits for flood damages downstream. The reasoning behind investigation of this option was that the area upstream of the railway bridge is undeveloped and increases to flood levels upstream would not significantly increase damages.

Photo 9: Railway Arch Bridge on Currawong Creek

Figure A3 shows the change in peak flood levels that would result in the 1% AEP event from blocking the northern arch of the bridge (left arch looking from upstream in Photo 9). This modelling indicated that although peak flood levels would increase upstream of the bridge, the constriction would not reduce total flow through the bridge, and velocity through the other arches would increase to compensate for the loss of waterway area. Flood levels downstream would not be significantly reduced, and scour/erosion issues around the bridge structures would potentially be exacerbated.

There are other considerations for this option that would reduce its viability, such as possible heritage status of the bridge, and the potential to compromise the integrity of the railway embankment through scour, seepage, or overtopping flows in larger events.

Given these drawbacks and the lack of efficacy, this option is not recommended for implementation or further investigation.

Similar considerations apply to the railway crossing of Cunningham Plains Creek, near Aurville Road to the north of town. The culvert at this location has a relatively small capacity in relation to the creek capacity and catchment size (see Photo 10), resulting in significant constriction and temporary floodwater storage in the 1% AEP event (see Diagram 4).

Photo 10: Railway Culvert at Cunningham Plains Creek

Diagram 4: Cunningham Plains Creek Constriction at Railway Culvert

The constriction results in a level-pool backwater that extends back over Aurville Road, which will render the road impassable even in relatively small events (more frequently than a 5% AEP, the smallest event considered in this study). Any further restriction of the culvert would further compromise the flood immunity of Aurville Road and the isolation of the community to the north, without a significant flood reduction benefit further downstream. Therefore, an intentional restriction to the capacity of either of these railway crossings is not recommended.

SPECIFIC OPTION ASSESSED – Neill Street Causeway Modifications

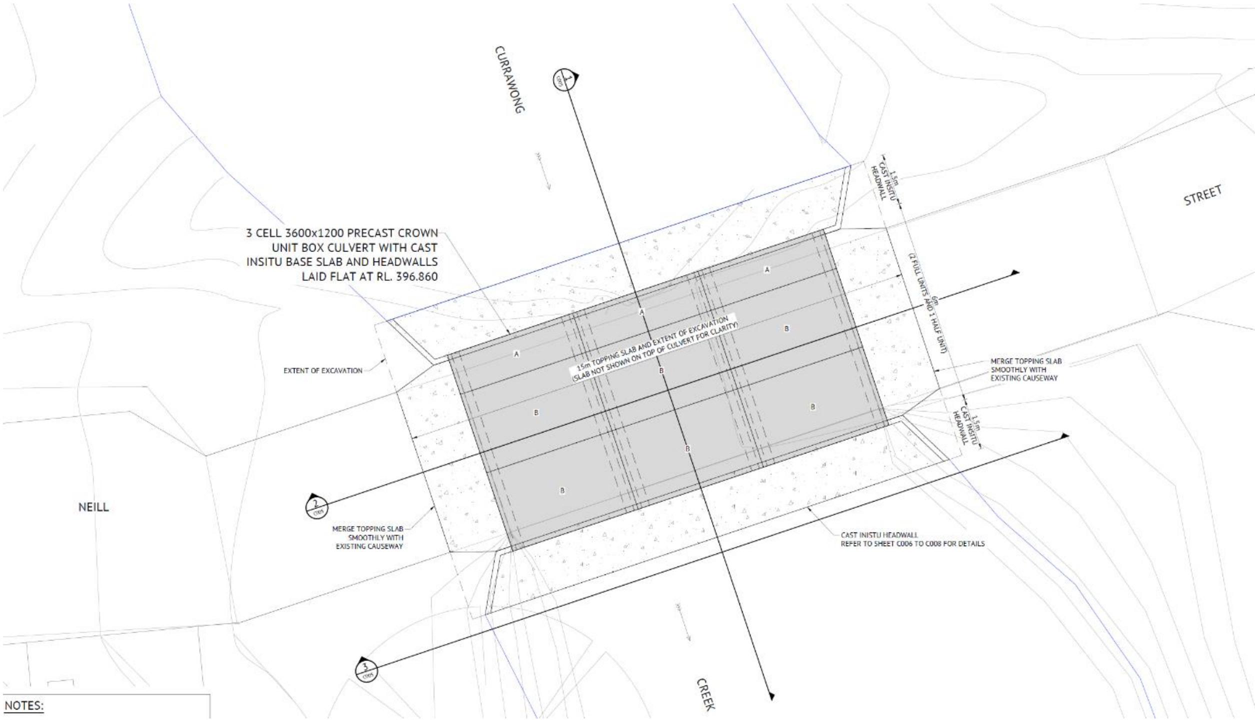
Photo 11: Neill Street Causeway (November 2018)

The Neill Street Causeway embankment is reasonably high (Photo 11). WMAwater undertook modelling to investigate whether lowering the height of this embankment would reduce the overbank flood depths through Roberts Park and surrounding properties. Figure A4 shows the change in peak flood levels that would occur if the causeway crest was lowered by 0.6 m to a level of 371 mAHD (from 371.6 mAHD currently). The results indicate that this measure would not be effective at reducing flood levels for major events that affect properties on Iris Street (e.g. the 1% AEP), and therefore is not justifiable for flood mitigation reasons. This is because the flood depth in the creek channel exceeds 3 metres during major flood events like the 1% AEP, significantly overtopping the causeway such that it has a minor effect on the overall floodplain capacity in large floods.

However, modifications to the causeway may have other benefits. There is evidence that the turbulence created downstream of the causeway as water flows across the crest is creating erosion and scour problems, despite extensive armouring of the causeway batters. There may be additional environmental benefits that could be realised in conjunction with the proposed Precinct Masterplan works in the area (such as fish passage).

Additional modelling was undertaken to investigate the effects of upgrading the culvert at the Neill Street causeway to three cells of 3600 mm width and 1200 mm height – significantly larger than the existing 450 mm diameter pipes – while keeping the crest level of the causeway at current levels (see Diagram 5). The intent of this upgrade would be to improve fish passage and reduce erosion downstream of the culvert. This modelling indicated that there would be no adverse impacts on peak flood levels from undertaking these works. These works may therefore be undertaken to produce benefits apart from flood mitigation, without requiring further investigation of whether there would be adverse flood impacts.

Diagram 5: Indicative Culvert Upgrade at Neill St Causeway Under Consideration by Council



SUMMARY AND RECOMMENDATIONS

The capacity of all major bridge crossings was investigated with a view to implementing this measure. However no locations were found that could be justified taking into account the high cost, risks, and limited reduction in peak flood levels for affected areas.

Lowering of the Neill Street causeway and/or upgrading in the culvert capacity would not significantly affect flood behaviour, but may have other benefits such as reduction of erosion and scour, improved fish passage, and improved vehicle trafficability in low flow conditions.

5.3.3. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. There are examples in Sydney where shops install a temporary steel barrier at the door if heavy rain is forecast, or when closing up for the night.

DISCUSSION

Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times, such as in Murrumburrah-Harden.

SUMMARY AND RECOMMENDATIONS

In the study area, demountable defences are not suitable to be used to reduce flood risk and inundation, due to the lack of suitable locations for their placement and insufficient available warning time. However for non-residential buildings they may offer a means of retro-fitted flood protection, and should be considered further by non-residential building owners (see Section 5.5.3 below for further discussion).

5.3.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a creek or drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream, or that the works do not create ongoing difficulties and expense with maintenance and erosion.

DISCUSSION

In general the open channel areas within the study area are relatively efficient carriers of flood waters and little benefit can be obtained through modifications to the channel. Concrete lining or straightening cannot be justified in an urban area for social and environmental reasons. In many urban areas vegetation clearing is often suggested by the local community to increase the channel conveyance. However in the study area dense vegetation within creeks does not appear to be of significant concern.

SPECIFIC OPTION ASSESSED – Channel Modification from Ward St to Iris St (FM03)

Diagram 6: Local Creek Flow path from Harden Public School to Currawong Creek

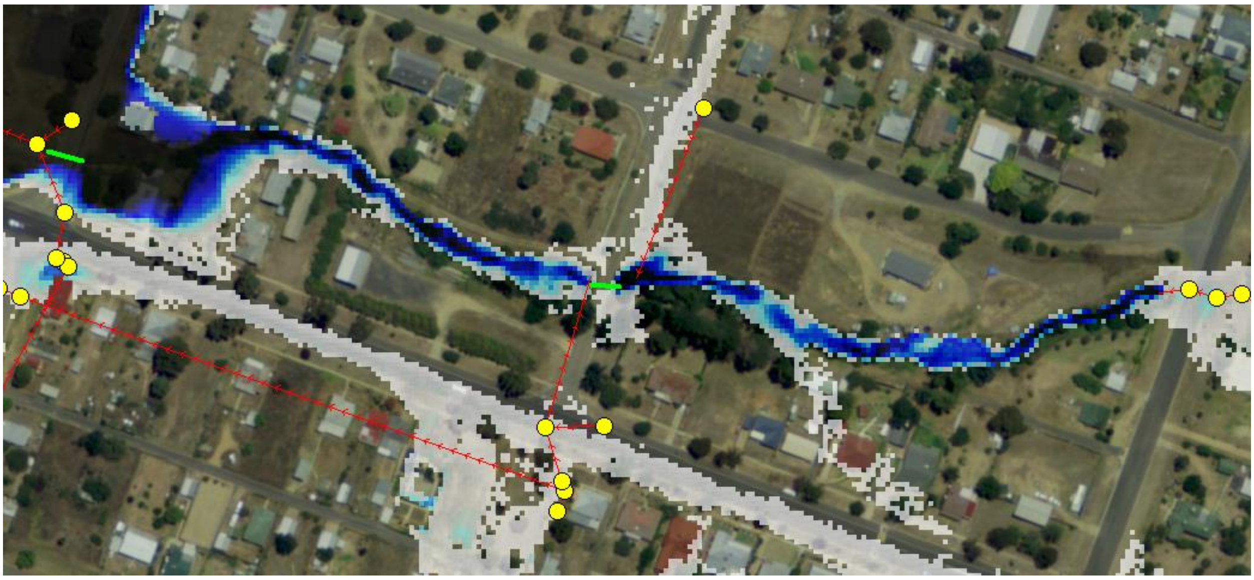


Photo 12: Local Creek Looking Upstream from Iris Street

There is relatively low existing flood risk from the open section of local creek channel between Harden Public School at Ward Street and Iris Street (Photo 12). In the 1% AEP event, local runoff is generally contained within the channel (Diagram 6). The overbank flooding in the lower part of the channel is primarily related to mainstream flood affectation from Currawong Creek (via backwater).

While “cleaning out the creek” is often a popular management response suggested by the community, the real benefits are typically minimal and there are numerous environmental limitations. Long term benefits are not possible without continual maintenance. The condition of the creek at the time of the study is considered reasonable for hydraulic capacity, and further investigation of creek modification works are not recommended for inclusion in the detailed investigation stage.

SUMMARY AND RECOMMENDATIONS

Channel modification measures were considered to provide little benefit to developed land. Additionally, environmental impacts are likely to be significant. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated in detail.

Hilltops Council already undertakes some weed control and bush regeneration along creek systems, and these routine maintenance activities should be maintained.

5.3.5. Channel Construction

DESCRIPTION

New channels or flow path diversions can sometimes be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration, particularly in overland flow areas.

DISCUSSION

In most urban areas there is generally little scope to undertake this measure as there are existing development constraints, and where viable will often have already been undertaken. This measure may require additional land take, will generally involve significant costs and may have adverse environmental impacts.

SPECIFIC OPTION ASSESSED – Overland Flow path at Harden Nursery

There is an overland flow path that runs from Lucan Street near Albury Lane, behind the Harden nursery and adjacent residence, and out to Albury Street across the entrance to the Harden Bowling Club (Diagram 7). Landscaping works have been undertaken at some point since 2010 to formalise the flow path to some extent (compare Photo 13 and Photo 14), but these structures are unlikely to withstand major flows and may not be effective in larger events.

Targeted consultation with the affected residents and business owners indicated the flooding was a serious problem, and that over-floor flooding had occurred in the recent past (including in February 2019), resulting in serious flood damage and sewer overflow. The residents indicated that the flow path used to be an open gully, which was filled and replaced with an underground pipe.

Diagram 7: Overland Flow path at Harden Bowling Club and Nursery

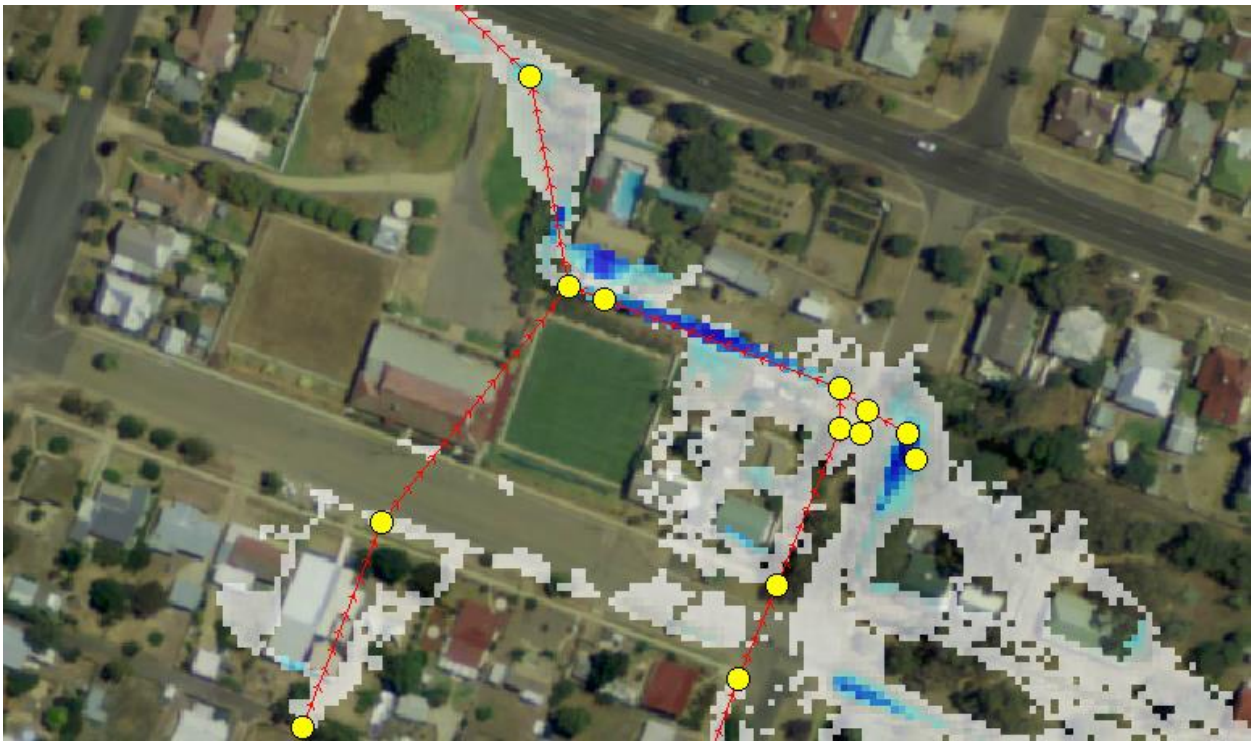


Photo 13: Overland flow path at Harden Nursery (February 2010 – Google Streetview)

Photo 14: Overland flow path at Harden Nursery (September 2019 – Site Visit)

WMAwater modelled the following potential improvements to the swale:

- A reduction in ground levels of 0.3 m by excavation between Lucan Street and the Bowling Club entry, subject to there being sufficient cover above the pipe.
- Construction of an improved solid block retaining wall approximately 0.5m high along the northern side of the swale, between the nursery and the flow path.

Figure A5 shows that this option would significantly reduce peak flood levels and extents within the affected properties for the 1% AEP event. Similar or greater improvements would be anticipated for smaller events.

At the time of writing of this study, Council staff had already investigated flood complaints in this area and committed to local improvement works, including:

- Installation of retaining wall to gain a 500-800 mm in height along northern side of drainage line/laneway at rear of nursery starting South east corner of Nursery fence, wall to terminate about 20 m along the north/south fence line near old tennis court fence/past house and tanks extents. This wall is to be erected just off fence line to gain a further 500 mm in effective channel width as well as height containment.
- An additional raised grated pit before pipe work heads north at rear of nursery to improve inflow to the pipe network.

These works are consistent with those investigated in the modelling, and could be further improved by excavation to reduce the ground levels within the swale if there is sufficient ground cover above the pipe.

The works in this location would produce significant local benefits and also be highly cost effective and could be undertaken by Council maintenance staff, without requiring grant funding to be sought from the state government.

CONSULTATION SUBMISSION AND FURTHER ANALYSIS

A submission was received in relation to the flow path at this location during the public exhibition of the Draft FRMS report. The submission made the following observations:

To whom it may concern,
It became apparent by observing the water flow at the time of the flooding event on Feb 5th 2019 that provoked this survey and the debris pattern afterwards that several points are worth considering:

1. *Flood water coming down the east side of Lucan Street has a catchment beginning from near the Country Club and Golf Course, and upon reaching the junction of Lucan Street and the lane between Albury and Binalong Street has to turn 90° into a pipe beneath Lucan Street which is incapable of accepting the water volume or the angle of entry.*
2. *Water coming from the lane between Albury and Binalong Street has its catchment origins near McLean Oval and also has to enter the pipe at the same junction of the lane and Lucan Street.*
3. *Debris build up at this point prevents water entering the pipe system and therefore is forced to remain on the surface.*
4. *Shallow gutters on the western side of Lucan Street overflow rapidly in a storm let alone a flood situation and also cannot cope with debris build up at the entry points again forcing water to remain on the surface.*

I believe the pipes in what was previously an open gully behind the Harden Nursery should have coped with what was a severe flood event if the entrance points could have been:

a) *Better location,*
b) *Better sized, and*
c) *Had more effective grating to deflect debris from blockages.*

Additional suggestions relating to the above were provided in the submission and are not repeated here.

The assertion in the submission is that in the February 2019 event and other storms, the pipe beneath the flow path (previously an open channel) does not flow full, due to a lack of inlet capacity and blockages that prevent water from entering the pipe at Lucan Street. This assertion can be tested by analysing the model results at this location to determine whether the pipe is flowing full in the modelled events, and determining whether the total flow rate (pipe and overland) could be contained within the pipe, assuming no inlet constraints.

Diagram 8 shows the pipes sizes (diameter in metres) for the stormwater network in the area. The pipe from Lucan Street to Albury Street has a diameter of 1.05m. It is fed upstream by a 0.525 m pipe coming down Lucan Street, as well as a 1.05m pipe across Lucan Street that connects to inlets in the low point.

Diagram 8: Pipe Diameters (m) near Harden Bowling Club and Nursery

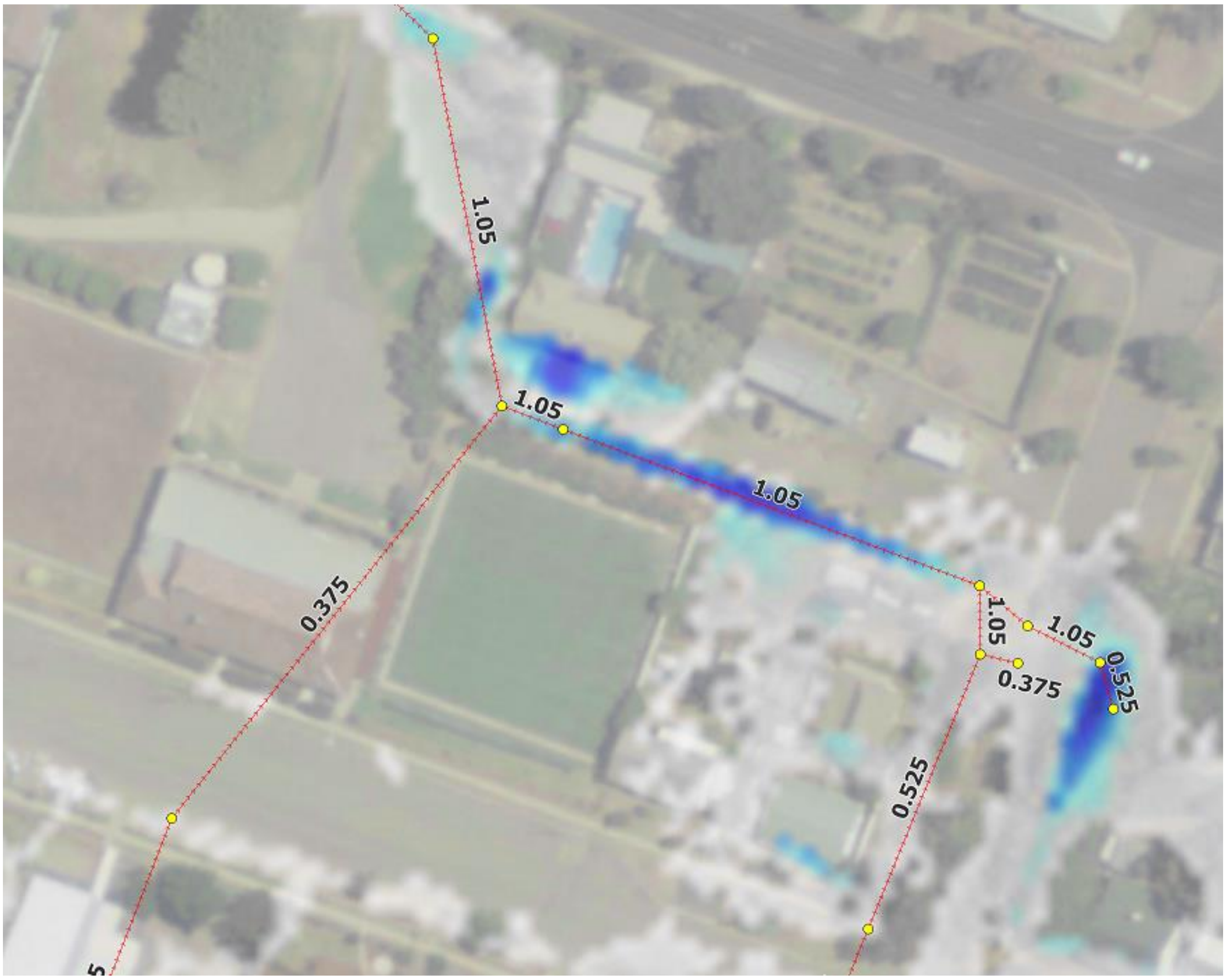


Table 9 gives the modelled peak flow in the pipe and overland flow path for the 5% and 1% AEP design events.

Table 9: Peak Flows (m^3/s) for flowpath near Harden Nursey and Bowling Club

Event	Peak Flow (m3/s)		
	Pipe	Overland	Total
5% AEP	0.99	0.86	1.85
1% AEP	1.11	1.48	2.59

Diagram 9 shows the percentage of pipe capacity utilised in the modelling for the 5% AEP event. It indicates that the 1.05 m pipe is only flowing at 67% capacity in this event. This indicates that the submission is correct in that there is insufficient upstream inlet capacity to fill this pipe, and that this issue arises primarily due to the lack of pipe drainage upstream of Lucan Street along the catchment area to the south-east.

Diagram 9: Pipe Capacity Utilisation (%) near Harden Bowling Club and Nursery

However, the modelling indicates that the pipe downstream through the Bowling Club land, also 1.05 m diameter, is at 91% capacity in the same event, due to additional inflow from the smaller pipe that joins from the south-west, as well as additional inlet capacity along the flow path. This suggests that even if inlet capacity is increased on Lucan Street, there may not be significant improvements (i.e. a reduction in the amount of overland flow) unless the pipe network downstream is also upgraded, as the total capacity will be limited by the pipes downstream through the bowling club and across Albury Street.

Nonetheless it is recommended that additional inlet capacity be provided in the vicinity of Lucan Street to increase inflow into the pipe, along with suitable design to mitigate against blockage as suggested in the submission.

RECOMMENDATIONS

Improvements to the flow path adjacent to the Harden nursery are recommended for implementation, as per the summary below:

- A reduction in ground levels of 0.3 m by excavation between Lucan Street and the Bowling Club entry, subject to there being sufficient cover above the pipe.
- Installation of retaining wall to gain a 500-800 mm in height along northern side of drainage line/laneway at rear of nursery starting South east corner of Nursery fence, wall to terminate about 20 m along the north/south fence line near old tennis court fence/past house and tanks extents. This wall is to be erected just off fence line to gain a further 500 mm in effective channel width as well as height containment.
- An additional raised grated pit before pipe work heads north at rear of nursery to improve inflow to the pipe network.
- Additional inlet capacity at Lucan Street.
- Consideration of debris blockage mitigation as part of the design of the new inlets.

5.3.6. Drainage Network Modification

DESCRIPTION

The drainage network outside the creek system comprises Council's pit and pipe network. Installing larger pipes will decrease the quantity of overland flow and thus flood levels. Hydraulic restrictions in the system affect upstream flood levels due to backwatering effects. However due to the relative small percentage of flow carried by the pipe system in a large (1% AEP) event any improvements will have minimal benefit except in the smaller events (typically < 10% AEP).

DISCUSSION

Increasing the size of pipes or installing more inlet capacity (possibly to compensate for blockage) will have a benefit but as noted above these type of works will have minimal benefit in the large floods which generally are the cause of above floor inundation.

SPECIFIC OPTIONS ASSESSED – Albury Street Cross-Drainage at West Street

On the western approach into town, the road crest of Burley Griffin Way acts as a partial obstruction to overland flow from some of the minor creek channels running from north to south. A dish drain along the northern side of the road collects runoff and diverts flow eastwards, potentially exacerbating flooding issues for properties between Vernon Road and West Street (Diagram 10). On the site inspection it was observed that there are localised drainage works near these properties that suggest nuisance flooding in the past (see Photo 15). A new building has also been constructed with very little freeboard above an adjacent stormwater inlet (see Photo 16).

WMAwater investigated a potential improvement at this location involving diversion of flow across Burley Griffin Way to the south, deflecting it away from the low lying properties between West Street and Vernon Street. The changes in peak flood levels for the 1% AEP event are shown on Figure A6, and are relatively insignificant. This suggests that any nuisance flood issues in this location are likely from local runoff from properties to the north, between Burley Griffin Way and the railway line.

Diagram 10: Overland Flow along Burley Griffin Way

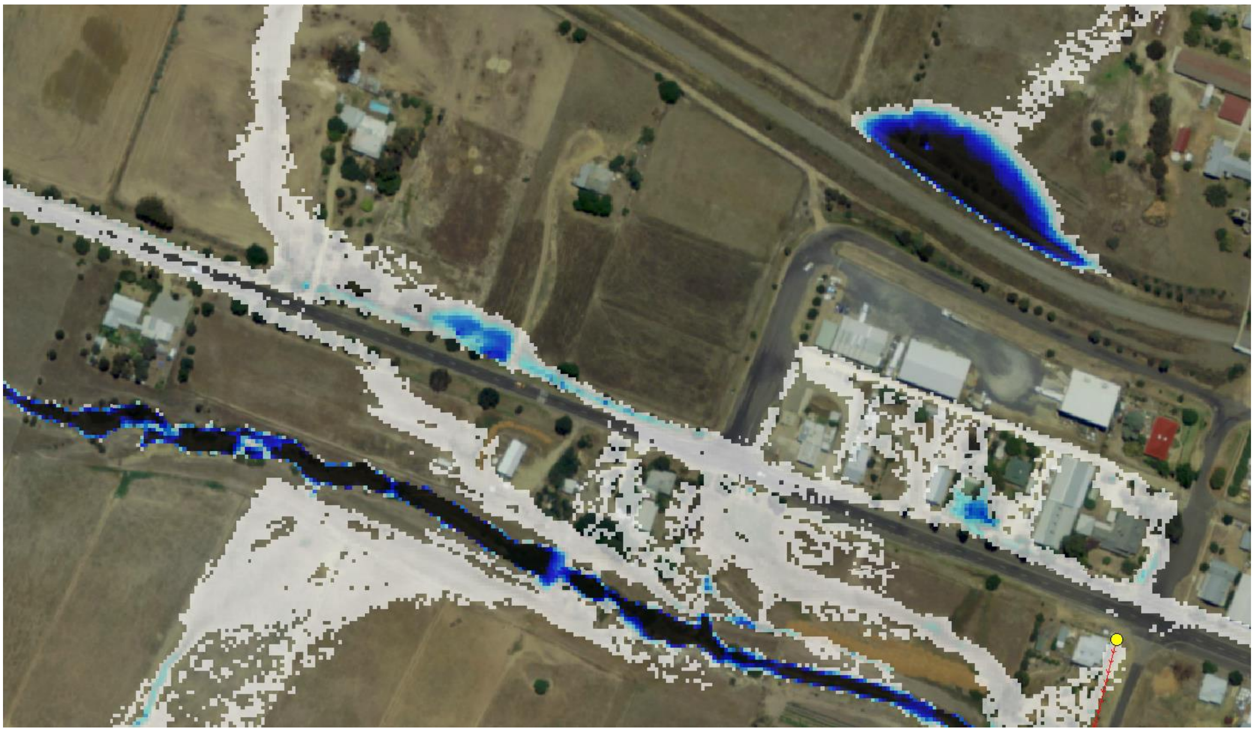


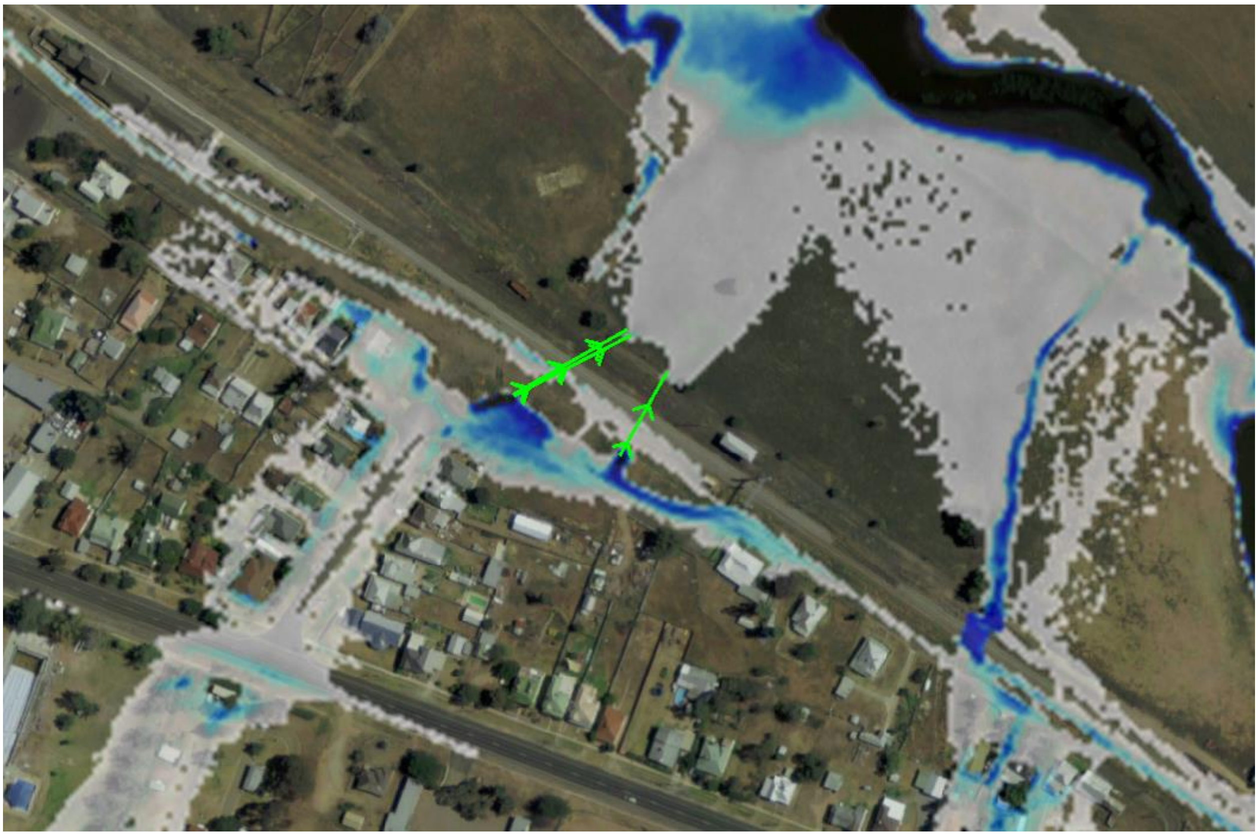
Photo 15: Properties at 369-371 Albury Street (February 2010 – Google Streetview)

Targeted consultation with residents in this area suggested there had not been significant flood damages in the past, and drainage was not a major concern. This option was therefore not investigated further.

Photo 16: New Building at 371 Albury Street (September 2019 – Site Visit)

SPECIFIC OPTION ASSESSED – Whitton Lane Railway Culverts

Diagram 11: Railway Cross-Drainage Locations along Whitton Lane near Short Street



There are localised pockets of property flood affectation along Whitton Lane from local overland flow, primarily adjacent to the railway line which has an elevated embankment crest compared to the upstream ground level. There are four separate drainage lines across the railway embankment (see Diagram 11).

Some of the drainage inlets are in poor condition or susceptible to blockage due to the surrounding ground conditions, particularly in the vicinity of Short Street. There are properties in Short Street that are relatively low-lying, and flood damages in this area may be sensitive to blockage of the railway cross drainage (see Photo 17 and Photo 18).

Photo 17: Stormwater Inlets near Whitton Lane at Short Street

Photo 18: Obstructed Stormwater Inlet near Whitton Lane at Short Street

During the site inspection in September 2019, it was observed that a culvert under the railway line further east had been recently upgraded (see Photo 19). A conversation with a resident from

Spacky Lodge indicated that the works had been undertaken by RailCorp in response to observed blockage and flow diversion across the railway line during the February 2019 storm. This pro-active response by RailCorp at this location suggests that the organisation may be amenable to additional upgrades along Whitton Lane, if it can be demonstrated there would be a significant reduction in flood risk to property and within the rail corridor.

Photo 19: Upgraded Railway Culvert near Spacky Lodge

WMAwater undertook modelling to determine the impacts of an increase in drainage capacity at the culverts in Photo 17 and Photo 18, near Short Street, equivalent to a doubling in pipe capacity. Figure A7 and Figure A8 shows the change in peak flood levels for the 5% AEP and 1% AEP events respectively. This option produces a reasonable reduction in flood levels and extents affecting properties at the bottom of Short St.

Given the benefits produced by upgrading these pipes, the relatively low cost, and the propensity for blockage of the inlets of these culverts, it is recommended that this option be pursued further. This option would need to be undertaken by Railcorp, which already completed the similar upgrade for the nearby culvert (Photo 19). Scheduling of the work will need to take into account when there is a suitable period of track closure for rail maintenance work. This option can be completed with low to medium priority given that only a small number of properties are affected.

RECOMMENDATIONS

Council should continually review the performance of the pit and pipe network after every rainfall event with say 50mm+ of rain in a day. This is already undertaken to a large extent by Council staff. Possibly this approach could be formalised and incorporate more feedback from the public who have first-hand experience of the problems at the time of the event. A questionnaire survey may be appropriate or even article in the media after a large event to ensure that all actions are taken to identify the problem areas and if cost effective and robust solutions can be found.

Where routine pit and pipe repairs or replacements are being considered by Council (e.g. need to realign, pipe failure, earthworks etc.) then an evaluation should be undertaken to determine whether a pipe size upgrade can be undertaken at the same time.

Council should approach Railcorp about providing an upgrade to the culvert capacity in Whitton Lane near Short Street, and constructing an improved headwall to reduce the propensity for blockage.

5.3.7. Pipe and Culvert Maintenance

DESCRIPTION

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges.

DISCUSSION

A common issue with all residents in flood liable areas is the perceived lack of maintenance within the creek or piped drainage systems. This perception arises as residents see the build-up of debris either before during or after the event and think that this is a major contributor to flooding.

Blockage from vegetative debris played a role in the flood affectation across the railway line and adjacent residences near Spackys lodge in February 2019, and was also observed during the site visit at other culverts near Short Street (see Photo 17 and Photo 18 above). Sediment build-up was observed within the Aurville Road cross-drainage pipes in November 2018 (see Photo 20 below). Residents reported build-up of vegetation at various creek structures after the December 2010 flood. :

Whilst debris build-up does contribute to increased flood levels the issue is more complex than may be first assumed for the following reasons:

- Council already has a routine debris removal program for the pit and pipe network;
- Council does undertake creek clearing if advised of major debris build up (fallen trees or similar);
- It is generally only during a storm event that there is a major release of debris into the drainage system due to fallen trees, wheelie bins swept into the creek, fences fall over or water and wind sweeping debris from yards or other sources. Maintenance prior to the event does little to reduce these debris sources;
- Blockage of small culverts has little impact in large events as the percentage of flow in these structures is very small and thus has only a small impact on peak flood levels.

Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively the implementation of trash racks or bollards upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. An indicative cost is $5,000 to $20,000 per item.

Some Councils have introduced silt and vegetation management plans to address this issue. However it is acknowledged that these schemes are costly for Councils to operate and must be continued forever to be effective. These schemes are generally welcomed by the residents who appreciate that Council is listening and addressing their concerns.

SPECIFIC OPTION ASSESSED – Aurville Road and Railway Culvert Maintenance

Diagram 12: Flooding Across Aurville Road and Backwater from Railway Embankment

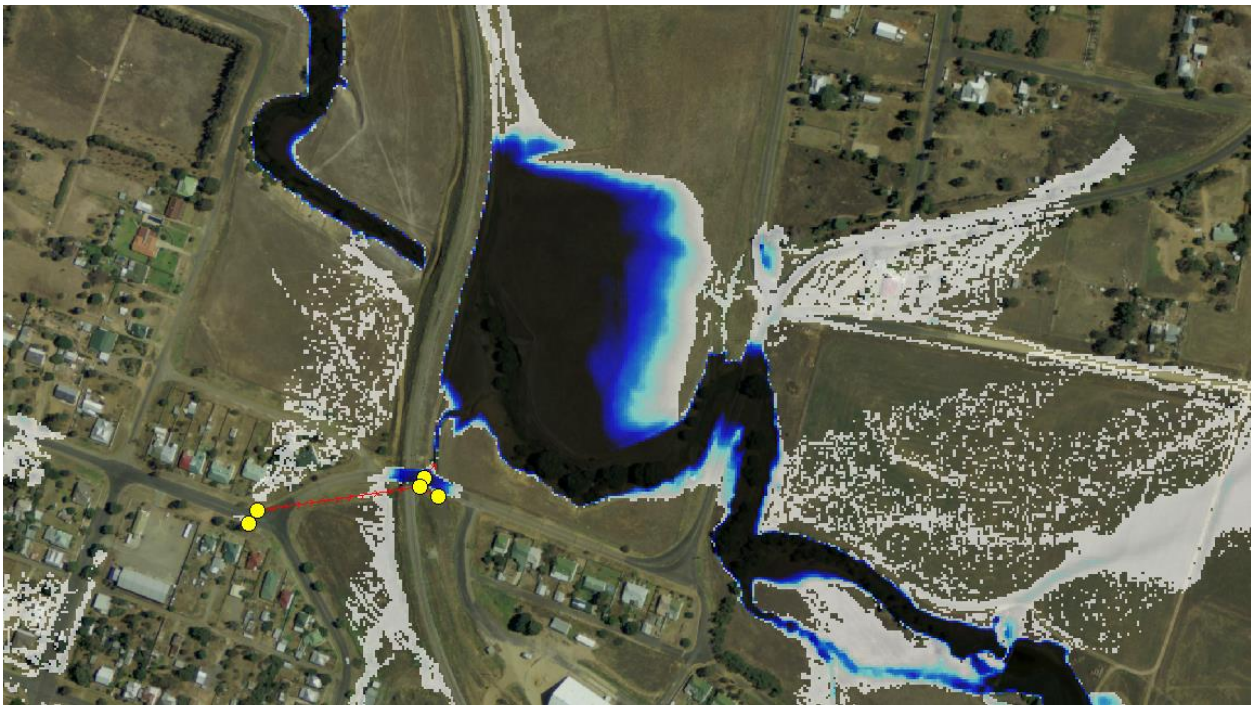


Photo 20: Blockage at Aurville Road Culverts (November 2018)

Aurville Road is subject to relatively deep inundation even in frequent events. One of the key factors in the flow behaviour is backwater from ponding behind the railway embankment further downstream (see Diagram 12). The railway embankment is very high and does not overtop in a 1% AEP event, resulting in deep backwater upstream and back across Aurville Road. Sedimentation in the Aurville Road cross-drainage pipes was observed during the site inspection (Photo 20), which may be related to the backwater influence reducing flow velocity in the pipes and preventing self-cleaning.

Potential mitigation measures to improve the flood immunity of Aurville Road might include raising the road profile, along with construction of a bridge or major culvert upgrade. However, such measures would likely be prohibitively expensive, and the main benefits would only be a slight improvement in convenience, given that the road is unlikely to be inundated for extended periods.

Structural works to upgrade Aurville Road are therefore not recommended for detailed assessment, although measures to improve safety and discourage driving across the road while it is flooded will probably be worthwhile (see Section 5.4.4). It is recommended that routine clearing maintenance of the Aurville Road culverts be undertaken at more frequent intervals.

RECOMMENDATIONS

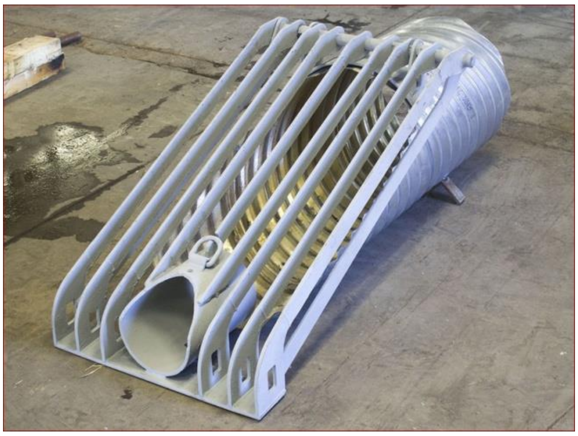
Council already has a creek and drainage maintenance program. However it is important that this measure is reviewed by Council to ensure that it is working efficiently and effectively as possible. The following guidelines are proposed to minimise the risk of blockage:

- ensure that as far as possible significant amounts of debris (natural and man-made) are regularly removed from the creek system and particularly at culvert and bridge crossings;
- minimise man-made debris which can enter the creek system. This may include inspecting the creek system to ensure potential debris providing locations are identified and controlled. For example, a timber yard should not be allowed to store timber in the floodplain without adequate fencing;
- following each flood undertake a survey of the creek system and contact residents to establish where significant blockages have occurred;
- where debris continually accumulates then debris control structures could be installed (image below). However these are never 100% effective and in some cases may accentuate the problem by acting as a debris collector themselves.

Residents are reminded to take photos and to advise Council of any debris build in the pit and pipe or creek systems. This can be done online or by contacting Council, and will ensure that reported problem areas can be addressed and repeated areas at risk of blockage added to the regular cleaning cycle.

Council should specifically implement an increased frequency of monitoring and cleaning of debris at the Aurville Road culverts on Cunningham Plains Creek, and the Whitton Lane culverts near Short Street.

Example of Blockage Prevention Device



5.3.8. Retarding Basins and OSD (On Site Detention)

DESCRIPTION

Retarding basins work by storing and controlled release of runoff after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased runoff caused by urban development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

There are no existing retarding basins built in the catchment constructed solely for flood mitigation, although throughout the upper catchment there are several farm dams that have a similar effect of reducing downstream flow rates if they are not full when rainfall occurs. Furthermore there are some drainage structures (such as those discussed in Section 5.3.2 above) that act like retention basins in major storm events. This section documents the potential for modification to those structures and the construction of additional basins.

DISCUSSION

Retarding basins can significantly reduce peak flows in urban overland flow areas and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Whilst retarding basins appear to be a fairly simple and effective means of controlling runoff and water quality in urban catchments there are a number of potential issues that need to be resolved. Importantly it should be noted that basins only reduce flood levels downstream not upstream. Unless considerable excavation is undertaken the flood levels at the site of the basin and possibly upstream will increase. Another limitation is that the intentional impounding of water can produce hazardous depths within the basin, and the risk of failure and release of water from the basin also needs to be considered. The issues to consider are summarised in Table 10 below.

Table 10: Considerations for Retarding Basins

ISSUE	COMMENT
Size and Location:	In order to be effective at reducing peak flows and benefiting water quality the basin area must cover a reasonably high percentage of the upstream catchment. The larger the basin, the more effective it will be. The outlet controls are also important in the design of the basin and generally comprise a low flow culvert and a weir which overtops in a large event. It is difficult therefore to find a location which can accommodate a basin and is not used for some other purpose.
Cost:	Whilst construction costs of the basin and wall in an urban environment will be high, additional costs are associated with any alterations to services (gas, electricity, telephone, water, sewerage, roads, etc.) that are within or in close proximity to the proposed basin. There will also be some ongoing maintenance cost. Some sites in urban areas, which at first glance may appear suitable, are unviable due to the deposition of inappropriate fill material in the past (e.g. rubbish site, buried asbestos or other forms of waste).
Benefit:	Whilst any basin will provide some peak flow reduction and water quality benefit this must be balanced against the cost, and whether there are more cost effective methods. For example, it is generally acknowledged that public education and awareness and point source reduction provides the greatest benefit from a water quality perspective. The benefit for peak flow reduction is subject to the size of the basin and the outlet works. These are not easily defined at a concept stage, as detailed survey and design is required. Small basins generally provide the greatest peak flow reduction in small more frequent events, when the basin volume is a high percentage of the total flood volume. However, in these events there is often only minor above floor damage or minor hazard to mitigate. In large events, basins (unless very big) are largely ineffectual from both a water quality and peak flow reduction perspective. Also, for multi-peaked rainfall events the basin may provide some benefit in the initial peak but very little when the second or third peak arrives. The use of a basin for dual purposes (water quality and peak flow reduction) generally means that a compromise of the benefits for each purpose has to be reached. This is because the water quality purpose is best achieved by containing all the frequent inflows. For flood mitigation purposes, these frequent flows are generally not contained to allow the volume in the basin to be “empty” at the time of the peak inflow.
Competing Land Use and Availability of Land:	In an urban catchment, where areas of open space are very valuable, the loss of previously useable land is significant. Basins can have multi-uses, such as being used as sports fields when dry, but this can be difficult to achieve.
Environmental Impact:	In urban areas there is likely to be a high environmental impact with removal of vegetation and construction of an embankment wall and the lack of a potential basin site obviously restricts the use of this mitigation measure. The most preferred sites are within golf courses or any sports ground where many of the above issues can be negated.
Safety:	This is one of the most important factors to be considered when constructing a basin with a downstream urban area. Construction of a basin will change an open space area with a low hazard potential during rainfall events to an area with a greater hazard potential. Apart from the risk of wall failure and consequently a sudden rush of floodwaters, there is the risk that people may drown or be swept into the basin. This can be negated by using fencing but this then precludes the use of the basin for other purposes. Generally basins deeper than say 1.2 m are unacceptable as a person cannot wade out of them. Some basins can be designed to have shallow and gradual depths closer to the edges. However this means less potential storage volume over the same land area. The benefit of a reduction in hazard downstream must be balanced with the potential increase in hazard at the basin site. Constructing a basin may place a significant potential liability on the construction authority should it cause harm to persons in flood (or even non-flood) times. Signs can be placed advising of the hazard, however in a legal environment it is difficult to argue that this removes the construction authority’s responsibilities. Also children, older residents and non-English speaking background residents may not understand the signs.

Construction of additional retarding basins is unlikely to be a cost effective measure to negate flooding problems in the study area for the reasons noted in Table 10. All basins will provide some flow mitigation and water quality benefit. The benefit that can be achieved must be balanced against the loss of use of the land, the economic, social and environmental costs and concerns about liability if construction of a basin increases the flood hazard in the area. This study did not identify any suitable site to create a flood mitigation basin within the catchment when the above factors are considered.

On Site Detention (OSD) is a similar concept using small scale storage on a lot-by-lot basis, implemented to ensure that the peak flows emanating from a developed catchment are not increased above that under the "natural" catchment conditions. Development typically increases the peak rate of flow by changing pervious into impervious surfaces and introducing a piped drainage network that increases the speed and concentration of runoff. The use of OSD as a means of mitigating the adverse effect of increased density of urbanisation is discussed below.

Many metropolitan councils implement some form of OSD, to mitigate against increased peak flows and thus increased peak flood levels downstream when new development occurs. OSD is governed by applying a site storage requirement (SSR) and a permissible site discharge (PSD) to each property. The SSR and PSD are determined from a catchment based study and are unique to a specific sized catchment and the extent/location of development. For example in the upper part of an existing developed catchment OSD will ensure that the piped drainage system and properties immediately downstream do not receive increased peak flows from the proposed development. However in the lower part of the catchment, where the drainage system feeds into a lake or large river system, the increased rate of runoff from a new development may be beneficial as this means the runoff has disappeared before the upstream peak arrives. For this reason some Councils have a line below which no OSD is required. This approach is valid if only considering the increase in mainstream flows. It is not valid if considering the runoff in overland flow areas as any increase in downstream peak flows in overland flow areas will cause adverse impacts downstream.

The incorporation of OSD on new developments will not provide any benefit in reducing existing flood levels in the study area but can be considered as a potential means of mitigating the increases in peak flows which would result in increased flood levels above the existing levels. OSD should only be applied where there is a drainage system downstream that would be affected by the increase in flow.

In rural areas with lower development density, the benefits of OSD are debatable. Generally, the lower development density means that the changes in runoff are less severe, since there are more pervious areas where runoff can infiltrate into the soil between each hardstand area. The benefits need to be balanced against the costs of compliance with an OSD policy, which can add thousands of dollars in design and construction costs even to relatively minor developments.

The model scenario discussed in Section 6.3 below was designed to investigate the likely cumulative effects of development intensification in Murrumburrah-Harden, without implementing mitigation through OSD. That scenario showed that increases to peak flood levels from reasonable levels of ongoing development would not significantly increase flood affectation or damages for downstream areas (with localised increases generally less than 0.03 m). This suggests that an OSD policy is not required for this study area.

SUMMARY AND RECOMMENDATIONS

No sites have been identified as suitable for construction of an effective retarding basin that would significantly reduce flood levels in the study area. The application of OSD in the study area is not required, although this should be reviewed if development pressures increase significantly compared to current forecasts as indicated in the planning strategy (Reference 13).

5.4. Response Modification Measures Considered

5.4.1. Flood Warning

DESCRIPTION

It may be necessary for some residents to evacuate their homes during or following a major flood, though there are no records of significant evacuations being required in the study area. Modelling from the Flood Study indicates that evacuation from homes and businesses would only be required in very extreme events, much larger than a 1% AEP (i.e. rarer than a 1% chance per year). The properties requiring evacuation are generally those in the vicinity of the main creek, particularly to the west in the commercial area of Murrumburrah.

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services. It may also allow time for damage minimisation methods to be undertaken (raising articles above the flood level).

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding;
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators;
- the time required to complete a safe evacuation;
- the flood awareness of the community responding to a warning.

For smaller catchments a Severe Weather Warning is provided by the BoM but this is not specific to a particular catchment.

DISCUSSION

The Bureau of Meteorology is responsible for flood warnings on all major rural river systems. Flood warning systems are generally based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. This information is then provided to the SES who undertake evacuations or flood damage prevention measures (sand bagging or raising goods).

The Bureau of Meteorology provides flood warning services for larger river and creek systems across Australia. However the Bureau warning capability is limited for locations with an effective warning time of less than 6 hours. The Bureau does not provide specific flood warnings for the Currawong Creek Catchment.

The benefit cost ratio of flood warning systems depends on the cost to install or upgrade an existing system and the benefits that accrue in terms of a reduction in tangible and intangible damages. The reduction in tangible damages is less important than the reduction in intangible damages (safe and easy evacuation to high ground) which cannot readily be incorporated in a traditional benefit cost assessment. Also there is only a limited amount of tangible damage reduction that is possible as damage to the building fabric, carpets, cabinets and other fixed items cannot generally be mitigated.

Flooding in the study area occurs relatively quickly and residents may potentially be caught unaware. Water level gauges that emit an alarm once a certain level is reached have been installed in other catchments of similar size. The main issues with these gauges are vandalism, maintenance and the ability or willingness of residents to respond accordingly and are probably only suitable in areas of high risk to life.

A major limitation to the effectiveness of a warning system in Harden/Murrumburrah is that there are very few areas subject to frequent flood damages or flood risk in smaller flood events. This means that the warning system would only be used in rare situations, reducing the benefits, while the costs of installation and maintenance are fixed. Furthermore, there are no existing rain gauges in the upper catchment that can provide reliable real-time rainfall estimates.

Capital costs of warning systems can include the installation of rain or water level gauges, development of new modelling tools suitable for providing real-time warning in the catchment, installation of system infrastructure such as cameras or sirens, and hosting platforms or internet "dashboards." Maintenance costs can be significant and are a significant drawback to flood warning systems. Maintenance costs can include:

- Maintenance of rainfall and stream gauges and telemetry (if installed),
- Data storage and hosting costs, and
- Costs to train new Council or SES personnel in the use and limitations of the warning system.

These maintenance costs will typically exceed the capital costs over the life of the system.

SUMMARY AND RECOMMENDATIONS

The greatest improvement in the accuracy and ability to respond to any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event with particular emphasis on the adequacy and accuracy of the emergency response.

The catchment is too small with a very quick response time (two hours or less). Installation of a catchment-specific flood warning system is not warranted due to relatively low benefits for relatively high cost. However the BoM is continually working on improving its Severe Weather Warnings and in time it may be appropriate to link these to SMS on mobile phones in the area. If installation and maintenance costs for warning systems come down substantially due to improvements in technology, then installation of a local warning system may become viable. It is therefore recommended to review the feasibility of implementing a warning system periodically (approximately every 5 years), along with consideration of other catchments in the LGA.

5.4.2. Flood Emergency Management

DESCRIPTION

As mentioned in Section 5.4.1, it may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the lead agency (the SES). Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- there can be confusion about 'ordering' evacuations, with rumours and well-meaning advice from other residents taking precedence over official directions which can only come from the lead agency, the SES
- they are hazardous for both rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers, and
- people (residents and visitors) do not often appreciate the dangers of crossing floodwaters.

DISCUSSION

The SES has the skills and experience to undertake the necessary evacuations should they be required. However during major storm events it is likely that all emergency services will be fully occupied in the local area and the SES should not be relied upon for immediate assistance.

The SES and Council rely on flood intelligence documents to effectively manage flood risk. The flood modelling results developed in the Flood Study represent a significant improvement in the understanding of flood risk at Murrumburrah-Harden, and the emergency management response is likely to be improved by incorporating relevant information into the SES Local Flood Plan.

A key part of any flood emergency is the recovery arrangements, a well thought out and carefully managed recovery will ensure that residents and the community are able to be "back on their feet" as quickly as possible. This phase is very important and requires input from many different authorities.

The most important issue is to ensure that all residents are fully aware of the risks associated with flooding and this is addressed in Section 5.4.3.

SUMMARY AND RECOMMENDATIONS

The SES should review their flood emergency management approach ensure that the required response for the study area is up to date, based on the modelling developed in the Flood Study and including feedback from recent flood events. Priority should be given to the implementation of this process once completed, which will continue to involve ongoing community education and awareness.

The SES should also note the information about road crossings in Section 5.4.4, and the depth of overtopping for key roads in various AEPs provided in Appendix F of the Flood Study.

5.4.3. Public Information and Raising Flood Awareness

DESCRIPTION

The success of any flood warning system, risk to life / damage minimisation and the evacuation process depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has the community been adequately informed and educated? How aware is the community of how this threat will be exacerbated with sea level rise?

Flood Preparedness: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households and businesses to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

The above can be improved upon through the implementation of an effective Council and SES run flood awareness program. The extent of the program can vary from year to year depending upon the circumstances.

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc.

Photographs (of less importance with digital photography) and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner. To some extent many of the above issues for the study area have already been addressed by the community as a result of previous floods (though these floods were of small magnitude).

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the recent minor floods which caused minimal damage, the community generally has a low level of awareness at this time (it will decline as the time since the last flood increases and may increase as a result of community flood or climate change awareness programs).

- *History of residence*. Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. Also it is very likely that new residents will be aware from advice at the time of their property purchase (Section 10.7 certificate) or from neighbours after they move in. It is very unlikely that a new resident buying a house adjacent to an open channel will not be aware of the potential of flooding. However in the upper parts of the catchment the potential of flooding from overland flow is unlikely to be well understood.

- *Whether an effective public awareness program has been implemented.* A comprehensive awareness program has not previously been undertaken by Council or the SES, though there have been articles in the national and local press regarding flooding. Most residents are generally more aware of flooding than in the past through social media or media outlets showing videos taken during floods as well as from the awareness of climate change.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods (larger than the recent events) will occur in the future. Also once they have experienced what they consider to be a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP (1 in 100 year) event (or sometimes termed a 100 year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred. A similar analogy is after “tossing” a coin 5 times and coming up with “heads” each time, the chance of “heads” on the next throw is still 50:50.

Some NSW Councils have initiated catchment-wide flood awareness strategies (for residential and commercial). Council and the SES have excellent information on flood awareness and other flood related and climate change information on their web sites. However residents have to be interested enough to access this information.

SUMMARY AND RECOMMENDATIONS

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures as well as advice provided on the Council and SES websites. Council and the SES are both active in updating their flood information for all catchments and this should continue.

Table 11 provides examples of various flood awareness methods that can be employed.

Table 11: Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive measure which can be effective if residents take the time to absorb and apply the suggestions. The pamphlet can inform residents of ongoing implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding within the study area (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council could initiate a Community Working Group framework (undertaken in other catchments elsewhere) and this would provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, floodplain management, etc.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of peak water level data from future floods	Collection of data (photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. This might also include establishment of peak water level marker poles and which house floors are inundated.
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 10.7 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all tenants and visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood affectation effects database	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as debris blockage or such like.

The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

5.4.4. Improved Flood Access, Road Closures and Notifications

DESCRIPTION

Access in times of flood is important in all flood liable areas to ensure that residents can travel safely to higher ground or critical facilities.

DISCUSSION

In urban areas flood access it is not as critical as in rural areas as the duration of closure is short (less than 2 hours) and there are generally alternative routes. Also in urban areas vehicle incidents (breakdowns and accidents) as well as the effects of storm damage (fallen trees) mean that it is not possible to guarantee that any road (whether inundated or not) will be passable in a severe storm event.

In rural areas early warning of road closures is important to ensure drivers make informed choices. In urban areas the short available waring time means that early warning is not possible and drivers must rely on their own experience (heavy rain falling) or listen to the media, and always follow SES advice to not drive or walk through floodwaters.

Table 12 and Table 13 indicate the road overtopping levels and depths on key access roads in times of flood. Information about road overtopping is also provided in Appendix F of the Flood Study report. Locations of roads subject to significant overtopping depths are indicated on Figure 5. There are other numerous other locations that may be subject to shallow overtopping of less than 0.2 m depth, both within the study area and on the major access routes outside of town. The exact depth of overtopping of these roads will depend on local storm intensity and is likely to be relatively brief.

For the 1% AEP and larger events, the Albury Street Bridge will potentially be inundated and will require closure. The bridge should be closed when flooding approaches the underside of the bridge deck.

Table 12: Peak Flood Levels for Flood Affected Roads

Location	Overtopping level (mAHD)	Peak Flood Level (mAHD)					
		5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Aurville Road	397.2	397.88	398.01	398.73	399.16	399.95	403.68
Albury Street (Burley Griffin Way)	375.3	373.59	374.24	375.13	375.57	375.97	387.19
Neill Street	371.6	373.95	374.46	375.24	375.68	376.05	387.34
Vernon Street	373.4	373.32	373.37	373.48	373.54	373.67	384.65
Cunningar Road	443.7	444.15	444.20	444.26	444.27	444.31	445.62
Ward Street	386.4	386.50	386.49	386.51	386.52	386.53	387.63
Lucan Street	402.8	402.91	402.91	402.92	402.93	402.94	403.20
Jugiong Road	388.3	388.57	388.58	388.60	388.60	388.62	388.92

Table 13: Peak Overtopping Depths for Flood Affected Roads

Location	**Peak Flood Level (mAHD)**					
	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
Aurville Road	0.68	0.81	1.53	1.96	2.75	6.48
Albury Street (Burley Griffin Way)	-1.71	-1.06	-0.17	0.27	0.67	11.89
Neill Street	2.35	2.86	3.64	4.07	4.45	15.74
Vernon Street	-0.08	-0.03	0.08	0.14	0.27	11.25
Cunningar Road	0.45	0.50	0.56	0.57	0.61	1.92
Ward Street	0.10	0.09	0.11	0.12	0.13	1.23
Lucan Street	0.11	0.11	0.12	0.13	0.14	0.40
Jugiong Road	0.27	0.28	0.30	0.30	0.31	0.62

It is likely that hazardous flow will occur across the major access routes to town in locations not covered by this study, such as Wombat Road, McMahons Reef Road, Burley Griffin Way, Jugiong Road, and Cunningar Road. Education of residents not to drive on flooded roads is the primary method for reducing risk to life, as it will not be feasible to upgrade all road crossings to be flood free, or to mobilise sufficient emergency response resources to close roads at all affected locations.

On minor creek crossings the enlarging of culverts or raising of the road would generally result in less frequency of overtopping. These works should be considered when upgrading or any works are proposed on flood liable routes.

RECOMMENDATIONS

No specific road raising works to improve flood access are proposed as part of this study. Depth indicators at road crossings are an appropriate cost effective measure to advise drivers of the depth of flood waters. However, advice from the SES is that drivers should not enter any flooded road crossing as even at shallow depths vehicles can be moved and potentially be swept into floodwaters or crashing thus presenting a significant risk to life.

The main Albury Street Bridge should be closed as soon as water is within 0.5 m or so of the underside of the bridge deck. Installation of depth indicators at the Aurville Road crossing of Cunningham Creek is recommended specifically for implementation.

5.5. Property Modification Measures Considered

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

5.5.1. House Raising

DESCRIPTION

House raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce flooding particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. It has limited application as it is not suitable for all building types, or properties in high hazard areas.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood, particularly in high hazard areas. Ideally floor levels should be raised to be above the level of the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

An indicative cost to raise a house is $80,000 though this can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house;
- generally only single storey houses can be raised;
- generally only timber, fibro and other non-masonry construction can be raised;
- generally only pier and non-slab on ground construction can be raised;
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

House raising as a flood mitigation option in the study area is unlikely to be a viable due to the lack of suitable buildings (not viable for brick buildings), and the relative cost compared to building replacement. However this measure is always available for residents to pursue if they are interested.

The floor level database prepared as part of this study (Section 3.2.1) did not include identification of houses that may be suitable for house raising thus suitable individual houses cannot be identified from the database. However experience in other areas has shown that generally all the houses that could be raised easily have been raised, the remaining ones are either too difficult to raise, have reached the end of their life or the owners do not wish to enter the raised house via steps.

Experience has shown that many owners of houses that potentially could be raised are not interested for reasons such as:

- they do not want an elevated entry to their house;
- the house is old without modern facilities and will be re-developed in the near future;
- owners will have to live elsewhere during the construction phase (possibly 2 months);

- owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace);
- whilst it is possible to raise most single storey non brick houses many owners consider the inconvenience too much of a burden;
- comprehensive flood insurance is now available from some providers.

RECOMMENDATIONS

There are few houses within the study area that may be suitable for house raising, and the benefits are likely to be limited. Rather than implementing a catchment-wide strategy, Council should advise residents of the possibility of house raising if they approach Council about flood problems, and investigate on a case by case basis. This is more likely to occur after a major flood has occurred.

5.5.2. Voluntary Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain.

DISCUSSION

Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place. Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program as long as a number of complying criteria are met.

A site inspection has indicated that there are no houses in the catchment which are considered high risk and frequently inundated in high hazard areas.

RECOMMENDATIONS

No houses have been identified as suitable for voluntary purchase. However should a resident be interested in pursuing this measure they should contact Council and it can be reviewed on a case by case basis.

5.5.3. Flood Proofing

DESCRIPTION

Flood proofing is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase. Dry proofing is often more feasible for commercial buildings which tend to have a more impermeable façade than residential buildings.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and other smaller barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

DISCUSSION

Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction. As such, flood proofing can be stipulated within Council DCPs as requirements for structures below the FPL.

Temporary flood barriers such as sandbagging and floodgates can be a cheaper option for existing properties, and can be useful where there is frequent shallow flooding, although it relies on someone to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process. This is particularly the case for overland flow inundation where the duration of inundation is short (< 30 minutes).

Hilltops Council should support flood proofing principles for existing development and structures which are below the FPL to reduce flood damages. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, and maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Whilst it is a requirement of the Floodplain Development Manual (Reference 2) that new residential properties have their flood levels above the 1% AEP event plus a freeboard, commercial properties are not necessarily subject to such a requirement unless stipulated by Council. New commercial buildings can be required to be flood proofed to the FPL when constructed which would include consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in a DCP. It is recommended that planning controls allow some flexibility in the type of proofing adopted.

Flood proofing can be a cost effective way to mitigate existing flood risk, especially in commercial buildings with limited openings and solid construction. For example, installation of sealed doors and windows on the basement of the Museum, or the use of removable temporary flood barriers, may have minimised the ingress of floodwaters in the December 2010 event (see Photo 21). The flood proofing could take the form of removable metal or wood sheeting with rubber seals that can be inserted slots at doorways, either internally or externally. The viability of this option will depend on the frequency with which these doors are required for access.

Photo 21: Flooding at Museum in December 2010

RECOMMENDATIONS

Flood proofing should not be relied upon in order to justify new development below Council's flood planning development controls. However they can be applied as a retro-fit measure for an existing flood liable development or to provide additional protection to above the minimum standards, and the DCP should allow for this.

Council should investigate specifically the feasibility of installing localised temporary flood barriers for the Museum building lower ground floor.

Note it is unlikely that State Government funds could be provided to retro-fit flood barriers through the state-wide flood mitigation program, except possibly in special circumstances where a widespread community benefit could be demonstrated.

5.5.4. Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a LEP. To make any significant changes to the provisions of a LEP, a planning proposal must be prepared.

DISCUSSION

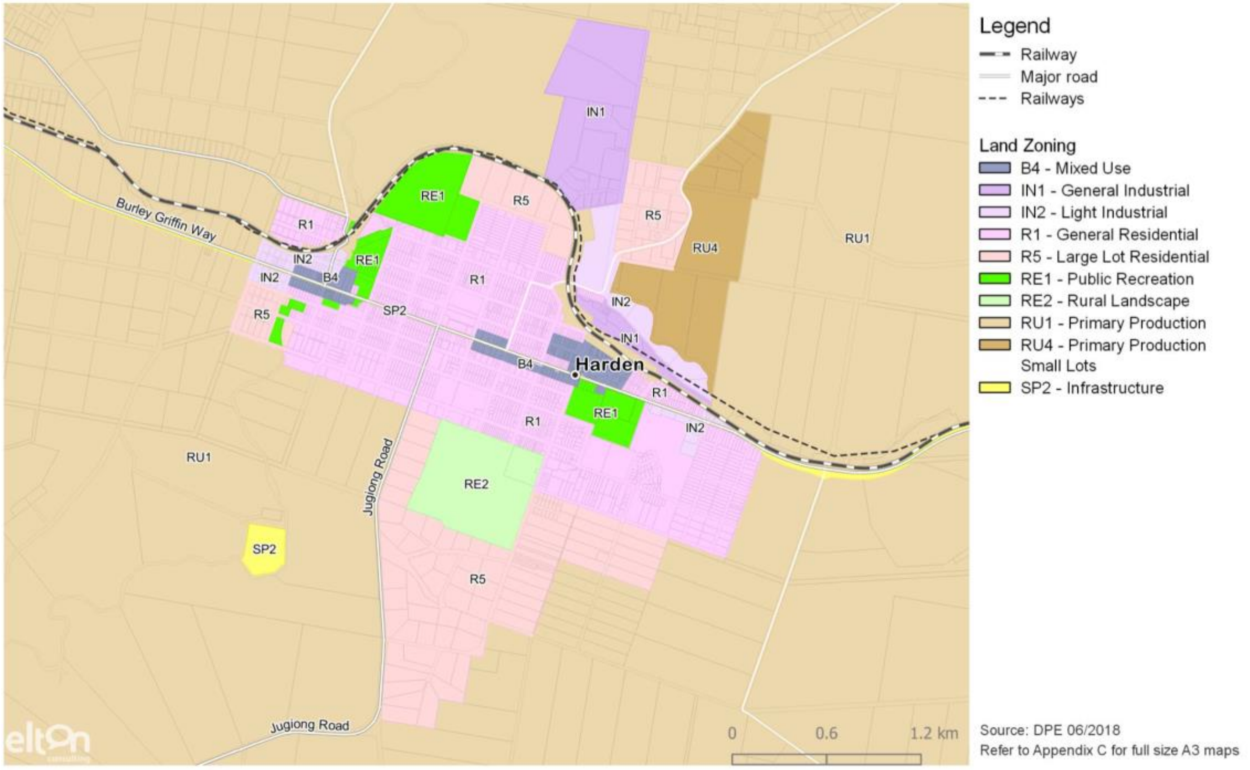
Zoning can be a powerful tool in reducing flood damages, however, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time.

REVIEW OF CURRENT LAND USE STRATEGY

References 11 and 13 contain a review and recommendations relating to current and future zoning in Harden/Murrumburrah. In order to understand the strategic planning direction for the study area, and the likely development pressures, WMAwater reviewed available planning documents and had a discussion with strategic planning staff at Hilltops Council. The review aimed to identify whether flood constraints require consideration as part of the ongoing strategic planning for these areas.

Diagram 13 shows current land use zoning in Murrumburrah-Harden from Reference 13.

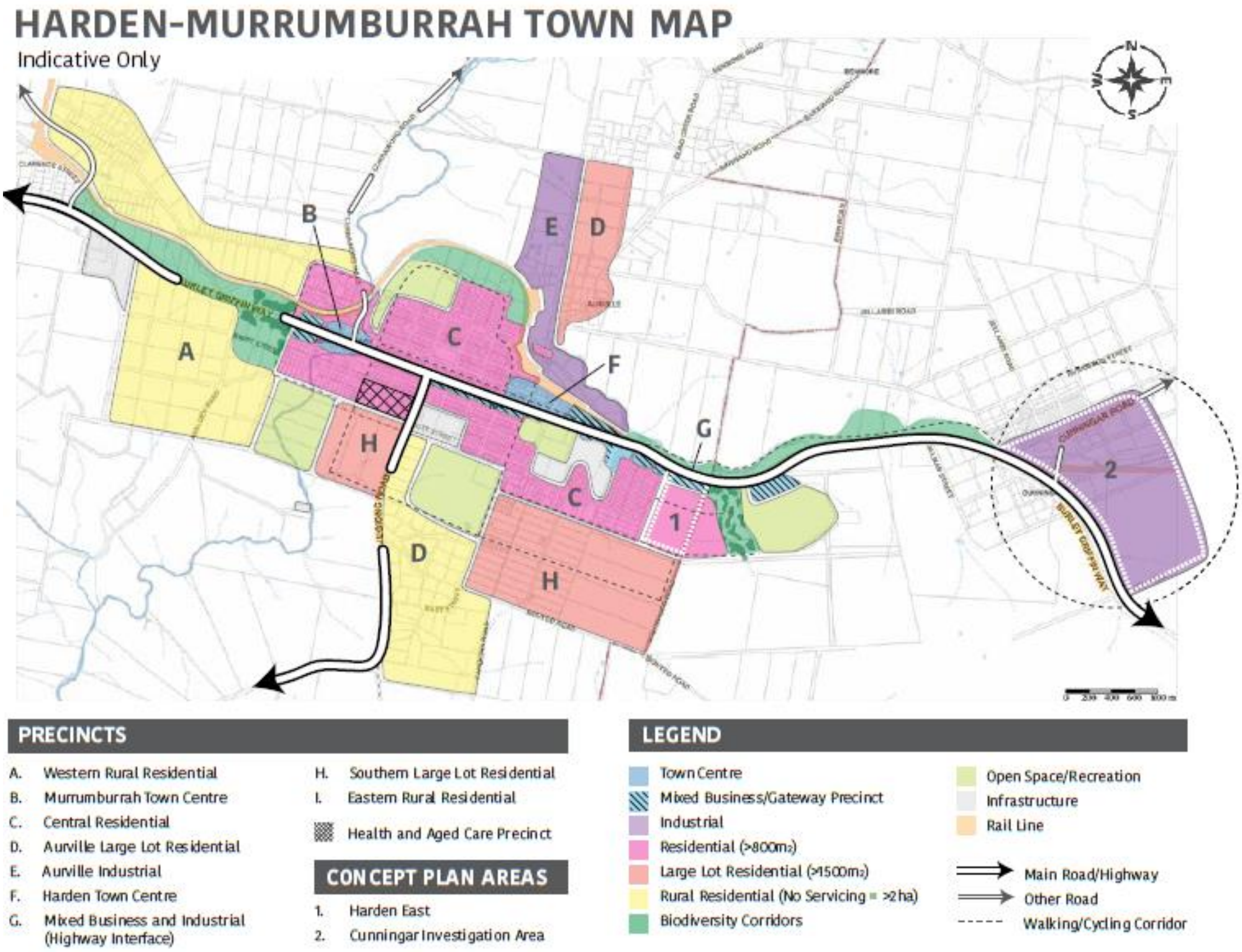
Diagram 13: Existing Land Use Zoning in Murrumburrah-Harden



Reference 11 identifies only minor zoning modifications to the B4 mixed use business precincts in Murrumburrah-Harden. The modifications would affect some flood-prone land in the vicinity of the Albury Street Bridge, but would not significantly affect the intensity of the land-use and flooding restrictions would be similar under either B4 or B2 zoning.

Diagram 14 shows urban expansion opportunities identified in Murrumburrah-Harden from Reference 14 (page 84 from that document).

Diagram 14: Indicative Strategic Land-Use Zoning Planning (Reference 14)

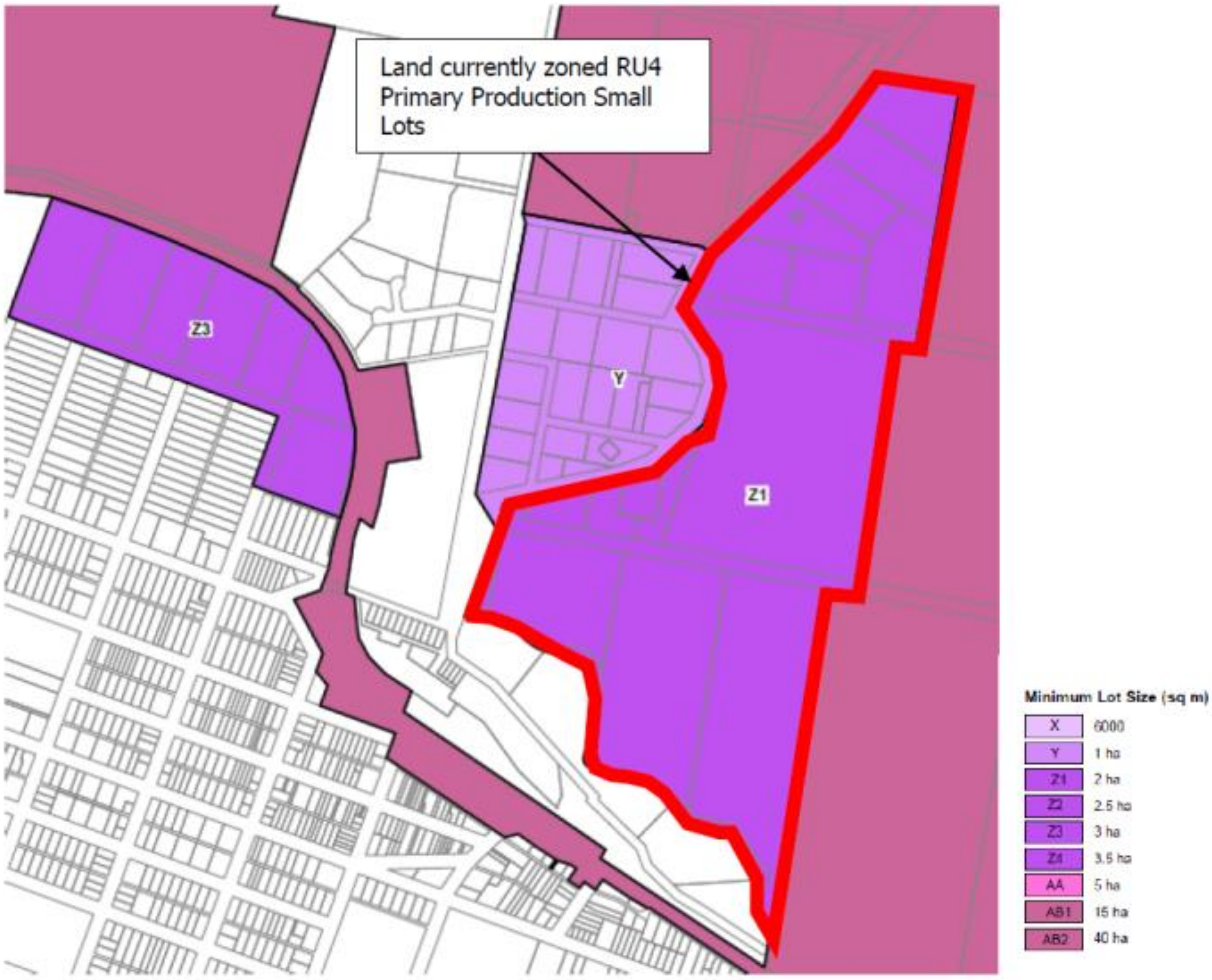


These areas do not generally have significant flood constraints that would affect the potential rezoning discussed in Reference 13 or 14. In particular, the areas marked “Aurville Large Lot Residential” and “Southern Large Lot Residential” are well situated with regards to flood risk for that type of residential development expansion, as are the proposed rural residential and mixed use zones.

The areas north of town are affected by flooding from Cunningham Plains Creek (as shown in more detail in Diagram 15). The area marked Z3 in Diagram 15 is bounded by Cunningham Plains Creek to the south, and the railway line to the north. Although a large proportion of the lots are on high ground above the PMF level, flooding could create access and isolation issues, even for relatively minor flood events. Construction of adequate access bridges to these lots could be a significant constraint requiring significant initial capital outlay ongoing maintenance expense. The LSPS identifies these areas as potential biodiversity corridor, which would also be appropriate.

The area marked Z1 on Diagram 15 (close to the Aurville Large Lot Residential Area) is not directly affected by flooding, but relies on the existing bridge at Aurville Road for access to town. As discussed in Section 5.4.4, Aurville Road is affected by flooding, and will become impassable in moderate flood events, possibly for several hours. The potential for isolation will need to be considered if development results in an increase in the population that is dependent on this access point. However it is noted that isolation periods would be relatively short (hours rather than days), and there is less hazardous egress via Gloaming Rd/Jellambi to Cunningar Road, and access to town back along Burley Griffin Way in case of emergency. These constraints are probably not significant enough or hazardous enough to restrict development of these areas, provided suitable education about driving through floodwater and provision of suitable signage at the crossing is provided.

Diagram 15: Potential Land-Use Zoning Modifications – RU1 North of Town (Reference 13)



RECOMMENDATIONS

No changes to the current land use zoning are recommended from a flood mitigation perspective. The current land use zones for the study area catchment comply with the current NSW standards.

Any future changes to the current land use zones must consider the potential flooding implications. The strategic land use zoning direction outlined in References 11 and 13 was reviewed and is generally not constrained by flooding considerations, apart from some areas on the northern side of town which may become isolated due to flooding, and where access to services could be constrained. Future rezoning decisions should take into account the flood risks outlined in this document and the Flood Study (Reference 1).

5.5.5. Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- uncertainty in estimating flood levels;
- differences in water level because of local factors; and
- potential changes due to climate change.

The FPL is used in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc.

DISCUSSION

The standard FPL for residential development as defined in the Manual is the 1% AEP event plus 500 mm freeboard. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example, in areas prone only to shallow overland flooding, application of the 500 mm freeboard can be excessive.

Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building / development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

According to the 2005 NSW Government Floodplain Development Manual (Reference 2) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL (Flood Planning Level) is actually provided given the following factors*:

- uncertainties in estimates of flood levels;
- differences in water level because of "local factors";
- increases due to wave action;
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change. This relates solely to rainfall increase which has not been accurately determined by the Intergovernmental Panel for Climate Change (IPCC).

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). For example, in a future flood 1% AEP event blockage (due to say fallen trees) may elevate the peak level just upstream. However, such an event would be considered as rarer than the 1% AEP as that type of blockage is an exception as it would not always occur in every flood.

There is no scientific reason for assuming a 0.5m allowance for freeboard. In some locations (say Windsor on the Hawkesbury River) it could be argued that a greater freeboard should be applied as the PMF is several metres above the 1% AEP, thus 0.5m represents only a relatively small increase in flood magnitude. At other locations a 0.5m increase above the 1% AEP may approach the PMF level and thus represents a very large increase in flood magnitude (this is particularly the case for overland flooding). Council could adopt varying freeboards across its LGA however this is likely to be confusing to manage by Council staff and it is difficult, if not impossible, to justify the criteria as to why one area should have a different freeboard to another. For simplicity a 0.5m freeboard is adopted by nearly all Councils in NSW for mainstream flooding. Some Councils adopt a smaller freeboard when the depths of inundation in urban areas, with no defined creeks or channels, are shallow (less than 0.3m).

RECOMMENDATIONS

The Floodplain Development Manual (Reference 2) recommended FPL of the 1% AEP event plus 0.5 m freeboard is considered appropriate for the study area for mainstream flooding. When drafting the DCP, Council should also consider the application of lower freeboard to set floor levels in overland flow areas (for example 0.3m). An example set of criteria for applying lower freeboard levels could be based on areas away from open watercourses or sag points in roads, where 1% AEP flow depths are less than 0.3 m. This consideration need not override the definition of the Flood Planning Area specified in the LEP.

5.5.6. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. A FPA map is a required outcome of the FRMS&P and the properties affected are termed flood control lots.

DISCUSSION

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus 500 mm freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may therefore be applied to development which is not flooded in a 1% AEP event.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

RECOMMENDATIONS

The FPA derived in this study (as per Section 6.1) is recommended for adoption at Murrumburrah-Harden.

5.5.7. Changes to Planning Policy

DESCRIPTION

Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- guide new development away from high flood risk locations;
- ensure that new development does not increase flood risk elsewhere; and
- develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Examination of existing risk throughout the study area indicates that managing this risk is problematic due to the very short warning times available. However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long term management of these areas and how this can be facilitated by planning tools. For example, high risk areas may need to be rezoned or have more stringent development controls applied to ensure areas of safe refuge onsite for shelter-in-place and flood compatible buildings.

DISCUSSION

There is currently no active Development Control Plan (DCP) for Murrumburrah-Harden, and no flood-related development control policy used by Hilltops Council. There is a need to prepare a DCP that provides guidance about implementation of specific controls to achieve the broader principles stated in the LEP. While there are currently separate LEPs for different areas of Hilltops Council, it is planned that a Council-wide LEP will be drafted in future, and it will be necessary to have an appropriate flood chapter in the DCP, or separate floodplain management policy, to accompany this LEP.

Council should address development in flood risk areas in a DCP, and provide matrices which apply varying degrees of restrictions to development based on the land use and flood risk. Applying stricter development controls in the more hazardous or frequently flooded areas has the potential to reduce the long term flood risk.

Of note is that the study area comprises both mainstream (relatively deep and fast flowing) and overland (generally shallow flow but can be fast flowing) flooding. Many Councils develop different or modified controls for these different flooding regimes. For example, with shallow depth inundation a 0.5m freeboard may be considered too severe if such a level is above the PMF.

Overland flow is also more affected by local structures, such as fencing, than mainstream flooding where generally the majority of flow follows a well-defined path. Consideration might be given to having development controls that address these local issues with new development applications. These considerations will need to extend to other flood-prone areas of the LGA.

Cumulative impacts of continued development and urban density intensification also needs to be considered in floodplain management. However this issue is of less relevance today than in the past as all new developments in the floodplain will be required to undertake a flood impact assessment. Thus all new developments (public and private) in the floodplain should be designed to have minimal (<10mm) impact on surrounding properties and there should be minimal cumulative flood impacts on downstream properties.

In urban areas with a short critical duration (say <2 hours) the safe evacuation of residents either before or during a flood is not possible and can present a greater risk than remaining in the house / building. Flooding in the overland flow parts of the study area may occur rapidly with no effective and reliable warning. Thus the flood is upon residents before they are aware of the problem (it could occur at night). All new buildings should therefore be designed to be structurally sound (certified by a structural engineer) during a flood up to 0.5m above the 1% AEP and with a floor at that level. Residents will therefore be able to shelter in place until the flood passes (<1 hour). In a life threatening emergency residents should call the SES or police for rescue rather than attempt to drive or walk through floodwaters.

RECOMMENDATIONS

Development of LEP and DCP flood development controls or a floodplain management policy is recommended as one of the higher priority measures in the Floodplain Risk Management Plan.

It is recommended that the LEP be based on the standard instrument clause, but with an additional provision to allow Council to identify land subject to flood planning controls based on available Flood Study information or risk considerations. For example, the Gosford LEP has a typical Flood Planning clause (7.2) applying to land below the “Flood Planning Area,” defined as the 1% AEP flood level plus 0.5m freeboard, but contains an additional clause as follows to address evacuation and emergency response (i.e. risks to life) up to the PMF. An example clause is provided below.

7.3 Floodplain risk management

(1) The objectives of this clause are as follows—

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) ***This clause applies to land between the flood planning level and the level of a probable maximum flood****,*

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land—

(a) caravan parks,
(b) correctional facilities,
(c) emergency services facilities,
(d) group homes,
(e) hospitals,
(f) residential care facilities,
(g) tourist and visitor accommodation,
(h) critical community infrastructure.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

The DCP will need to include mapping that identifies different controls applying to different area of land, based on some kind of classification of the flood risk. In other Council areas, this has commonly been implemented by adopting a High/Medium/Low flood risk precinct approach, typically based on high/low hazard categories for the 1% AEP event and the extent of the PMF. Some Council areas have frameworks based on hydraulic hazard, or flood function, or a combination of the above. The approach discussed in 6.2.2 combines the above considerations and is recommended for use unless there is a strong preference from Council staff for an alternative approach.

Council will need to determine the framework that provides a good balance between managing the particular flood risks of the LGA, without being overly complex or onerous such that it hinders implementation or becomes an unnecessary compliance burden.

Regardless of the framework adopted, it is likely that some additional processing of Councils existing flood information from other Flood Studies (such as Young, Boorowa, and Jugiong) will be required to obtain a consistent set of mapping across the LGA. Depending on the framework adopted, it is likely this processing can either be completed in-house by Council staff, or by engaging a flood consultant (costs for this processing estimated as less than $10,000).

5.5.8. S10.7 Certificate Notifications

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land.

Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

7A Flood related development controls information

(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.

(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.

(3) Words and expressions in this clause have the same meanings as in the standard instrument set out in the Standard Instrument (Local Environmental Plans) Order 2006.

Legal reviews of the effectiveness of s.10.7 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (i.e. the flood planning classification category) and also whether flooding applies generally to the area or more specifically to the land which is the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- the type of flooding;
- whether flooding is from major rivers or local overland flooding; and
- the extent of flooding (whether widespread or relatively confined).

It should be noted that the s.10.7 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in a s.10.7 (2) Planning Certificate, there is scope within a s.10.7 (5) Planning Certificate for providing this additional type of information.

Some Councils include detailed flooding information in s.10.7 (5) Planning Certificate as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.10.7 (5) Planning Certificates could include:

- flood levels / depths over the property;
- percentage of property which is flood affected;
- the likelihood of flooding;
- floor levels (from Council's floor level survey if available); and
- potential flood hazard.

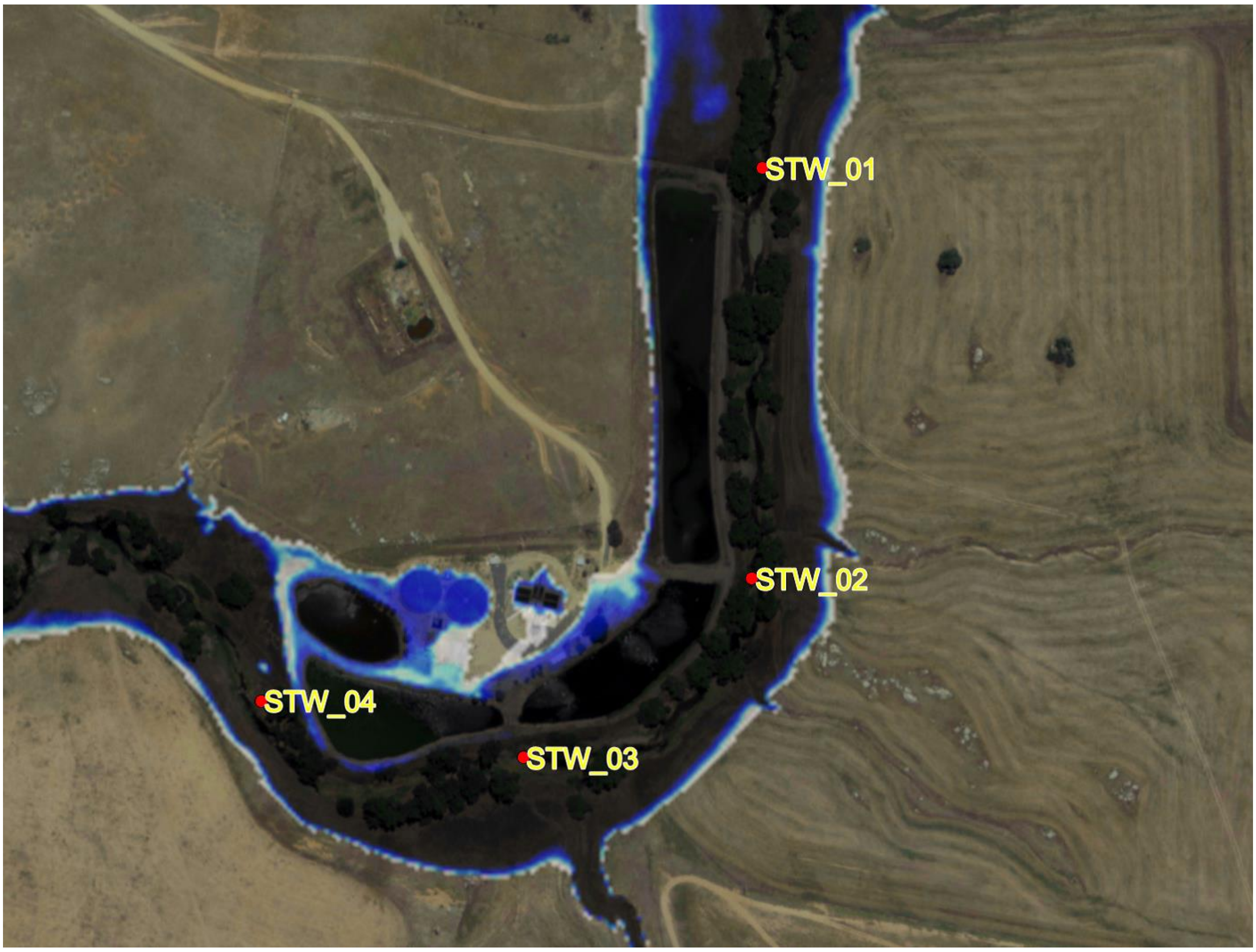
Council currently does not provide property-based flooding information on Council’s website which might benefit the community. More detailed information can only be obtained from Council.

RECOMMENDATIONS

Council should provide S.10.7(2) and (5) planning certificates containing relevant details about flood affectation. The statements of these certificates may need to be revised to reflect varying levels of availability of this information across the LGA.

5.5.9. Relocate Ponds at Sewage Treatment Works (PM03)

Diagram 16: Sewage Treatment Plant



Council has indicated that the storage ponds at the sewage treatment works (Diagram 16) have flooded in the past, resulting in environmental impacts. Council is investigating the feasibility of relocating some of the infrastructure in the plant. This may be feasible, as the ground levels rise reasonably quickly above the modelled flood levels at the site. However there will be limitations on what can be achieved as the treatment plant itself is likely to remain in place.

Figure 6 shows the flood extents for different AEPs at the plant. Table 14 shows the peak flood levels in the creek at the points indicated on Diagram 16.

Table 14: Peak Flood Levels at Sewage Treatment Plant

Location	Overtopping level (mAHD)	Peak Flood Level (mAHD)					
		5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
STW_01	366.3	367.3	367.8	368.3	368.6	368.9	379.5
STW_02	366.3	367.0	367.6	368.1	368.3	368.6	379.5
STW_03	366.3	366.7	367.3	367.7	367.9	368.1	378.8
STW_04	366.3	365.4	365.7	366.2	366.5	366.9	378.2

Diagram 17: Potential Sewage Treatment Plant Levee Alignment

The banks at the edges of the ponds along the creek are at a level of approximately 366.3 mAHD. This level is about 1.3 m below the 5% AEP level at the upstream end of the ponds, and 0.9 m above the 5% level at the downstream end. In all events modelled for this study, the ponds would be inundated. The floodplain is quite incised at this location, so the change in flood extent is relatively small from the 5% AEP to 0.2% AEP, despite variation in flood level of nearly 2 m.

A levee could potentially be constructed on the alignment shown in Diagram 17 by raising the edges of the ponds or constructing a wall. The profile of the levee could vary according to the profile of the flood levels in the creek. To achieve a 5% AEP protection level with 0.3 m freeboard, the upstream end of the levee would need to be at 367.6 mAHD (1.4 m above current bank height), and 365.7 mAHD at the downstream end (the existing bank is already 0.7 m above this level).

Figure A9, Figure A10 and Figure A11 show the impacts on peak flood levels from constructing a levee with a protection level of the 5% AEP, 2% AEP and 1% AEP events respectively. Figure A9 shows that attempting to protect to the 1% AEP design level would severely constrict the floodplain, resulting in major flood level increases of over 1 m, requiring a much higher levee that would cause even higher impacts. It is therefore considered unfeasible to build a 1% AEP levee at this location. However Figure A10 and Figure A11 indicate that a levee built to the 2% AEP or 5% AEP would potentially be feasible without causing widespread offsite changes in flood affectation.

RECOMMENDATIONS

It is recommended that Council further investigate whether changes to the ponds or construction of a higher levee bank to a 5% AEP or 2% AEP standard is a feasible and cost effective measure to mitigate flooding at the Sewage Treatment Works, taking into account other operational factors and available funding.

5.6. Flood Insurance

DESCRIPTION

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments, and spreads the costs over the wider community.

DISCUSSION

Insurance of any type is a way of managing risk. The insurance company collects the flood premiums in exchange for a fee, invests the money and return it when there is a claim. Thus flood insurance does not reduce the quantum of flood damages. Prior to the South East Queensland floods of January 2011 insurance companies had only sparse knowledge of flood liable areas but subsequently flood extent databases have been created covering all major urban areas and many rural areas in Australia. The amount of the flood insurance premium depends upon the flood risk. Thus in highly flood liable areas the annual flood premium can be several thousand dollars but in low risk areas it can be minimal.

It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an effective long term floodplain management measure as it does not reduce flood damages or risk to life.

RECOMMENDATIONS

No specific actions are recommended although individuals should be aware that there is a range of flood insurance products available for residential property, and that the available coverage varies significantly with different insurance providers.

6. ADVICE ON LAND-USE PLANNING

6.1. Flood Planning Area

6.1.1. Background

A key outcome of this study is the identification of land subject to flood-related development controls. The Harden Local Environment Plan 2011 (the LEP, Reference 7) is applicable under clause 6.5(2) to "land that is shown as "Flood Planning Area" on the Flood Planning Map, and other land at or below the Flood Planning Level [defined as the 1% AEP level plus 0.5m freeboard]. Land subject to this clause must usually be identified as such on Section 10.7 planning certificates.

The Flood Planning Area (FPA) is relatively straightforward to define for mainstream flooding. It is the extent formed by using the 1% AEP flood level plus 0.5 m freeboard, stretched outwards where required at the fringe of the floodplain. In mainstream flow areas, the creek banks usually rise by 0.5 m within a reasonably short distance of the 1% AEP flood extent, so the stretching process does not usually introduce major additional areas within the FPA. This method was found to be suitable for the majority of the Currawong Creek and Cunningham Plains Creek floodplains along the main channels.

Where overland flow is being modelled however, the "standard" FPA definition (1% plus 0.5 m) will tend to include lots that are not in fact flooded, sometimes even in the PMF, or those subject to only nuisance inundation. This will tend to apply even if a reduced freeboard (for example 0.3 m) is used. When defining the FPA for an overland flow area, a variety of criteria for defining the FPA are best examined initially. The purpose of this work is to seek a method, based on a quantitative and repeatable criteria, that consistently produces a FPA that best reflects those properties requiring management by way of 10.7 certificates in regard to flood related development controls. This is separate to standard stormwater design considerations that will apply to all developments, and which are assumed to manage drainage at an intra-lot scale for small catchment areas.

The state government does not provide a prescriptive methodology for defining the FPA. WMAwater developed an FPA for this study using techniques specific to the catchment area, based on consideration of the flow behaviour and testing of several methods. The methodology is documented below.

6.1.2. Methodology

There are a range of alternative approaches for deriving the FPA. One approach, which aims to retain consistency with the LEP definition, is to add 0.5 m freeboard to the peak water level outputs from the model, and attempt to "stretch" this surface across the terrain, to identify all the land below the Flood Planning Level. This technique generally works well for major creek and river channels, but not in overland flow areas. Another technique is to identify cadastral lots affected by flooding, including consideration of the 1% AEP and possibly a larger event as a surrogate for the freeboard allowance, then identify the entire lot as within the FPA. This is often an appropriate technique for overland flow areas, but has the disadvantage that there is not a clearly defined spatial extent within the lot for inclusion on planning maps.

For this study, the “add and stretch” technique was adopted, although with some modifications to filter out spurious results in overland flow areas. A summary of these steps is as follows:

1. The 1% AEP flood surface was filtered to remove areas of shallow depth (less than 150mm) or low conveyance (based on a depth-velocity product of less than 0.25 m^2/s). This filtering identifies the main creek and overland flow paths and reduces the issues associated with attempting to add freeboard and stretch in minor overland flow areas. Any areas identifies as floodway or flood storage were retained.
2. 0.5 m freeboard was added to the surface obtained from step 1, and the surface was extrapolated outwards, and cut off where it intersected with the terrain.
3. The result was trimmed to only include areas inundated in a short duration PMF event (15 minutes, depths greater than 0.1 m) to remove spurious results in overland flow areas.
4. Isolated patches not connected to the main FPA extent were reviewed to determine if they identified a significant flow path, and removed based on judgement if appropriate.

6.1.3. Flood Planning Area Mapping

The Flood Planning Area result obtained using the above methodology is mapped on Figure 7 (full study area) and Figure 8 (zoomed in on overland flow areas).

6.2. Land Use Planning Categorisation

The preparation of the flood chapter of the DCP, or flood management policy, will require consideration of how to categorise different areas of flood risk so that different planning controls can be applied. There are several methods of categorisation available. A possible method for this categorisation is provided below, although other methods such as relying purely on flood extents of different AEP, or flood hazard, are also adopted by various local governments in NSW.

6.2.1. Background

One of the primary objectives of the NSW Flood Prone Land Policy is to permit land use and development that is compatible with the nature of flooding in a particular area. For example, it is wise to limit use and development of land that is classified as floodway, since these are areas of conveyance and not only pose significant risks to humans, but any development in these areas can shift flood risks to other areas.

Under the auspices of the National Flood Risk Advisory Group (NFRAG) a series of guidelines have been developed to support national best practice in floodplain management. *The Technical Flood Risk Management Guideline: Flood information to support land use planning* (Reference 9) was developed to condense the complex flood mapping produced by a flood study into a simple series of planning constraint categories. This approach expands upon the historical use of simple flood planning levels to a consideration of flood evacuation and the flood function on different parts of the floodplain. The method allows strategic planners to make more holistically decision by identifying those locations that have might be above the simple planning level but have other large scale flood constraints that make them expensive to develop or have a significant increase in consequences in slightly larger events. Land use planning should consider the flood hazard, flood function, and evacuation potential (Figure D31 to Figure D34 in Appendix D of Reference 1) of the land.

This style of mapping provides information on how the level of constraints can vary across the floodplain allowing controls to be better targeted to the constraint. This mapping also identifies vulnerabilities and can help to suggest flood related development controls for residual flood risks in areas outside the FPA.

6.2.2. Flood Categorisation Methodology

The following range of flood map outputs were considered and combined to develop a Flood Planning Constraint Category Map for the study area:

- Flood Extents,
- Hydraulic Hazard,
- Flood Function,
- Flood Emergency Response Classifications for Communities, and
- Flood Planning Area.

The methodology adopted was to delineate the floodplain into four planning categories, consistent with the approach from the NFRAG guideline (Reference 9), adopting the 1% AEP as the defined flood event, and the 0.2% (1 in 500) AEP as the larger event. The definition for each FPCC category is provided below:

- FPCC1: Flow conveyance (floodway) and storage areas in the 1% AEP and H6 hazard areas in the 1% AEP. The majority of developments and uses have adverse impacts on flood behaviour. Consider limiting uses and development to those compatible with the flood behaviour. Development involving structures or fill in these areas is likely to produce adverse flood impacts in other areas.
- FPCC2: Flow conveyance (floodway) areas in the 0.2% AEP, H5 hazard category in the 1% AEP, H6 in the 0.2% AEP. Consider compatibility of developments and users with rare flood flows in the area. Many uses and developments will be vulnerable to flood hazard. Consider limiting new uses to those compatible with the flood hazard. Consider treatments to reduce the flood hazard which will not adversely affect flood behaviour. Consider evacuation difficulties.
- FPCC3: Outside FPCC2, but within the Flood Planning Area, and areas that are isolated by floodwaters. Hazardous conditions may exist creating issues for vehicles, people and buildings. Standard land-use and development controls aimed at reducing damage and exposure of the development to flooding in the 1% AEP are likely to be suitable. Consider the need for additional conditions for emergency response facilities, key community infrastructure and vulnerable users within these areas due to potential access difficulties.
- FPCC4: Outside FPCC3, but within the PMF extent. Consider the need for special development conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.

Areas identified as subject to isolation in the 1% AEP were included in the FPCC3 category. Although the guideline indicates these should generally be part of the FPCC2 category, in this instance the risks for these areas seem more consistent with FPCC3, in that they remain relatively flood free up to the PMF event, and the isolation would be of relatively short duration (in the order of a few hours). It is therefore appropriate that restrictions may need to be applied in these areas for emergency response facilities, key community infrastructure or vulnerable users.

The area designated FPCC2 is relatively small for this study area, and the approach could possibly be simplified by Combining FPCC1 and FPCC2 into a single category, depending on whether this is also suitable for other areas in the LGA.

Any changes in land use or new developments should be compatible with the nature of flooding in the area. The information contained in the flood study regarding the flood hazard, flood function and evacuation potential should be used in land use planning activities to ensure that proposed land uses do not increase the flood risk to people or property.

6.2.3. Land-Use Planning Category Mapping

The result obtained using the above methodology is mapped on Figure 9 (full study area) and Figure 10 (zoomed in on overland flow areas).

It is intended that this output should be reviewed to determine whether revisions to the approach are warranted to meet Council's requirements as part of adoption for flood planning in the DCP. This approach combines considerations of flood frequency, hydraulic hazard, flood function and isolation. It is recommended for use in identifying areas subject to varying degrees of development controls, unless there is a strong preference from Council staff for an alternative approach.

These categories and mapping can be used to comply with proposed changes under the 2020 NSW Flood Prone Land Package and the associated Section 10.7 planning certificate notification requirements (see Section 4.2.4).

6.3. Cumulative Development Assessment

An assessment was undertaken to identify whether cumulative development within the study area would be likely to produce changes in the flood risk over time, by changing the amount of runoff generated, or obstructing flow paths.

Council staff indicated the most likely source of development demand was new low density residential development on the outskirts of town, as well as extensions and redevelopment of existing properties within the existing residential area.

WMAwater investigated a scenario where the effective impervious area of the urbanised catchments was assumed to increase from 60% (assumption for current conditions in the flood study) to 90% to reflect this potential development. The changes in peak 1% AEP flood level are mapped on Figure 11. The cumulative effects of this change across the catchment would be relatively minor, with maximum flood level increases in the order of 0.1 m, and generally negligible across the catchment.

6.4. Climate Change

The sensitivity of the flood behaviour to climate change was investigated in the Flood Study (Reference 1).

Climate change is expected to increase short duration rainfall intensities and sea levels. Sea level rise will not affect flooding in the study area. The Bureau of Meteorology has indicated that there is no intention at present to revise design rainfalls to take account of the impact of climate change, as the implications of temperature changes on extreme rainfall intensities are presently unclear, and there is uncertainty about whether the changes would in fact increase runoff for major flood producing storms.

Any increase in design flood rainfall intensities will increase the frequency, depth and extent of inundation across the catchment. It has also been suggested that the cyclone belt may move further southwards.

Projected increases to evaporation are also an important consideration because increased evaporation would lead to generally drier catchment conditions, resulting in lower runoff from rainfall. Mean annual rainfall is projected to decrease, which will also result in generally drier catchment conditions. This is an important consideration for the Currawong Creek catchment where there are a relatively large number of farm dams that affect the amount of runoff that occurs through town. Under drier conditions, these dams will be less full on average when rain occurs, and a larger proportion of the initial rain will be collected in the dams. The calibration process indicated that the runoff estimates were highly sensitive to initial loss assumptions.

In light of the uncertainty, it is not recommended at this time that Council adopt a policy of assumed nominal increases to design rainfall/runoff resulting from climate change. However it will be necessary to monitor updates in climate science and advice from the Bureau of Meteorology. Periodic review should be undertaken to determine whether a formal climate change policy is required under Council's floodplain management sections of the Hilltops DCP.

7. INFORMATION TO SUPPORT EMERGENCY MANAGEMENT

Information requirements for emergency management purposes are outlined in the NSW state government guideline *SES requirements from the FRM Process* (Reference 8). There are specific inclusions listed for the Flood Study and Floodplain Risk Management Study phases.

Mapping and descriptions of flood behaviour were provided in the Flood Study report, including hazard mapping, emergency response classifications, and timing information about inundation of roads.

The SES operational response to flooding is typically guided by flood action cards, which indicate certain actions to be taken at certain river or creek flood levels (or warnings of those levels). The information requirements for the FRMS process are centred around providing information that can be used to prepare flood action cards, including referencing to the "Gauge Height" and the available time to respond to warnings.

The primary issues with providing this information for Murrumburrah-Harden are as follows:

- There is no stream gauge that the SES can monitor to determine the flood severity, or to which flood actions can be referenced.
- There is no pluviometer or alert rainfall gauge in the upper catchment that can provide a reliable proxy to indicate what rainfall has occurred in the catchment, and which could be linked to likely flood severity in town.
- There is no specific flood warning provided for the catchment. The only available flood warning under current arrangements would be general severe thunderstorm warnings issued for the region by the Bureau of Meteorology, and possibly Detailed Severe Thunderstorm Warnings identifying the likely path of major storms after they begin and are captured on radar. These warnings will provide no quantitative indication about the potential rainfall or flood event magnitude in the Currawong Creek catchment.
- The effective warning time for severe flooding is very short (within an hour or two of hours of intense rainfall occurring in the catchment).

Sensitivity about warning times can be analysed with the available modelling, but this analysis is inherently limited by the design storm burst approach that is used. In real storms, there is not a clear time at which the rainfall or flood event can be assumed to have started, and it may be impossible to distinguish between whether a storm is just typical heavy rain or a major flood producing event, given the lack of real-time data in the catchment. It is unlikely that pre-emptive flood response can be undertaken (such as evacuation or road closures) unless the community is willing to tolerate a large number of "false negative" events where the action is performed unnecessarily. The likely outcome of too many false negatives will be a lack of trust in the operational decisions, and unwillingness to comply when a major flood event does occur.

The feasibility of implementing additional flood warning infrastructure in the catchment is discussed in Section 5.4.1. The flood risk to life is relatively low in all events except the PMF, provided people avoid driving through floodwaters. Warning systems can have different levels of complexity and cost – however all require some level of ongoing cost to keep the system online, updated with correct information, and staffed by appropriate personnel. The costs for a catchment-specific warning system for Currawong Creek outweigh the benefits based on currently available technology, although that may change in the future with improved and cheaper flood warning platforms and instruments. Therefore, while additional flood warning infrastructure is not recommended presently, the availability and suitability of flood warning technology should be reviewed at regular intervals in the future.

8. ACKNOWLEDGEMENTS

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- Residents of Murrumburrah and Harden;
- Hilltops Council;
- NSW Department of Planning Industry and Environment;
- WaterNSW;
- Bureau of Meteorology; and
- State Emergency Services.

9. REFERENCES

1 WMAwater

Murrumburrah Flood Study
Hilltops Council, December 2019

2 **Floodplain Development Manual**

NSW Government, April 2005

3. Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)

Australian Rainfall and Runoff – A Guide to Flood Estimation
Commonwealth of Australia (Geoscience Australia), 2016
Datahub: http://data.arr-software.org/

4 Sinclair Knight & Partners

NSW Inland Rivers Flood Plain Management Study - Murrumbidgee Valley Summary Report 1987

5 The Harden Express and Central Southwest Advertiser

Murrumburrah Record Flood
February 1930

6 NSW Department of Environment and Climate Change

Floodplain Risk Management Guideline: Residential Flood Damages
May 2007

7 Hilltops Council
Harden Local Environment Plan
February 2011

8 NSW Government Department of Environment and Climate Change
SES Requirements from the FRM Process
October 2007

9 Australian Institute for Disaster Resilience
Guideline 7-5 Flood Information to Support Land-use Planning
Australian Disaster Resilience Handbook Collection, 2017

10 PSA Consulting
Hilltops Council Economic Growth and Land Use Strategy
Preliminary Findings Report
Hilltops Council, January 2019

11 PSA Consulting

Hilltops Council Economic Growth and Land Use Strategy
Strategic Directions and Recommendations Report
Hilltops Council, March 2019

12 Elton Consulting
Hilltops Rural and Residential Study
Hilltops Council, May 2019

13 PSA Consulting
Hilltops Freight and Transport Study
Hilltops Council, May 2019

14 Hilltops Council
Hilltops 2040 Local Strategic Planning Statement 2020-2040
June 2020

10. GLOSSARY

TERMINOLOGY OF FLOOD RISK

Australian Rainfall and Runoff (ARR, editors Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	20
	0.02	2	50	50
	0.01	1	100	100
Very Rare	0.005	0.5	200	200
	0.002	0.2	500	500
	0.001	0.1	1000	1000
	0.0005	0.05	2000	2000
Extreme	0.0002	0.02	5000	5000
			PMP/	
			PMPDF	

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% or 1 in 100 AEP event (sometimes referred to as a 100 year ARI), has a 1% chance of being equalled or exceeded in any year. ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events of 50% AEP or rarer and EY for all events more frequent than this.

GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area

	previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
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).
DRAINS	Stormwater Drainage System design and analysis program.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	

	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
LiDAR	Surveying method that measures distances via laser.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:
	$ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
	
	$ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
	
	$ major overland flow paths through developed areas outside of defined drainage reserves; and/or
	
	$ the potential to affect a number of buildings along the major flow path.

mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
RAFTS	Runoff routing model for hydrologic and hydraulic analysis of storm water drainage and conveyance systems.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	General runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
SOBEK	Integrated 1D/2D modelling suite for flood modelling, flood forecasting and optimisation of drainage systems.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
TUFLOW	One-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model).
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.

Figures

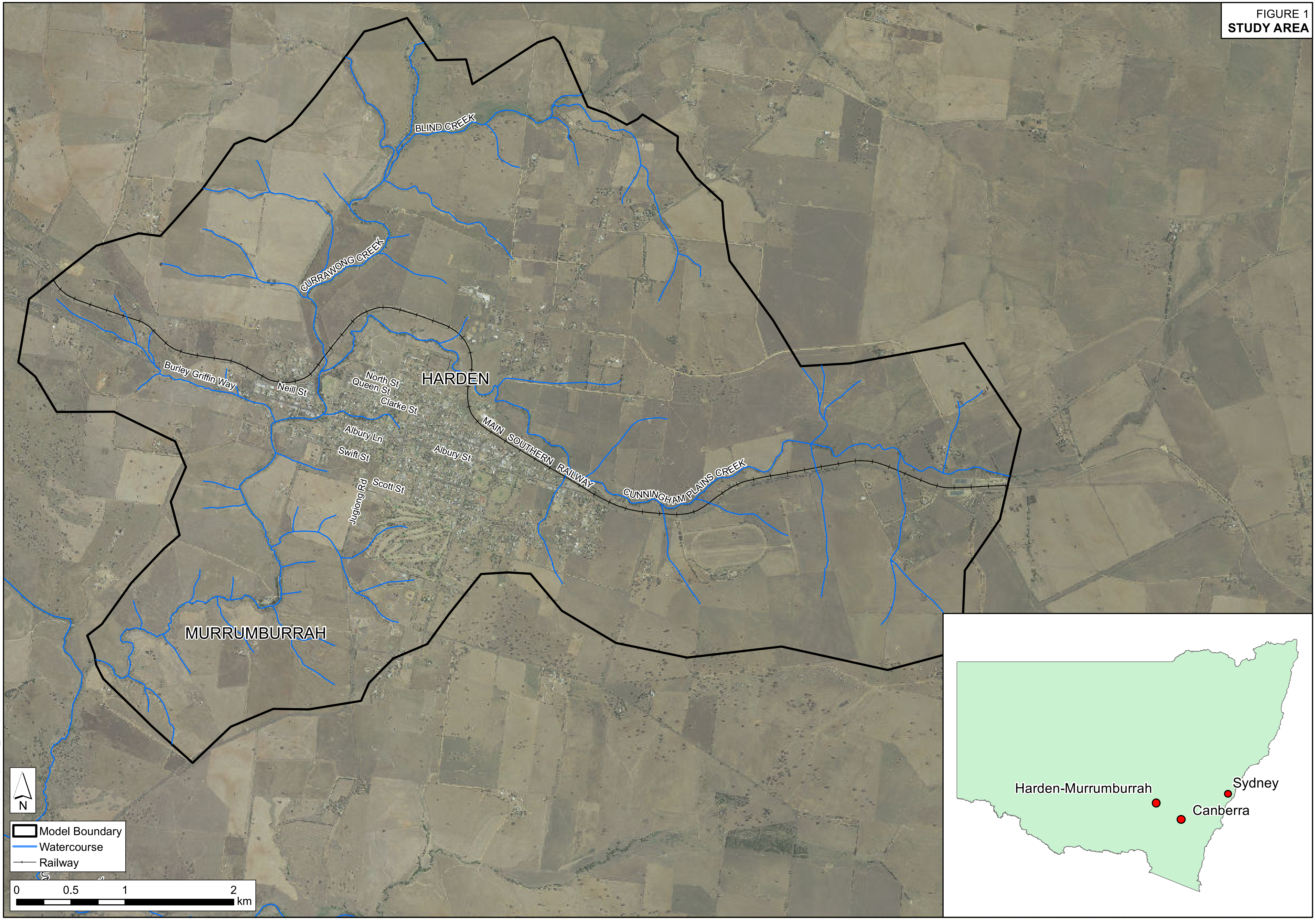
FIGURE 1
STUDY AREA
BLIND CREEK
CURRAWONG CREEK
HARDEN
MURRUMBURRAH
Burley Griffin Way
Neill St
North St
Queen St
Clarke St
Albury Ln
Albury St
Swift St
Scott St
Jugiong Rd
MAIN SOUTHERN RAILWAY
CUNNINGHAM PLAINS CREEK
N
Model Boundary
Watercourse
Railway
0
0.5
1
2
km
Harden-Murrumburrah
Sydney
Canberra
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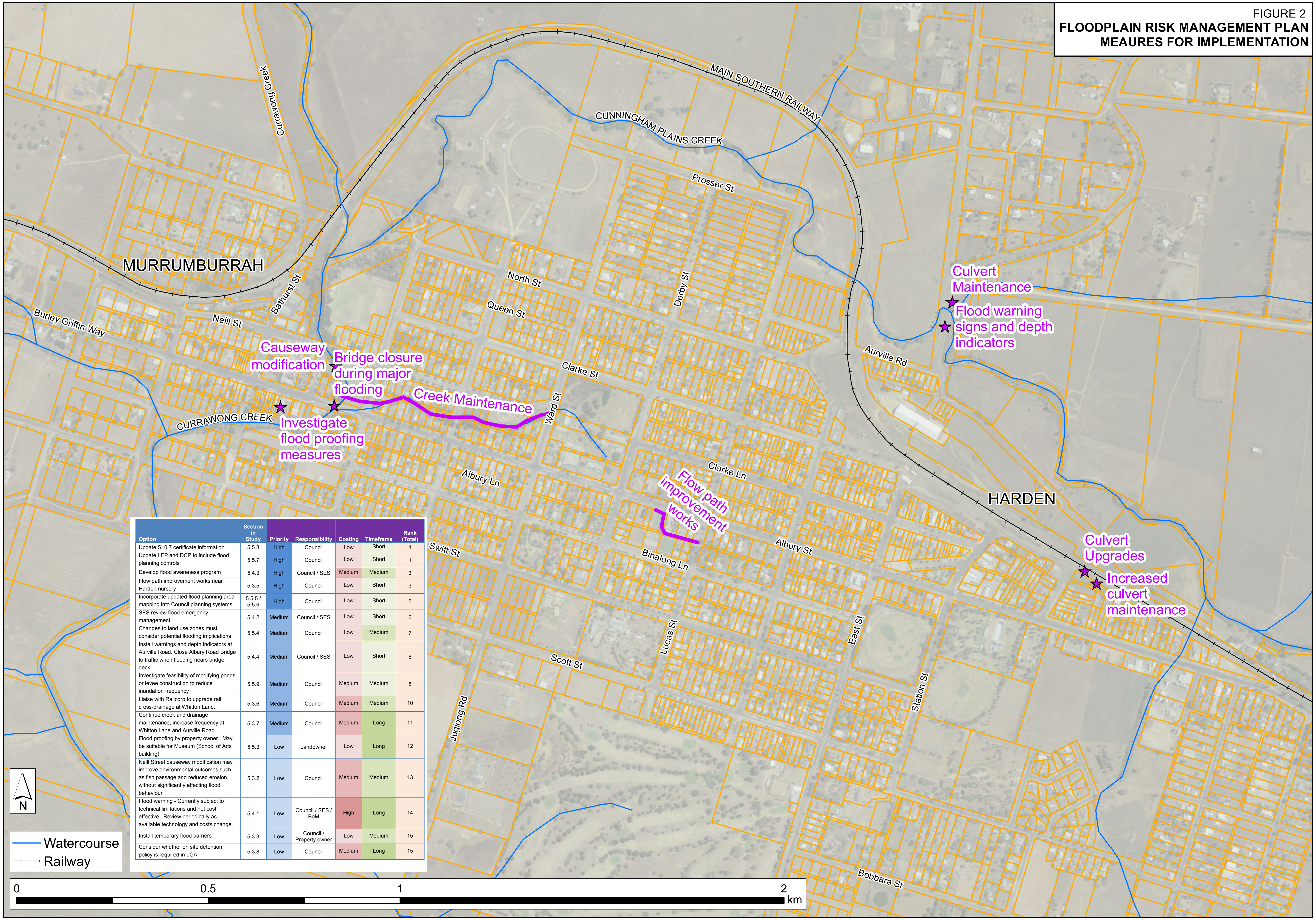
FIGURE 2

FLOODPLAIN RISK MANAGEMENT PLAN MEAURES FOR IMPLEMENTATION



Option	Section in Study	Priority	Responsibility	Costing	Timeframe	Rank (Total)
Update S10.7 certificate information	5.5.8	High	Council	Low	Short	1
Update LEP and DCP to include flood planning controls	5.5.7	High	Council	Low	Short	1
Develop flood awareness program	5.4.3	High	Council / SES	Medium	Medium	3
Flow path improvement works near Harden nursery	5.3.5	High	Council	Low	Short	3
Incorporate updated flood planning area mapping into Council planning systems	5.5.5 / 5.5.6	High	Council	Low	Short	5
SES review flood emergency management	5.4.2	Medium	Council / SES	Low	Short	6
Changes to land use zones must consider potential flooding implications	5.5.4	Medium	Council	Low	Medium	7
Install warnings and depth indicators at Aurville Road. Close Albury Road Bridge to traffic when flooding nears bridge deck.	5.4.4	Medium	Council / SES	Low	Short	8
Investigate feasibility of modifying ponds or levee construction to reduce inundation frequency	5.5.9	Medium	Council	Medium	Medium	8
Liaise with Railcorp to upgrade rail cross-drainage at Whitton Lane.	5.3.6	Medium	Council	Medium	Medium	10
Continue creek and drainage maintenance, increase frequency at Whitton Lane and Aurville Road	5.3.7	Medium	Council	Medium	Long	11
Flood proofing by property owner. May be suitable for Museum (School of Arts building)	5.5.3	Low	Landowner	Low	Long	12
Neill Street causeway modification may improve environmental outcomes such as fish passage and reduced erosion, without significantly affecting flood behaviour	5.3.2	Low	Council	Medium	Medium	13
Flood warning - Currently subject to technical limitations and not cost effective. Review periodically as available technology and costs change.	5.4.1	Low	Council / SES / BoM	High	Long	14
Install temporary flood barriers	5.3.3	Low	Council / Property owner	Low	Medium	15
Consider whether on site detention policy is required in LGA	5.3.8	Low	Council	Medium	Long	15

FIGURE 3
AVAILABLE SURVEY DATA

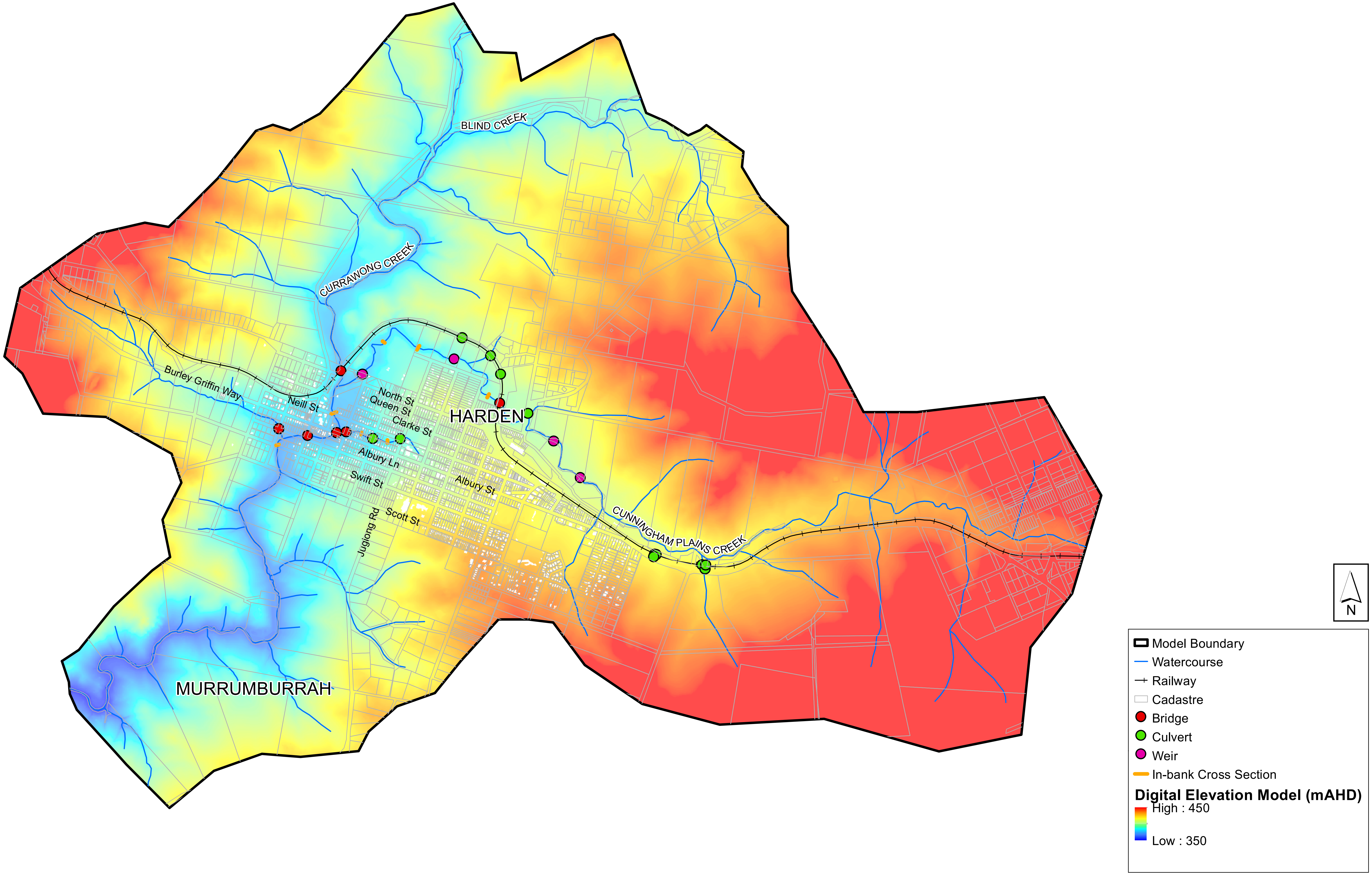


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FIGURE 4
FIRST EVENT INUNDATED
MAIN SOUTHERN RAILWAY
CUNNINGHAM PLAINS CREEK
Currawong Creek
Prosser St
North St
Queen St
Derby St
Bathurst St
Neill St
Burley Griffin Way
Clarke St
Aurville Rd
Ward St
HARDEN
CURRAWONG CREEK
Clarke Ln
Albury Ln
Albury St
Swift St
Binalong Ln
Lucas St
East St
Scott St
Station St
Jugiong Rd
MURRUMBURRAH
Bobbara St
Harden-Murrumburrah
Canberra
N
Model Boundary
Watercourse
Railway
Design Flood Event for which property is first flooded above floor
20% AEP
10% AEP
5% AEP
2% AEP
1% AEP
0.5% AEP
0.2% AEP
PMF
Not Flooded
0
0.25
0.5
1
km
J:\Jobs\118099\ArcMaps\FRMS\Figure04_First_Event_Inundated.mxd

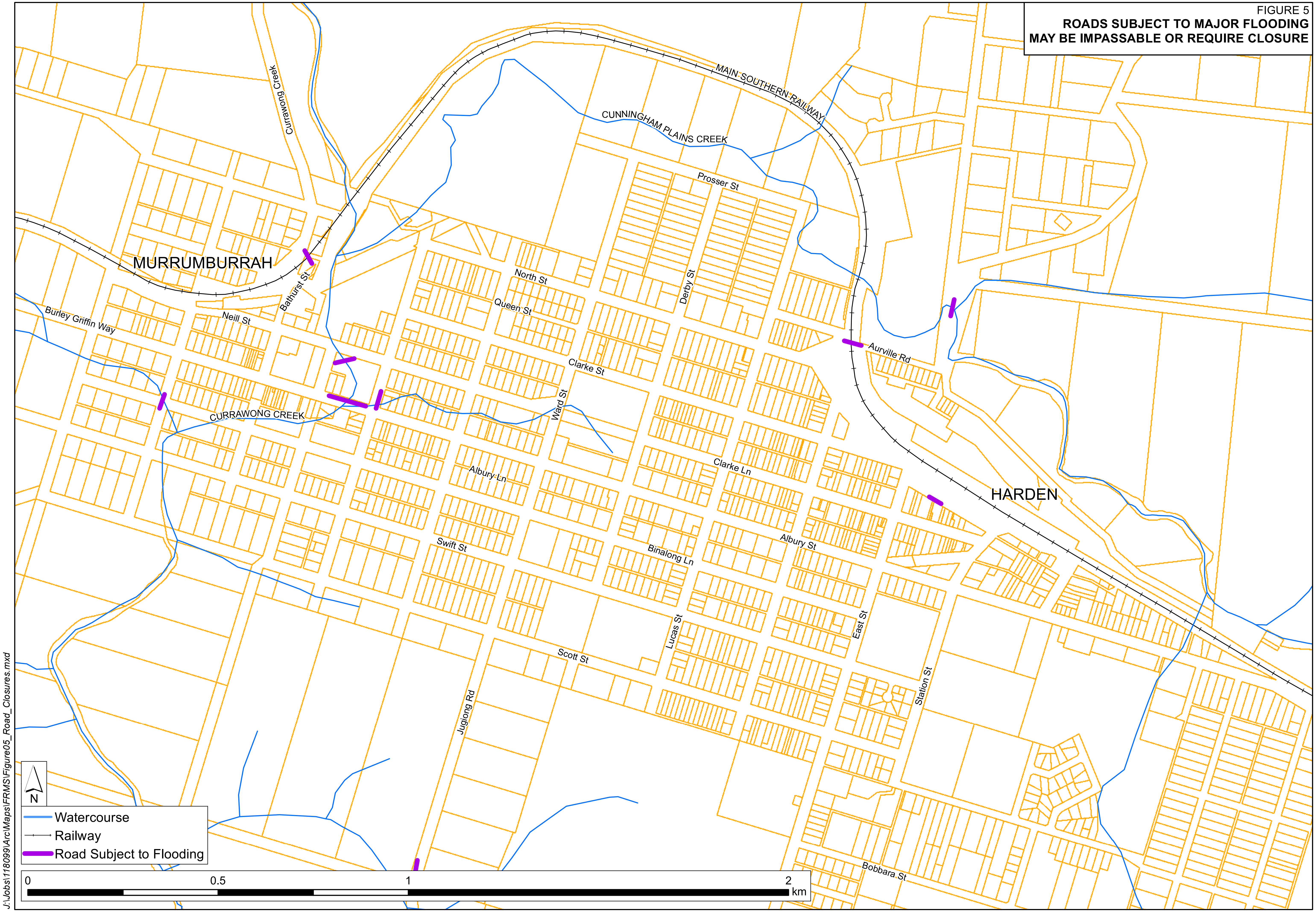
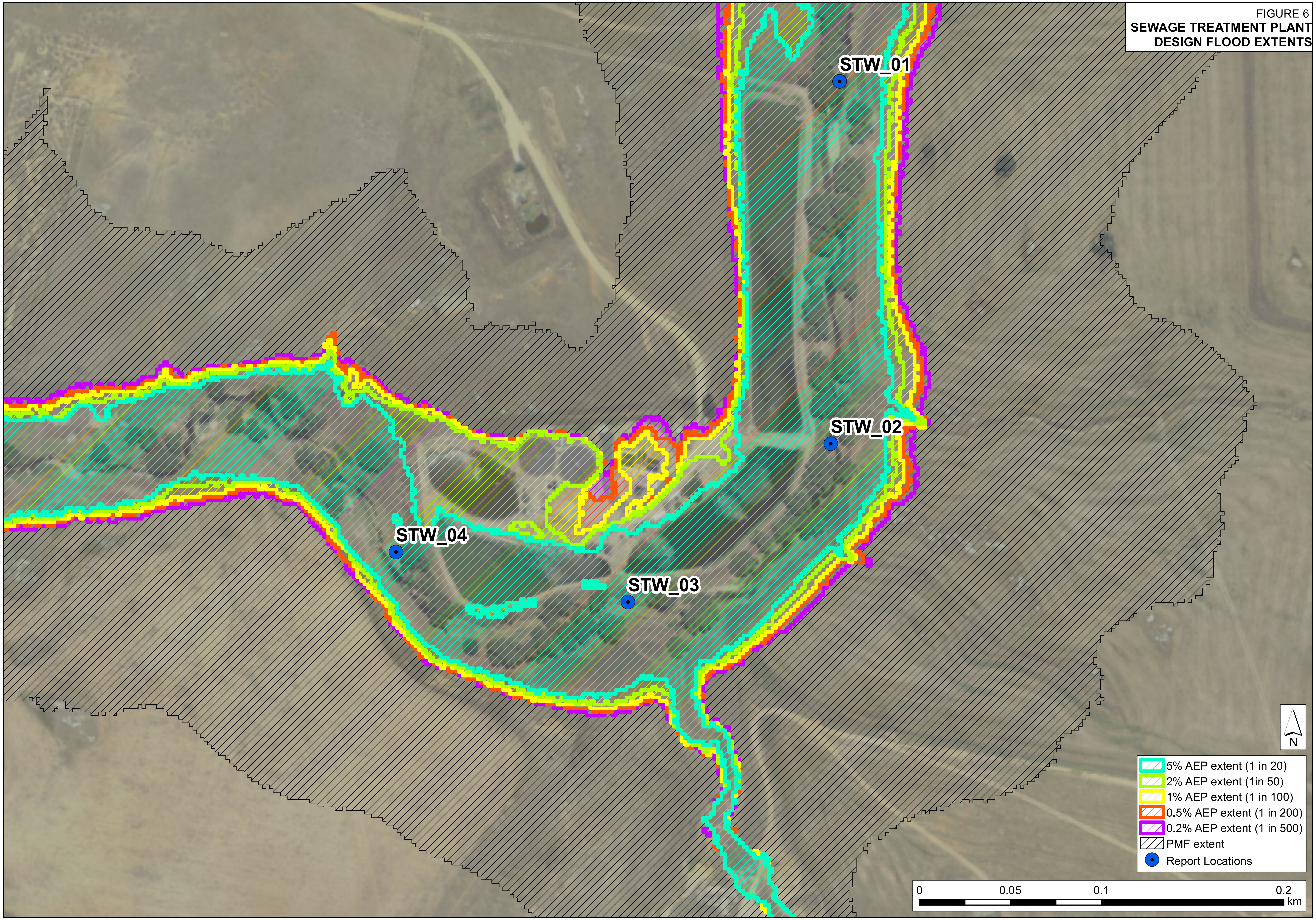


FIGURE 5
ROADS SUBJECT TO MAJOR FLOODING
MAY BE IMPASSABLE OR REQUIRE CLOSURE
MAIN SOUTHERN RAILWAY
CUNNINGHAM PLAINS CREEK
Currawong Creek
Prosser St
MURRUMBURRAH
North St
Queen St
Derby St
Bathurst St
Neill St
Burley Griffin Way
Aurville Rd
Clarke St
Ward St
CURRAWONG CREEK
Clarke Ln
Albury Ln
HARDEN
Albury St
Swift St
Binalong Ln
East St
Lucas St
Scott St
Station St
Jugiong Rd
Bobbara St
N
Watercourse
Railway
Road Subject to Flooding
0
0.5
1
2
km
J:\Jobs\118099\ArcMaps\FRMS\Figure05_Road_Closures.mxd

FIGURE 6
SEWAGE TREATMENT PLANT DESIGN FLOOD EXTENTS



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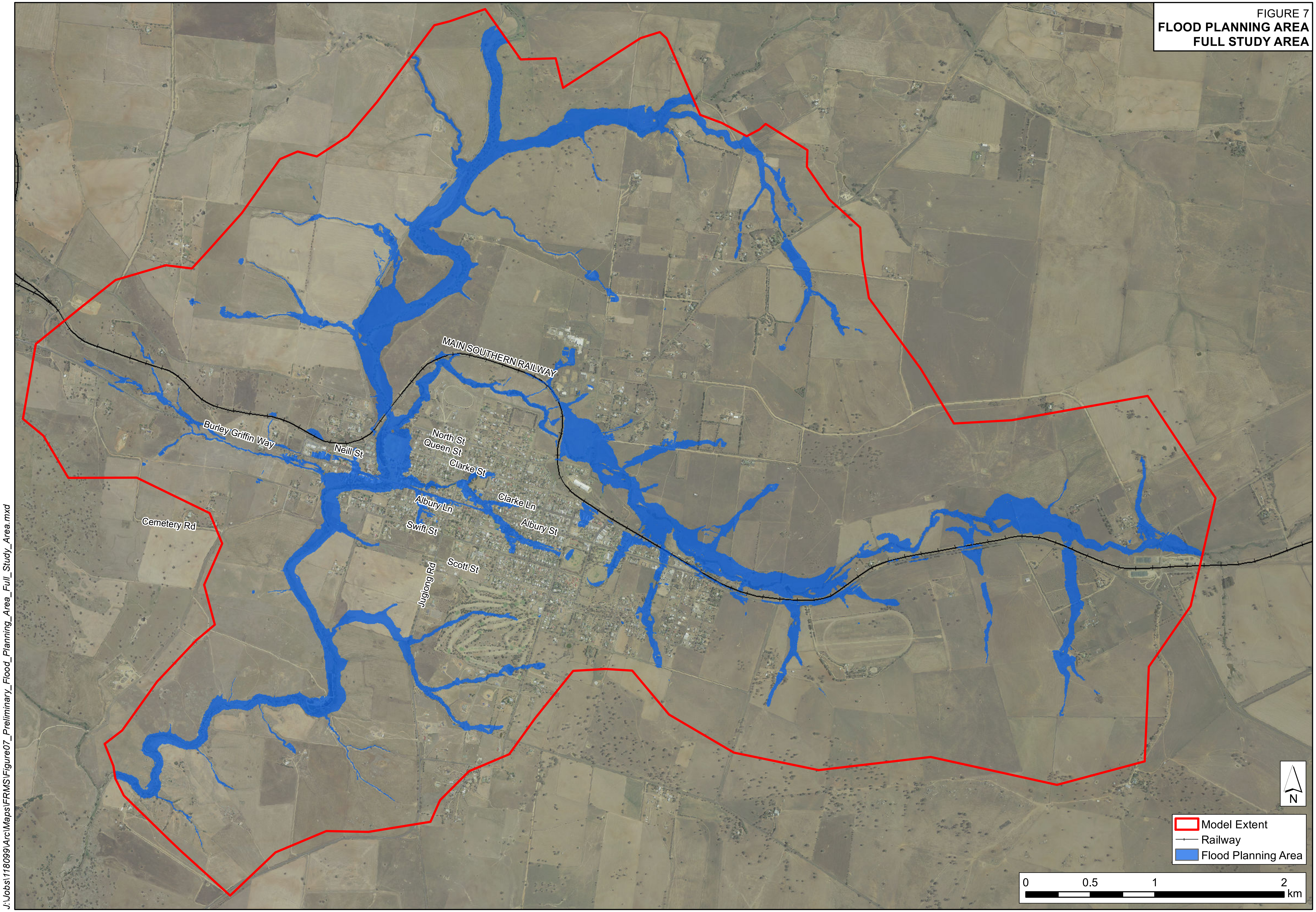
FIGURE 7
FLOOD PLANNING AREA
FULL STUDY AREA
MAIN SOUTHERN RAILWAY
Burley Griffin Way
Neill St
North St
Queen St
Clarke St
Clarke Ln
Albury Ln
Albury St
Swift St
Scott St
Jugiong Rd
Cemetery Rd
N
Model Extent
Railway
Flood Planning Area
0
0.5
1
2
km
J:\Jobs\118099\ArcMaps\FRMS\Figure07_Preliminary_Flood_Planning_Area_Full_Study_Area.mxd


FIGURE 8
FLOOD PLANNING AREA
OVERLAND FLOW AREAS
MAIN SOUTHERN RAILWAY
Currawong Creek
Prosser St
North St
Queen St
Derby St
Bathurst St
Neill St
Burley Griffin Way
Clarke St
Ward St
Aurville Rd
Clarke Ln
Albury Ln
Albury St
Swift St
Binalong Ln
East St
Lucas St
Scott St
Station St
Jugiong Rd
N
Model Extent
Railway
Flood Planning Area
0
0.125
0.25
0.5
km
J:\Jobs\118099\ArcMaps\FRMS\Figure08_Preliminary_Flood_Planning_Area_Overland_Flow_Areas.mxd

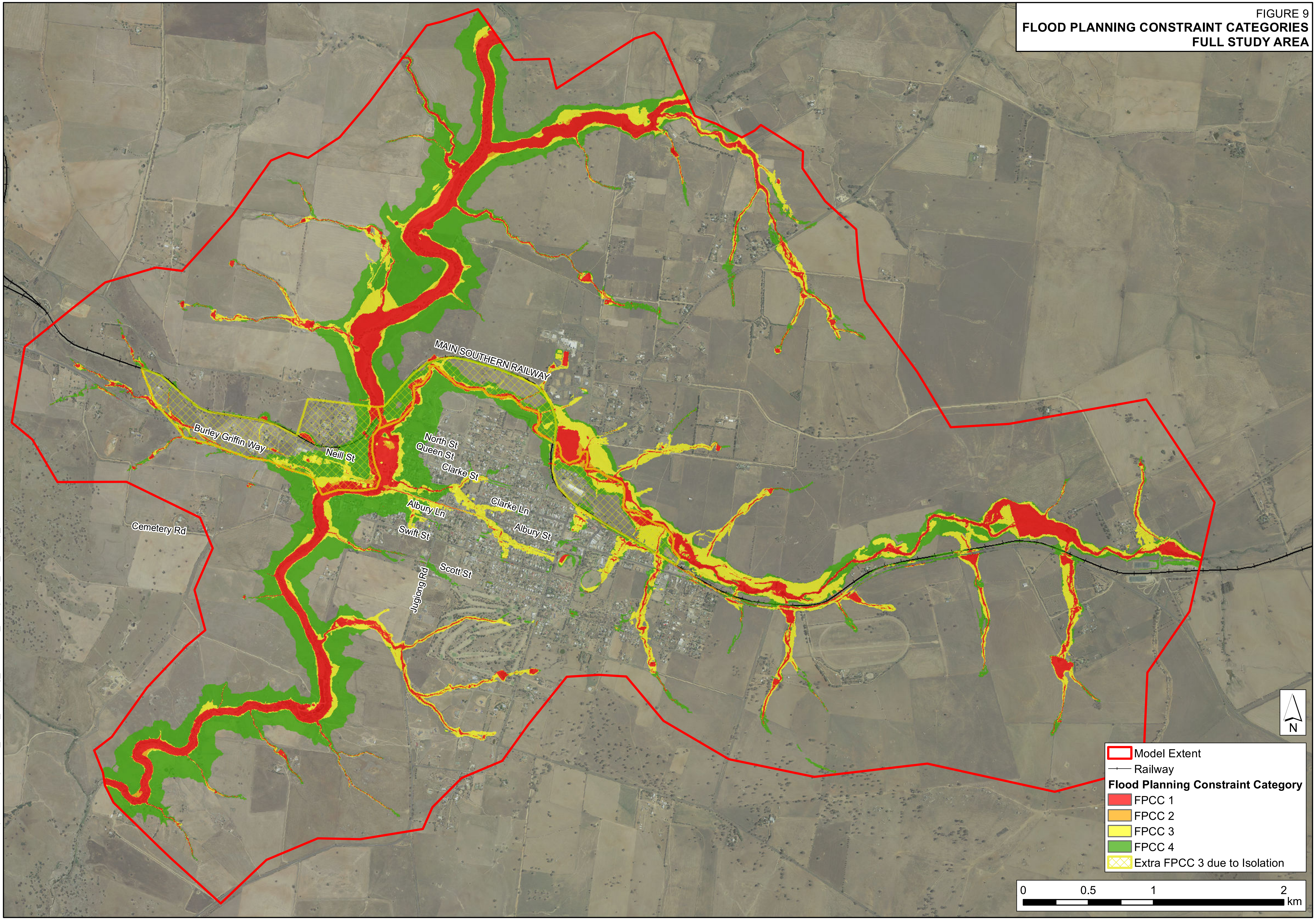
FIGURE 9
FLOOD PLANNING CONSTRAINT CATEGORIES
FULL STUDY AREA
MAIN SOUTHERN RAILWAY
Burley Griffin Way
Neill St
North St
Queen St
Clarke St
Clarke Ln
Albury Ln
Albury St
Swift St
Scott St
Jugiong Rd
Cemetery Rd
N
Model Extent
Railway
Flood Planning Constraint Category
FPCC 1
FPCC 2
FPCC 3
FPCC 4
Extra FPCC 3 due to Isolation
0
0.5
1
2
km
J:\Jobs\118099\Arc\Maps\FRMS\Figure09_Flood_Planning_Constraint_Categories_Full_Study_Area.mxd

FIGURE 10
FLOOD PLANNING CONSTRAINT CATEGORIES
OVERLAND FLOW AREAS

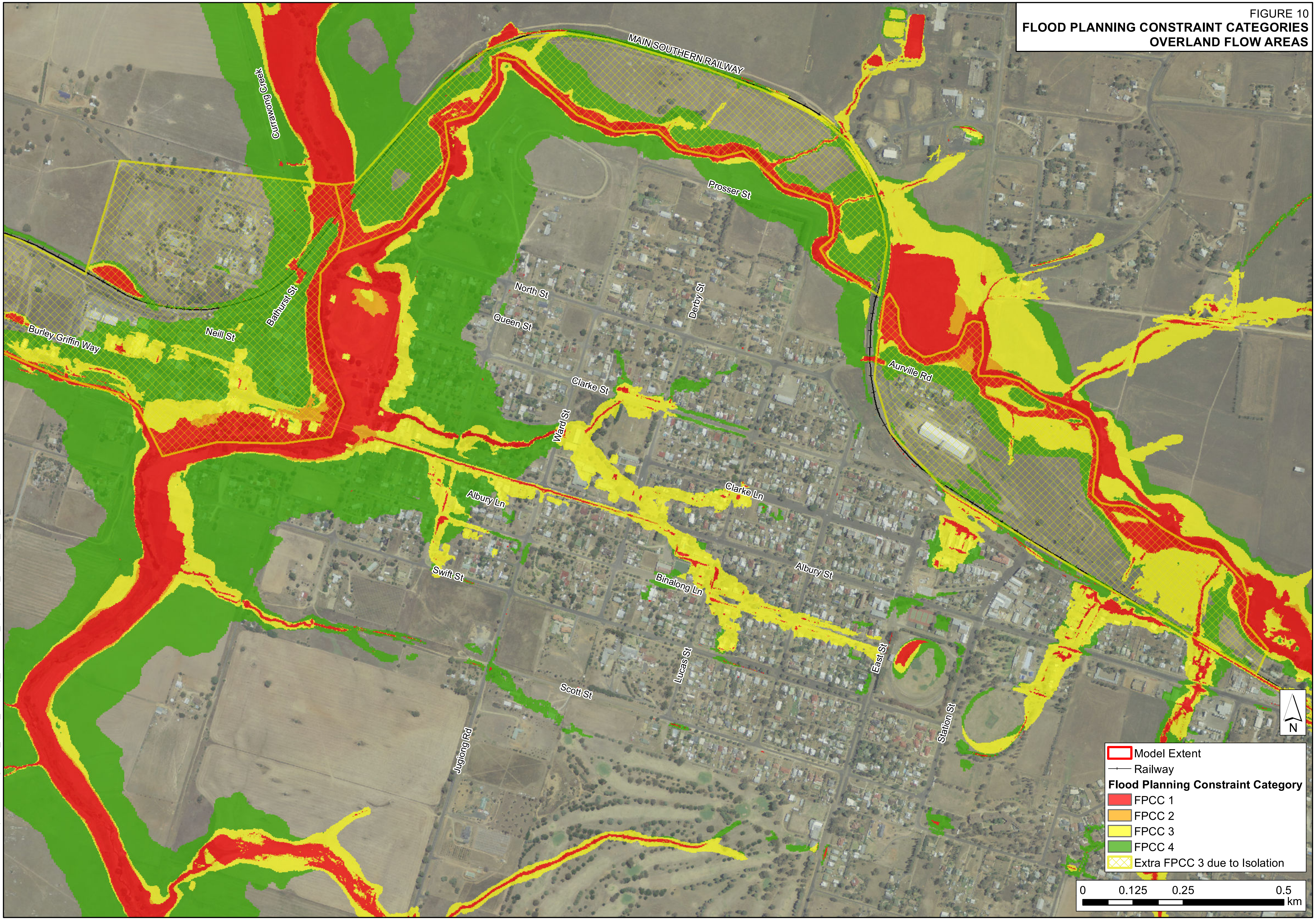

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FIGURE 11
CUMULATIVE IMPACTS ASSESSMENT
1% AEP CHANGE IN PEAK FLOOD LEVEL

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Appendix A

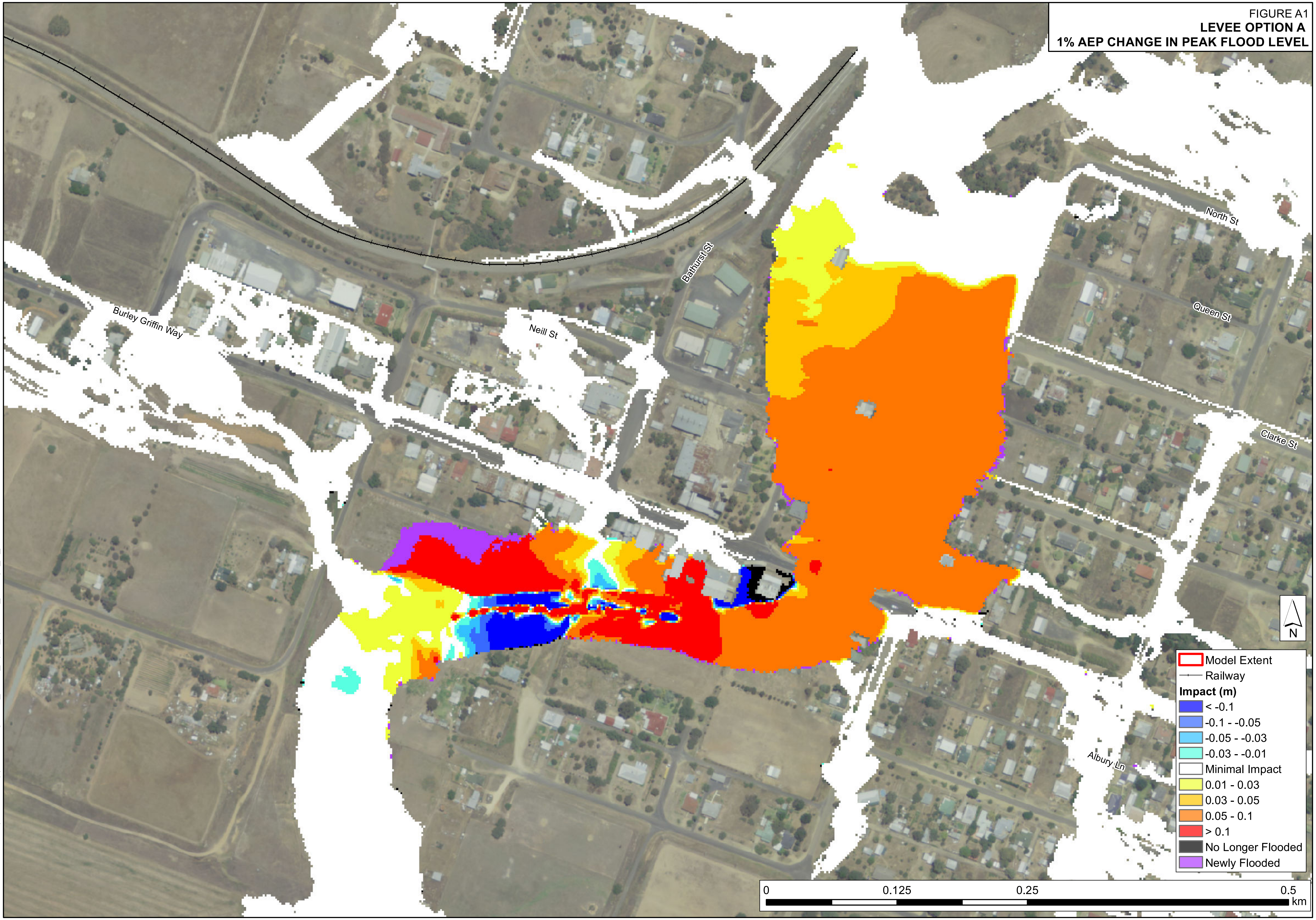
FIGURE A1
LEVEE OPTION A
1% AEP CHANGE IN PEAK FLOOD LEVEL
North St
Queen St
Clarke St
Bathurst St
Burley Griffin Way
Neill St
Albury Ln
N
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
0
0.125
0.25
0.5
km
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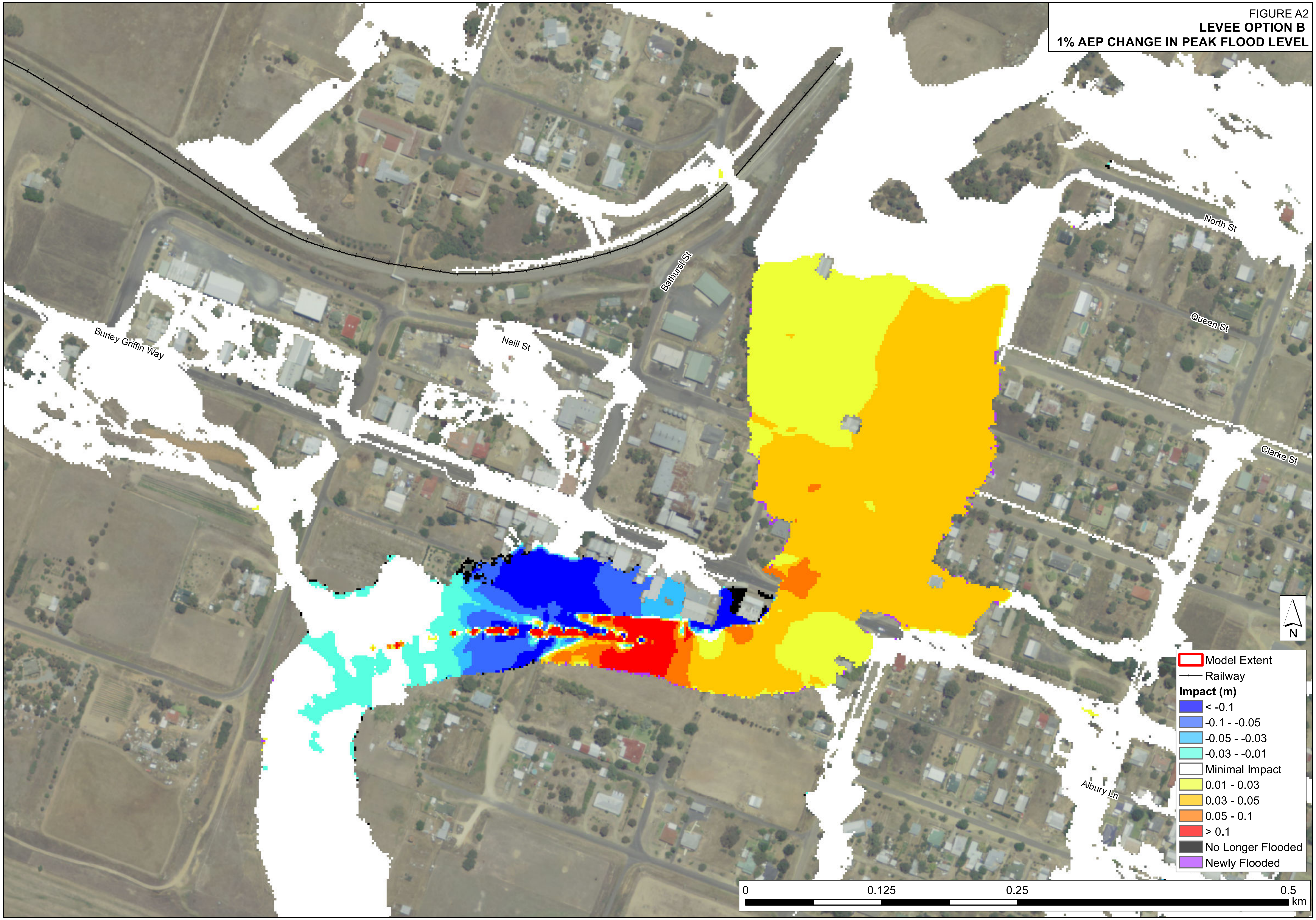
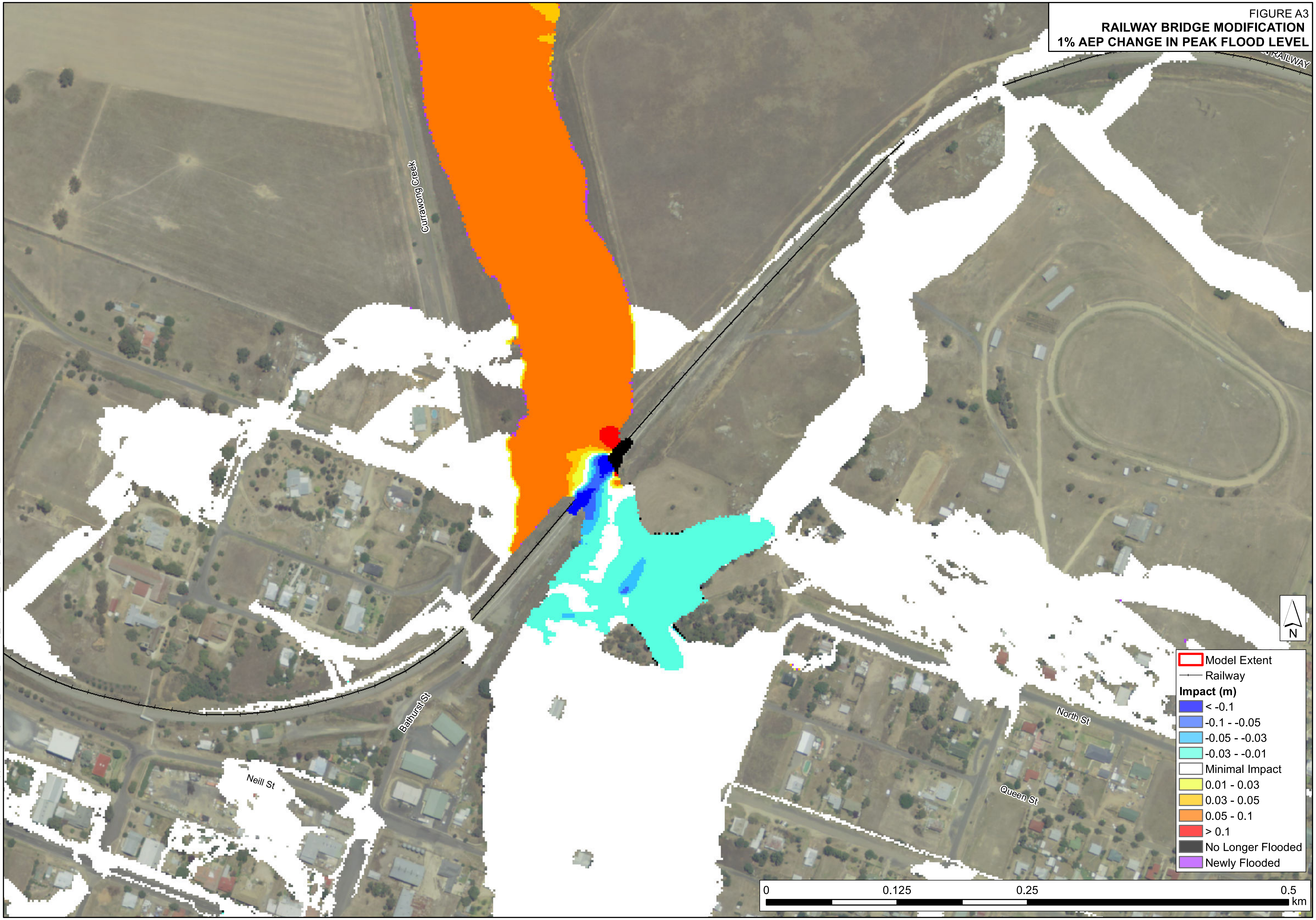


FIGURE A2
LEVEE OPTION B
1% AEP CHANGE IN PEAK FLOOD LEVEL
North St
Queen St
Clarke St
Bathurst St
Neill St
Burley Griffin Way
Albury Ln
N
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
0
0.125
0.25
0.5
km
J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA2_FM01_OptB_1pctAEP_Change_in_PeakFloodLevel.mxd

FIGURE A3
RAILWAY BRIDGE MODIFICATION
1% AEP CHANGE IN PEAK FLOOD LEVEL



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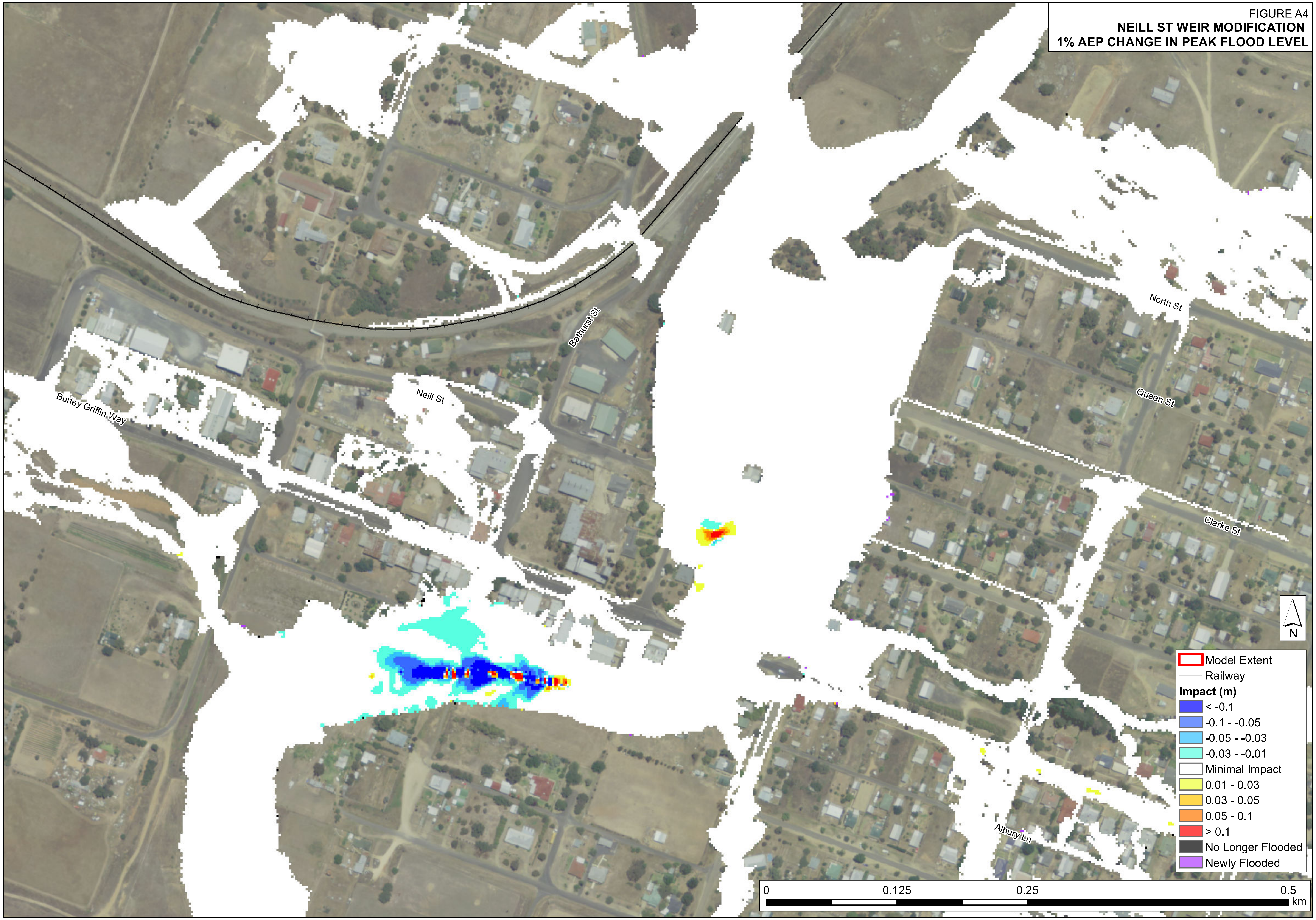


FIGURE A4
NEILL ST WEIR MODIFICATION
1% AEP CHANGE IN PEAK FLOOD LEVEL
North St
Queen St
Clarke St
Bathurst St
Neill St
Burley Griffin Way
Albury Ln
N
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
0
0.125
0.25
0.5
km
J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA4_FM08_NeillSt_1pctAEP_Change_in_PeakFloodLevel.mxd

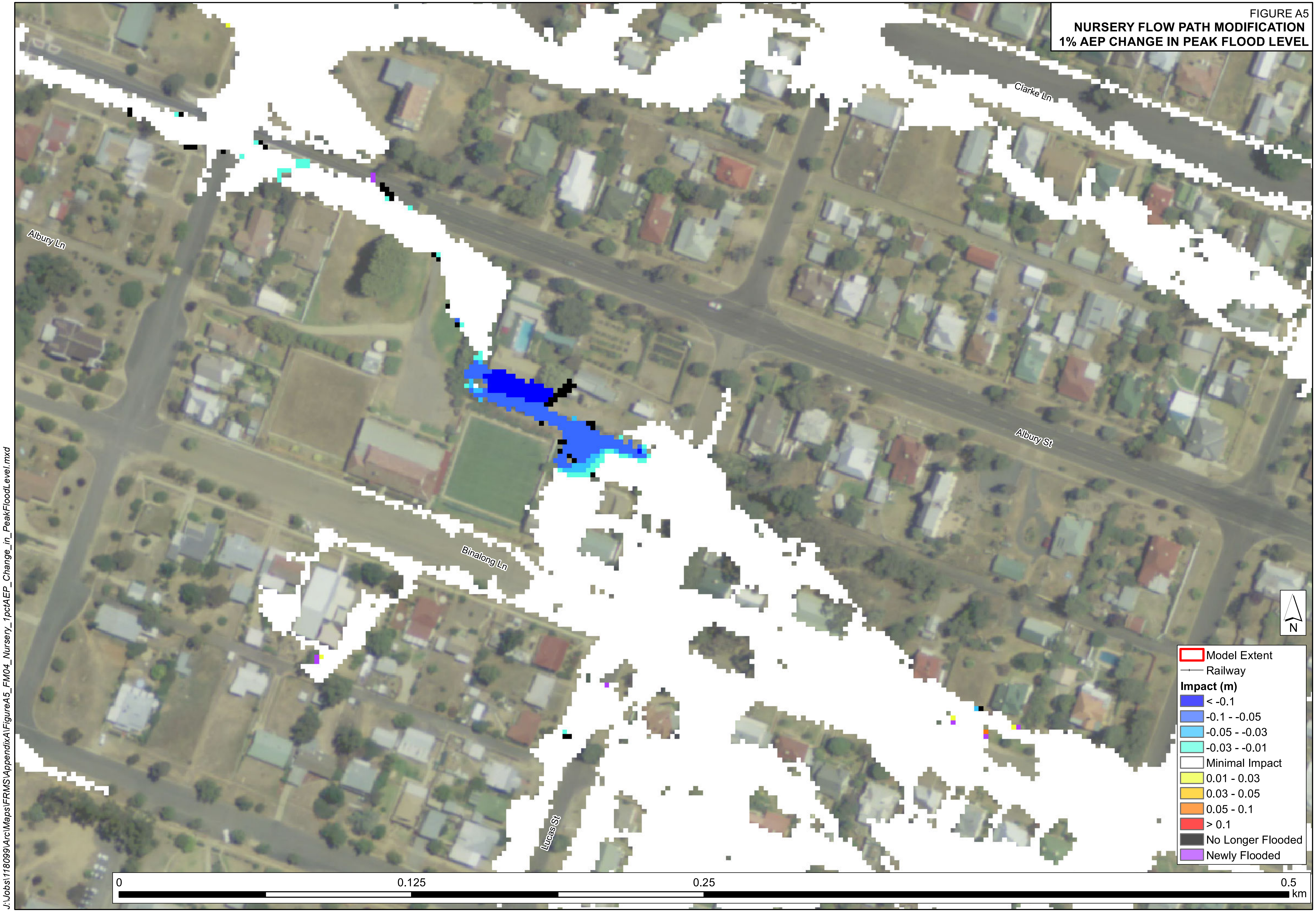
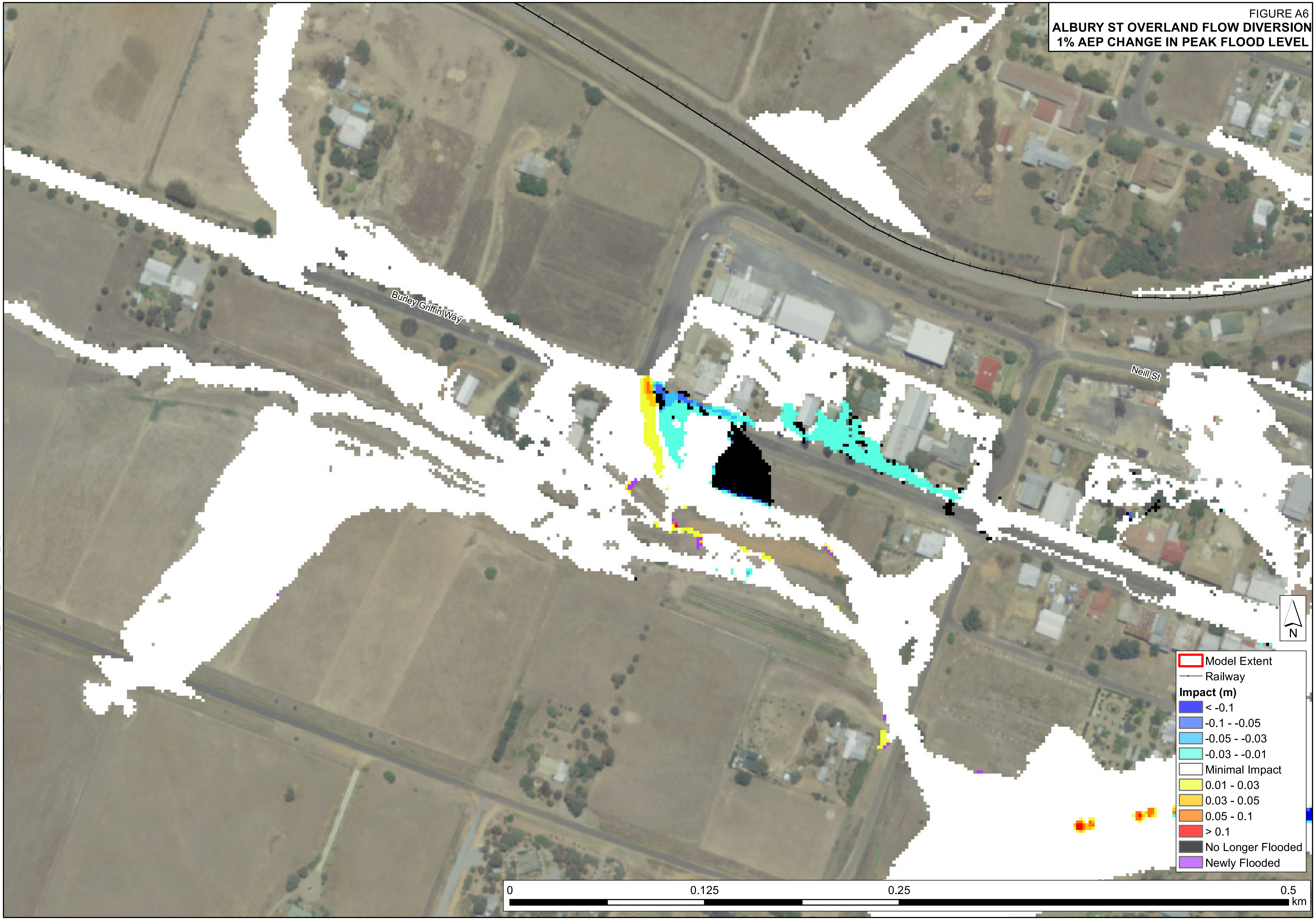


FIGURE A5
NURSERY FLOW PATH MODIFICATION
1% AEP CHANGE IN PEAK FLOOD LEVEL
Clarke Ln
Albury Ln
Albury St
Binalong Ln
Lucas St
N
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
0
0.125
0.25
0.5
km
J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA5_FM04_Nursery_1pctAEP_Change_in_PeakFloodLevel.mxd



J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA6_FM05_AlburySt_1pctAEP_Change_in_PeakFloodLevel.mxd

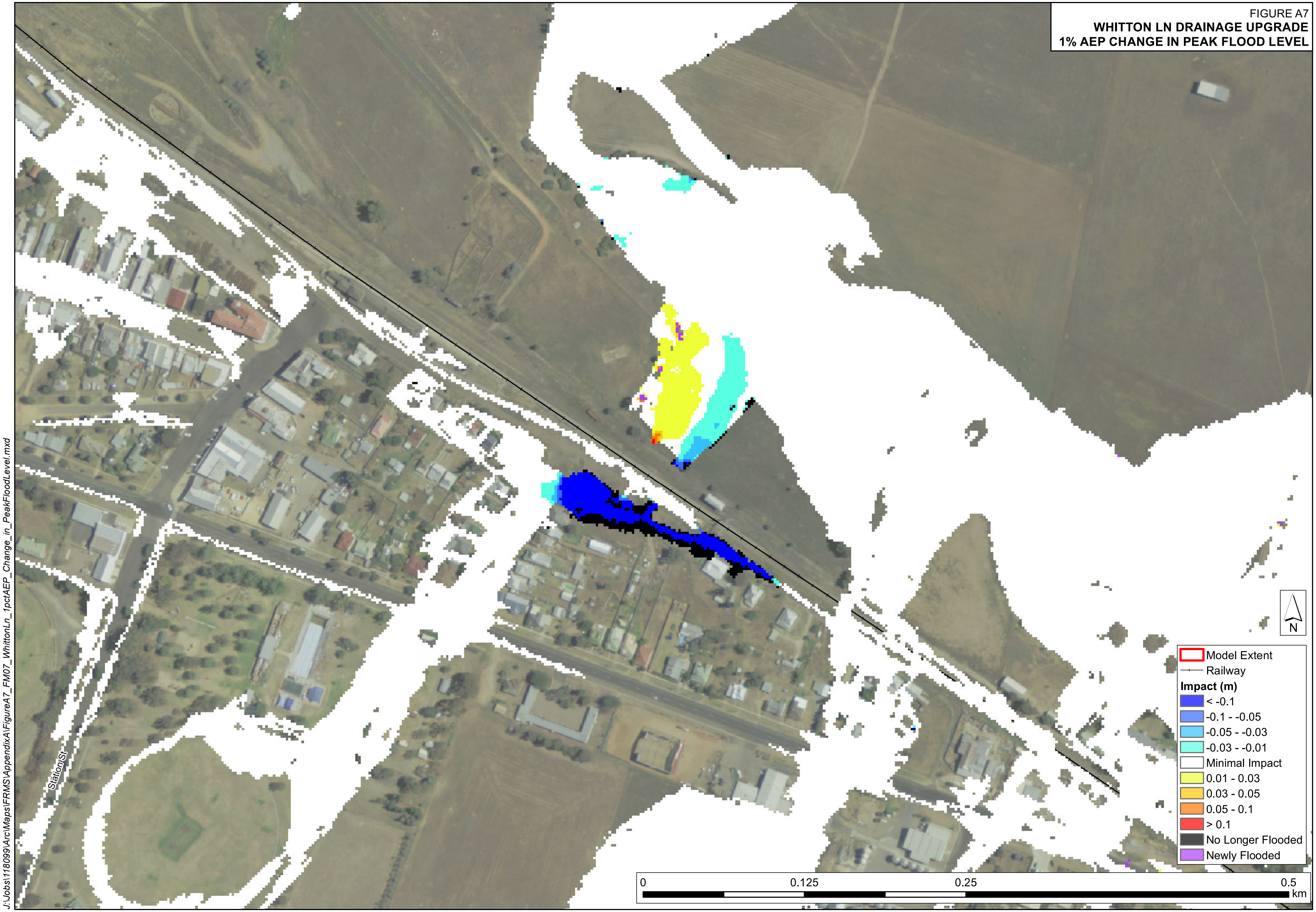


FIGURE A7
WHITTON LN DRAINAGE UPGRADE
1% AEP CHANGE IN PEAK FLOOD LEVEL
Station St
N
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
0
0.125
0.25
0.5
km
J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA7_FM07_WhittonLn_1pctAEP_Change_in_PeakFloodLevel.mxd

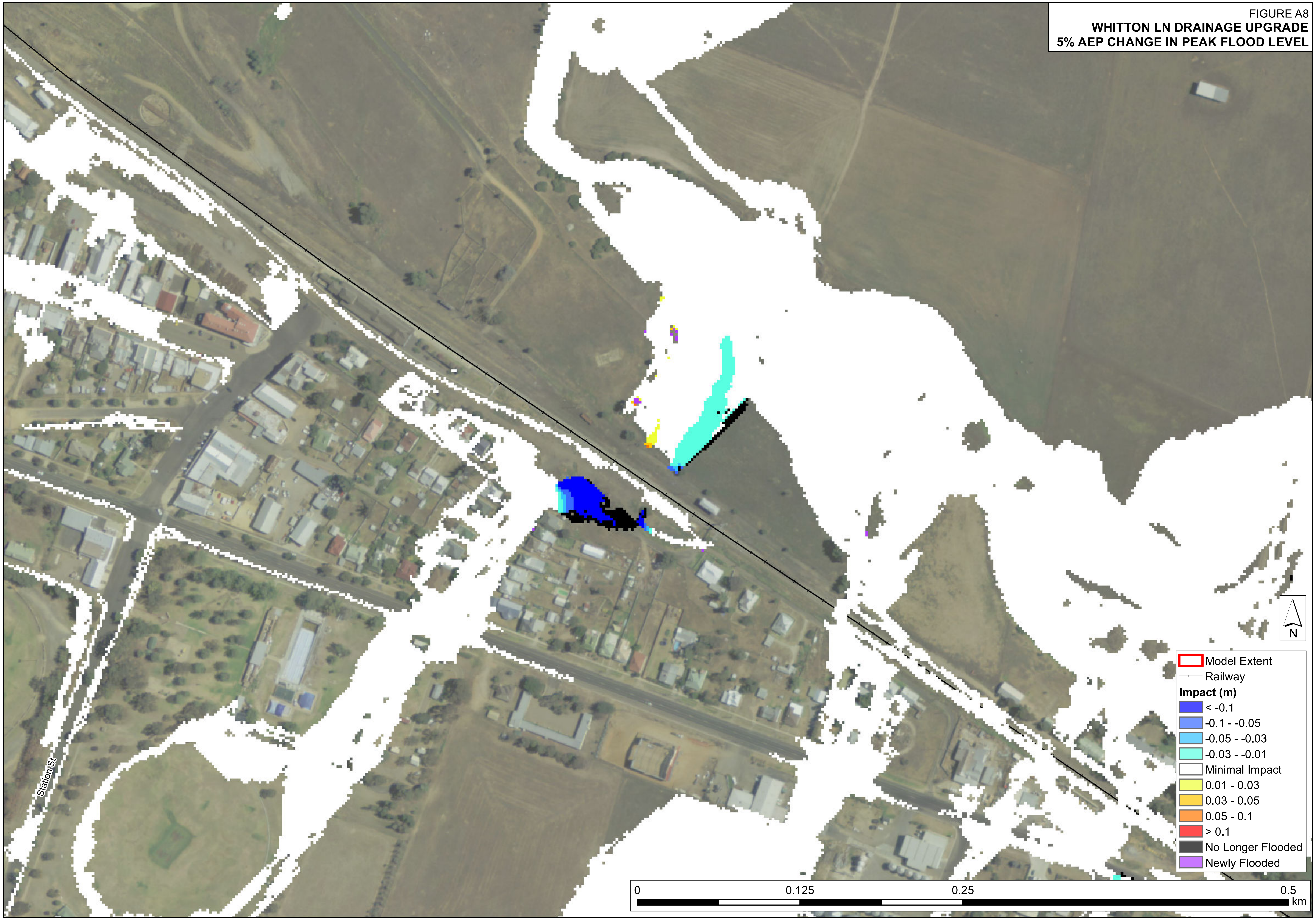


FIGURE A8
WHITTON LN DRAINAGE UPGRADE
5% AEP CHANGE IN PEAK FLOOD LEVEL
Model Extent
Railway
Impact (m)
< -0.1
-0.1 - -0.05
-0.05 - -0.03
-0.03 - -0.01
Minimal Impact
0.01 - 0.03
0.03 - 0.05
0.05 - 0.1
> 0.1
No Longer Flooded
Newly Flooded
N
0
0.125
0.25
0.5
km
Station St
J:\Jobs\118099\ArcMaps\FRMS\AppendixA\FigureA8_FM07_WhittonLn_5pctAEP_Change_in_PeakFloodLevel.mxd

FIGURE A9
SEWAGE TREATMENT PLANT LEVEE
1% AEP CHANGE IN PEAK FLOOD LEVEL

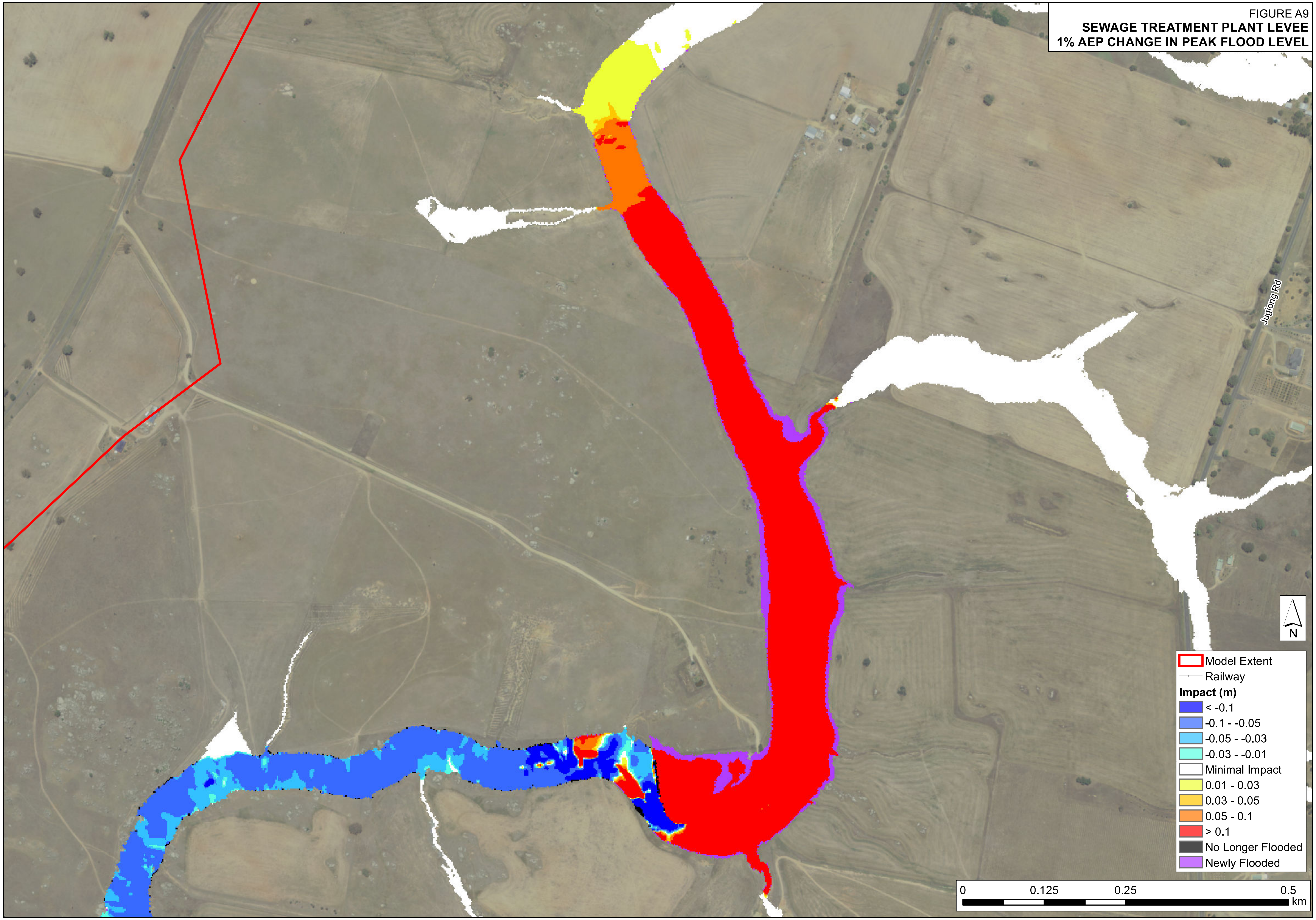


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FIGURE A10
SEWAGE TREATMENT PLANT LEVEE
2% AEP CHANGE IN PEAK FLOOD LEVEL

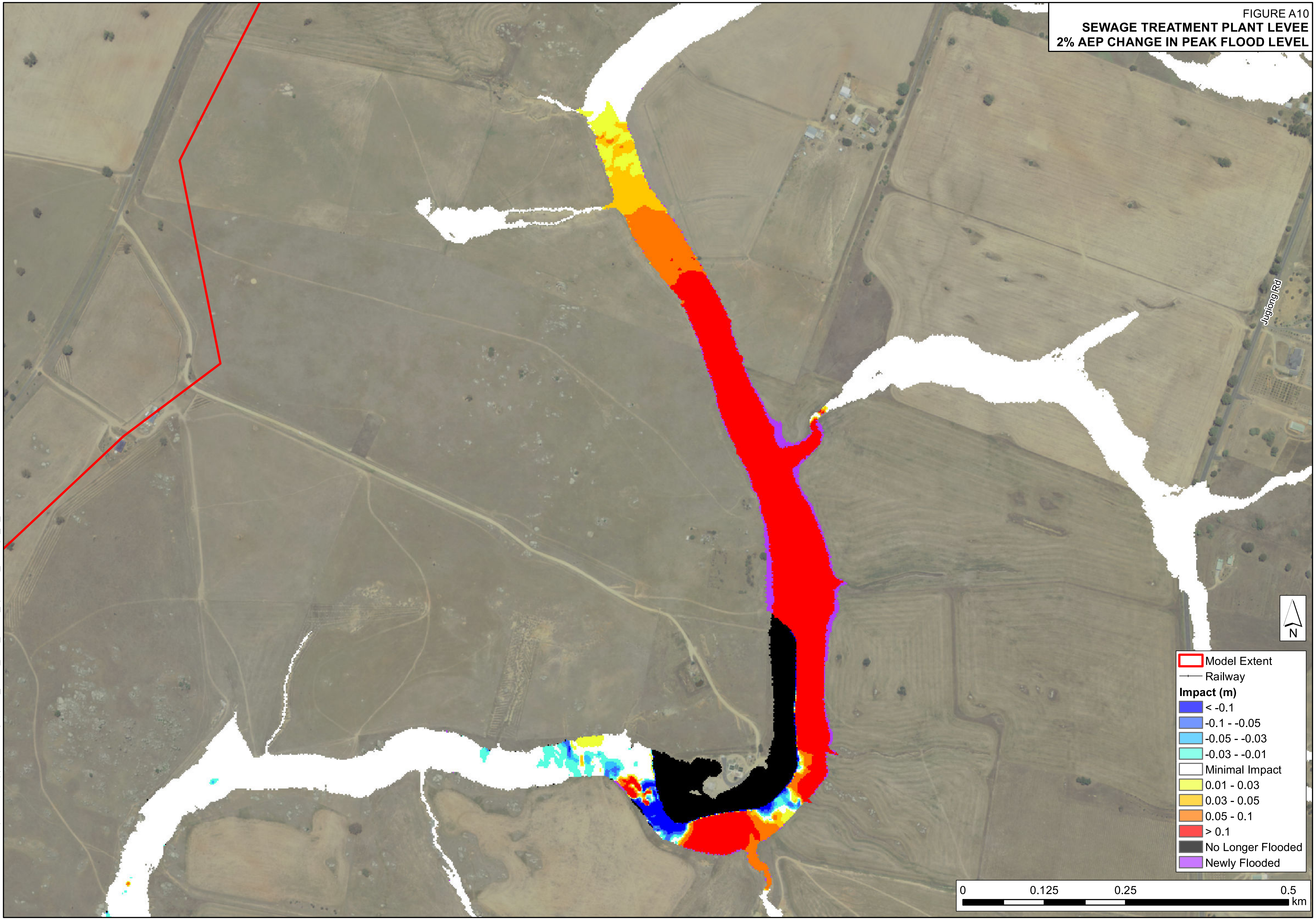

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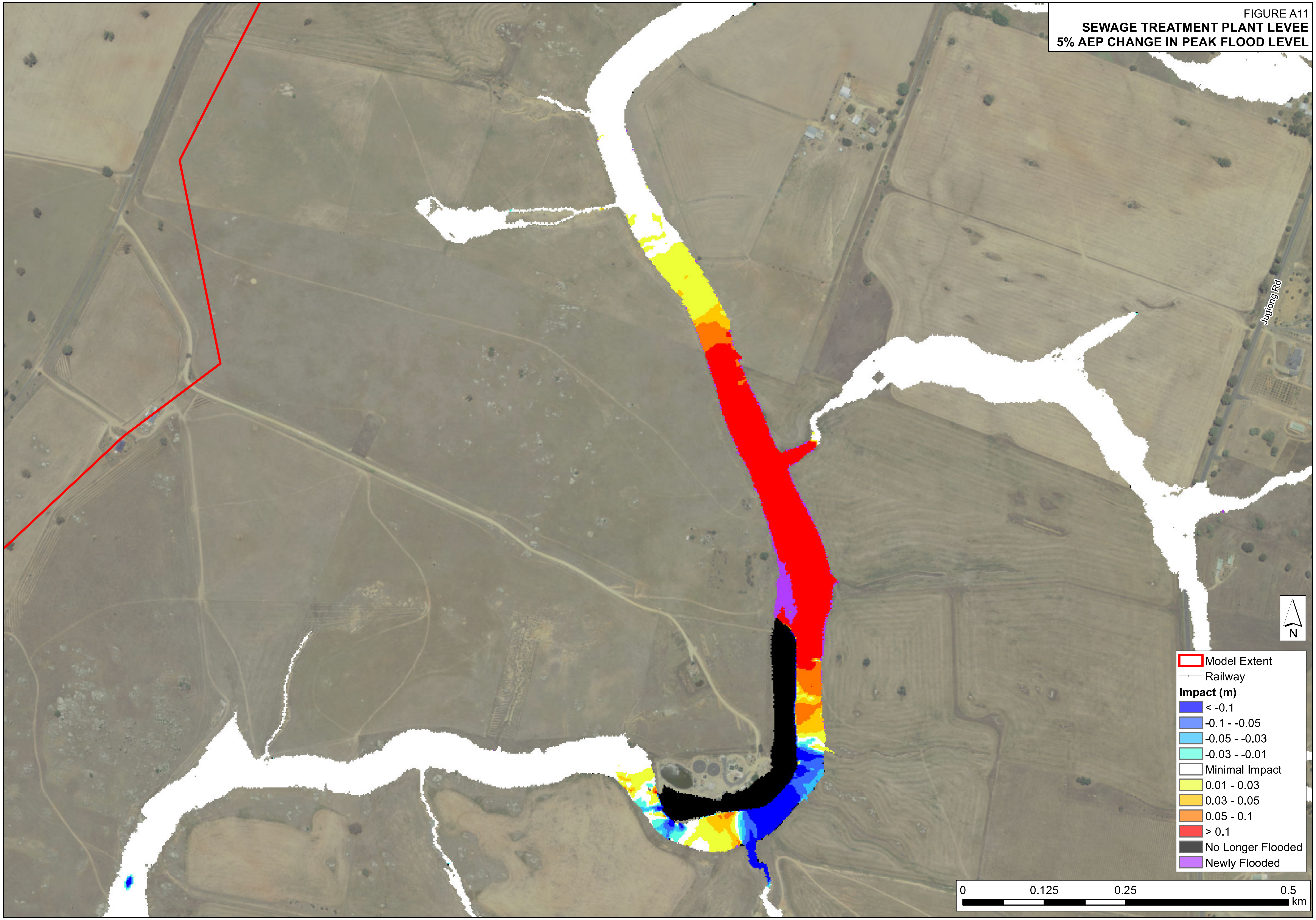
FIGURE A11
SEWAGE TREATMENT PLANT LEVEE
5% AEP CHANGE IN PEAK FLOOD LEVEL



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