Snowy Monaro Regional Council
Flood and Floodplain Risk Management Studies

Floodplain Risk Management Studies and Plans

Draft Report

March 2020

EXECUTIVE SUMMARY

Snowy Monaro Regional Council (the Council) has received financial support from the State Floodplain Management program managed by the Office of Environment and Heritage (OEH) to undertake flood studies and floodplain risk management studies for the towns of Cooma, Bredbo, Berridale and Michelago towns situated in south-east NSW.

This project composes stages 1 to 4 in the five-stage process outlined in the NSW Government's Floodplain Development Manual (FDM, 2005), as follows:

1. Data Collection
2. **Flood Study** – A comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management study and plan
3. **Floodplain Risk Management Study (FRMS)** - assess the impacts of floods on the existing and future community and allows the identification of management measures to treat flood risk
4. **Floodplain Risk Management Plan (FRMP)** - outlines a range of measures, for future implementation, to manage existing, future and residual flood risk effectively and efficiently
5. **Plan Implementation** - once the management plan is adopted, an implementation strategy (devised in Stage 4) is followed to stage components dependent on funding availability.

The flood studies for each town were finalised in mid-2019 and this report represents stages 3 and 4.

Report Overview

This report describes the flood risk assessment and evaluation of flood risk management measures. The flood risk assessment uses model outputs and other data developed as part of the flood study to quantify where flood risk exists in each town, across the range of possible floods. This assessment is then used to inform the identification and evaluation of a range of measures to manage flooding in each town. Measures that are recommended for implementation are then summarised in the Floodplain Risk Management Plan, which is presented as a table in this executive summary. The report contains the following sections:

- **Introduction** – objectives, end users and contacts
- **Background** – description of the four towns, overview of relevant policies and legislation, summary of previous studies and community consultation
- **Overview of Flood Behaviour** – summary of each town's flood mechanisms, historical floods, and design flood behaviour. This information is a summary of information presented in the flood study
- **Flood Risk Assessment** – Separate section for each town including flood hazard, hydraulic categories, levee function (where applicable), flooding hotspots, flood warning and emergency response
- **Flood Planning Area** – Description and presentation of the Flood Planning Area determined for each town
- **Flood Risk Management Measures** – description of the approach to flood risk management and then assessment and evaluation of property, response and flood modification measures for each town

Flood Risk Assessment

An assessment of each town's flood behaviour has been carried out to determine specific areas of flood risk across a range of metrics, including flood hazard, hydraulic categories, the existing levees, the economic impact of flooding and the flood warning systems. The risk assessment for each town is presented in Section 3 (Cooma), Section 4 (Bredbo), Section 5 (Berridale) and Section 6 (Michelago), with sub-sections on each of the metrics. The risk assessment found that:

- **Cooma** has significant flood affectation along sections of Cooma Creek and Cooma Back Creek, particularly in flood events of 10% AEP and larger. On Cooma Creek, property and road flooding occur when parts of the levee are overtopped, with potential for severe flooding particularly around Sharp Street and Commissioner Street. Cooma Back Creek also has the potential to flood roads and properties, with a flooding hotspot in the section of creek of north of Sharp Street which is subject to high risk flooding. There is a third creek flooding hotspot near the confluence of the two creeks, near Mulach Street. In addition to creek flooding, flooding occurs in the Polo Flat industrial area, and in some residential areas due to overland flow. There is an existing flood warning system in Cooma that has a target lead time of 1 hour, managed by the Bureau of Meteorology and the SES. The Average Annual Damage of flooding in Cooma is estimated to be $4.7 million.

- **Bredbo** has relatively little flood affection in smaller flood events, but in the 5% AEP and larger, Bredbo River can cause widespread inundation of roads and properties in the southern portion of the town. There is a second, smaller watercourse that passes through the town that causes hazardous road flooding at several locations, and can isolate a section of the town. In very rare to extreme flood events, a high water level on the Murrumbidgee River can exacerbate flooding of the Bredbo River or even cause flooding of the township of Bredbo. As with other towns, there are also localised instances of overland flooding. The Average Annual Damage for Bredbo is estimated to be $162,000.
- **Berridale** has areas of flood affectation along Myack Creek and Coolamatong Creek, where high creek flows overtops the channel banks and spreads over roads and property. Coolamatong Creek, which runs through the town, has minimal channel capacity and spreads onto main roads including Jindabyne Road and Myack Street, as well as low-lying properties. Coolamatong Creek tends to cause less property flooding but can cause hazardous road flooding at several road crossings. Kosciuszko Road which is a main arterial road providing access to Berridale and NSW Ski Fields, can also be flooded by Wullwye Creek/Myack Creek around 2 km north-east of town. As with other towns, there are various instances of overland flooding. The Average Annual Damage for Berridale is estimated to be $243,000.
- **Michelago** has relatively little flood affectation compared to other towns, with most areas of Michelago Creek's floodplain away from dwellings and roads. While in very rare events (e.g. 0.2% AEP) very few dwellings are directly affected by creek flooding, there is potential for severe inundation across the town in the Probable Maximum Flood (PMF). Flooding issues are limited to areas of overland flow adjacent to Ryrie Street, and isolation of properties outside of Michelago due to roads cut due to flooding. The Average Annual Damage for Michelago is estimated to be $137,000.

Flood Risk Management Measures

A range of flood risk management measures have been assessed for each town based on assessment of the flood risk, and consultation with Council and the community. The types of measures have been categorised as flood modification, property modification or response modification, in accordance with the NSW Floodplain Development Manual. Flood modification measures have focussed on upgrading the existing levee systems and several road culverts, and other civil works. Where appropriate measures have been modelled using multiple design flood events. Property modification options include a Flood Planning Area for each town, and recommendations for existing local planning policies. Response modification measures include recommendations for updates to the Local Flood Plan, an improved warning for Cooma and Bredbo and community flood education. A full list of assessed measures is set out in Section 8 and the recommended measures are summarised in Table 1.

Priority for each measure has been categorised as High, Medium or Low. High and Medium priority measures are recommended to be implemented in the short-to-medium term while Low priority measures are part of a long-term strategy for an area's development.

Table 1: Draft Floodplain Risk Management Plan

Option and Report Reference	Description	Responsibility	Priority
PM01 - Adopt updated Flood Planning Area for each town	A designated area in each town where Council planning controls, including minimum floor levels, apply to development.	Council	High
PM02 - Local Environment Plan Amendments	Revision of the LEP text to improve functionality.	Council	High
PM03 - Advice on Land-use Zoning Considering Flooding	Incorporation of flood risk into future zoning applications, and re-zoning of flood-prone areas	Council	Medium
PM04 - Updated Flood Planning Controls in the DCP(s)	Improvements to flood planning controls via the DCP, using the NSW standardised DCP and the Cooma Monaro DCP in the interim	Council	High
PM05 - Voluntary Purchase in Cooma	Voluntary purchase of residential lots with high hazard flooding in Cooma	Council	For discussion
RM01 - Warning Signage at Hazardous Road Crossings	Dynamic warning signage on certain roads to discourage vehicles entering floodwaters	Council with SES input	High
RM02 - Install automatic boom gates at high hazard/high traffic crossings	Automatic boom gates that prevent vehicles entering flooded roads	Council	Medium
RM03 - Community Flood Education	A program of awareness and education activities design to improve the community's response to a flood	Council and SES	High
RM04 - Updated Local Flood Plan and Intelligence Cards	Incorporate the findings of the current study into the area's Local Flood Plan	SES	High
RM05 - Investigation of Cooma Flood Warning System	In-depth analysis of the effectiveness of the Cooma flood warning system including areas of improvement	Council	Medium
RM06 - Cooma Flood Warning System Improvements	Installation of a new depth marker near Sharp Street bridge and other improvements	Council with BOM and SES input	High
RM07 - Bredbo Flood Warning System	Installation of new stream gauges and a warning network for Bredbo	Council with BOM and SES input	Medium
RM08 - Develop communications channels for road closures	Ensure information on road closures is disseminated across emergency response entities	Council, NSW Ambulance and SES	High
L01B - Increase Main Cooma Levee to 2% AEP Level of Protection	Increase the height of the Cooma Creek levee to the 2% AEP level of protection	Council	Medium
L01C - Increase Main Cooma Levee to 5% AEP Level of Protection	Increase the height of the Cooma Creek levee to the 5% AEP level of protection, slightly higher than what currently exists.	Council	High

Option and Report Reference	Description	Responsibility	Priority
C03 - Upgrade Culvert under Vulcan Street, Cooma	Raise a section of Vulcan Street and upgrade the Sandy Creek culverts	Council	Medium
Z02 - Enlarge Drainage Channel at Polo Flat	Increase the Polo Flat watercourse's capacity including culvert upgrades at road crossings	Council	Medium
Z04 - Re-grade and enlarge Cooma Back Creek downstream of Sharp Street	Increase Cooma Back Creek's capacity downstream of Sharp Street including steeper sides and removed vegetation	Council	For discussion
V01 - Vegetation management plan for all towns	A program for removal of non-native vegetation from the riparian zone of each watercourse	Council	Medium
M01 - Massie Street Bridge	Construction of a new bridge over Cooma Creek at Massie Street	Council	Low
C01B - Raise Road and Install Culvert at Short Street, Berridale	Raise Short Street over Myack Creek and upgrade the creek culverts	Council	Low
C02 - Upgrade Culverts at William Street, Myack Creek	Raise William Street over Myack Creek and upgrade the creek culverts	Council	Low

Next Steps

The draft FRMS&P will be reviewed by Council and public feedback invited via a public exhibition period. The finalised study including the recommended measures will then be put to Council for adoption.

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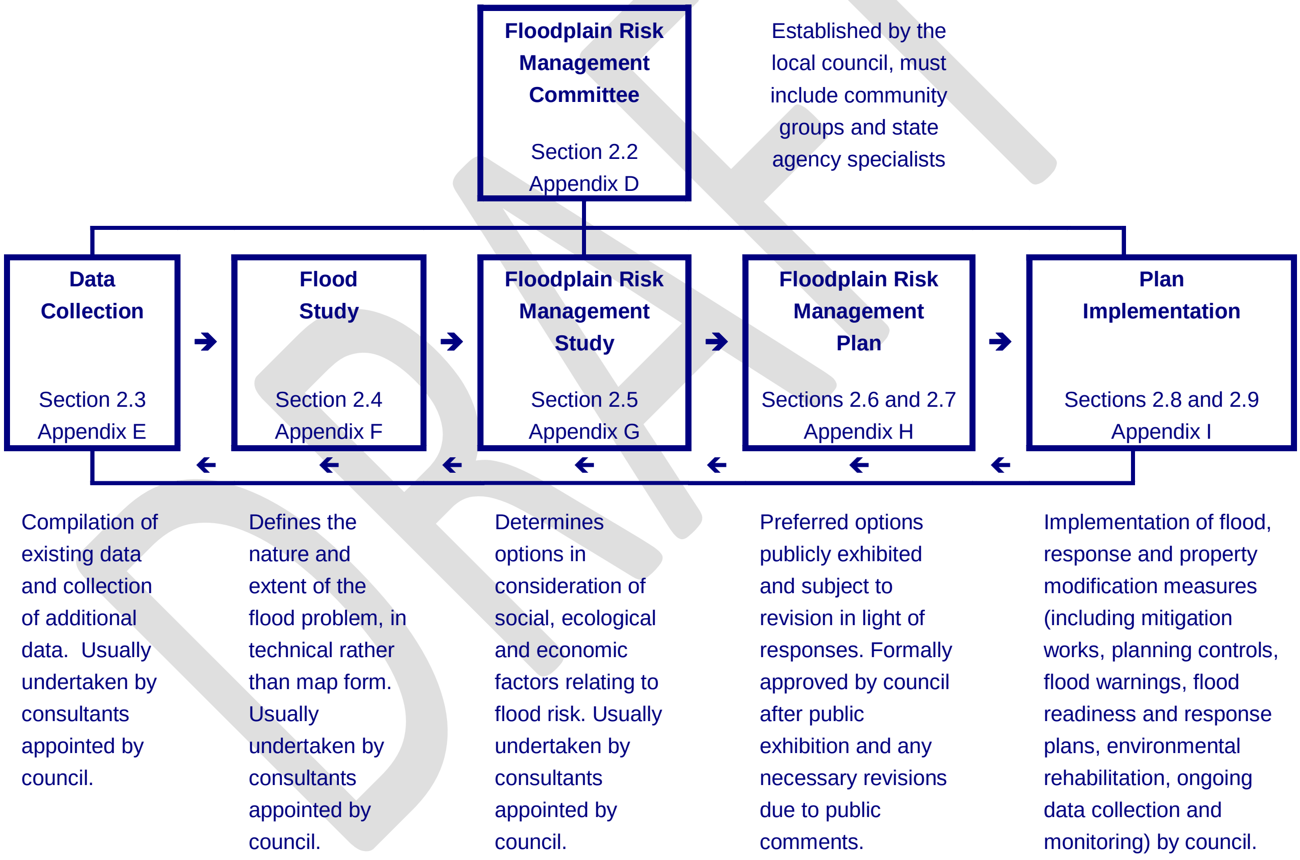
FOREWORD

The New South Wales (NSW) Government's Flood Prone Land Policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods.
Through the NSW Office of Environment and Heritage (OEH), NSW Department of Planning and Environment (DPE) and the NSW State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding, flood risk management, flood emergency management and land-use planning matters.
The Floodplain Development Manual (NSW Government 2005) assists councils to meet their obligations through a five-stage process resulting in the preparation and implementation of floodplain risk management plans. Figure 1 presents the process for plan preparation and implementation.

Image 1: The floodplain risk management process in New South Wales (FDM, 2005)



Source: NSW Government (2005)

1. INTRODUCTION

Snowy Monaro Regional Council (the Council) has received financial support from the State Floodplain Management program managed by the Department of Planning, Industry and Environment (DPIE) to undertake a flood investigation of the Cooma, Bredbo, Berridale and Michelago towns situated in south-east NSW.

SMEC Australia Pty Ltd (SMEC) with assistance from GRC Hydro Pty Ltd (GRC Hydro) have been engaged by Council to undertake flood and floodplain risk management studies for these towns.

This study composes stages 1 to 4 in the five-stage process outlined in the NSW Government's Floodplain Development Manual (FDM, 2005). These works include:

- **Data collection** – collection of all applicable data to be used for the ensuing stages of the studies;
- **Flood Study** – a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan;
- **Floodplain Risk Management Study (FRMS) –** assess the impacts of floods on the existing and future community and allows the identification of management measures to treat flood risk; and
- **Floodplain Risk Management Plan (FRMP) –** outlines a range of measures, for future implementation, to manage existing, future and residual flood risk effectively and efficiently.

Following the completion of the FRMP, the final stage of the FDM (2005) floodplain management process will involve implementing the findings of the FRMP. Further details of each of these FDM (2005) stages are outlined below.

1.1. Data Collection

The collection and collation of data necessary for the completion of the flood and floodplain risk management studies is a fundamental part of the floodplain management process. It is typically begun at the outset of the study, but generally continues throughout the period of the project as data becomes available. The quality and quantity of available data is key to the success of a flood study and FRMS.

1.2. Flood Study

A flood study is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide an understanding of flood behaviour and consequences for a range for flood events. Consideration of the local flood history, flood data is used to assist in the development of hydrologic and hydraulic models which are calibrated and verified to improve confidence in model results. **The flood study covering each of the four towns was finalised in mid-2019.**

1.3. Floodplain Risk Management Study

A floodplain risk management study increases understanding of the impacts of floods on the existing and future community. It also allows testing and investigating practical, feasible and economic management measures to treat existing, future and residual risk. The floodplain risk management study will provide a basis for informing the development of a floodplain risk management plan. **This report constitutes the Floodplain Risk Management Study.**

1.4. Floodplain Risk Management Plan

The floodplain risk management plan documents decisions on the management of flood risk into the future. The FRMP uses the findings of a floodplain risk management study, to outline a range of measures to manage existing, future and residual flood risk effectively and efficiently. This includes an itemised list of measures and prioritised implementation strategy. **An overview of the draft Floodplain Risk Management Plan has been included in the executive summary of this report.**

1.5. Objectives

The objective of this study is to improve understanding of flood behaviour and flood risk, and better inform the management of flood risk for Cooma, Bredbo, Berridale and Michelago. The study will also provide a sound technical basis for any further flood risk management investigation for each of these towns. Meeting the requirements of the identified end user groups (see Section 1.6), which have been tailored to the context of the flood situation, is a key objective of this study.

The Data Collection and Flood Study stages objectives include:

- Review all available flood related information for each of the four towns and their respective catchments;
- Develop and calibrate hydrologic and hydraulic computer models to simulate the rainfall/runoff process for the various rivers, creeks, streams and overland flow paths that affects each of the towns;
- Define design flood behaviour for each of the creeks, rivers and overland flowpaths for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP (Annual Exceedance Probability) events and the PMF (Probable Maximum Flood);
- Undertake sensitivity analysis to investigate potential changes associated with Climate Change and selected model parameters.

Using the findings of the Flood Study, the FRMS and FRMP objectives include:

- Definition of a Flood Planning Area for each town;
- Assess flood hazard, flood function and emergency response classifications;
- Providing information to support emergency management activities;
- Providing advice on land-use planning considering flooding and overland flow;
- An assessment of cumulative impact of development;
- The identification and preliminary assessment of management options;
- Detailed assessment of preferred options; and
- The development of a FRMP which list the recommended measures aimed at managing flood risk for Cooma, Bredbo, Berridale and Michelago.

1.6. Project End Users

The study outputs are suitable to inform decision making for investing in the floodplain; managing flood risk through prevention, preparedness, response and recovery activities; pricing insurance, and informing and educating the community on flood risk and response to floods. Each of these areas has different user groups, whose needs vary. The key end-user groups that this study aims to support are identified in Table 1.

Table 2:Project End Users

Potential end user group
High-level strategic decision makers
Community
Flood risk management professionals
Engineers involved in designing, constructing and maintaining mitigation works
Emergency management planners
Land-use planners (strategic planning and planning controls)
Hydrologists and meteorologists involved in flood prediction and forecasting
Insurers

1.7. Company Contact

Please refer any comments or queries in relation to this report to the contact persons below.

Company	SMEC	GRC Hydro
Name:	Fran Liao	Zac Richards
Position:	Associate Engineer - Water Resources, SMEC	Director
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2. BACKGROUND

2.1. STUDY AREAS

Cooma, Bredbo, Berridale and Michelago are situated in the Snowy Monaro Regional Council Local Government Area (LGA). The towns are located in the Snowy Mountains and Monaro regions of NSW in the elevated regions of the Great Dividing Range. The towns are situated to the south of the Australian Capital Territory (ACT) and north of the Victorian border. Cooma, Bredbo and Michelago are within the Upper Murrumbidgee River catchment and Berridale is situated in the Snowy River catchment.

Study areas for each of the towns are based on the project brief provided by Council and have been further refined considering existing and future development areas, flood liability of both mainstream and overland flow flooding, potential impacts from downstream/neighbouring catchments and consideration of the upcoming management studies.

Description of each of the towns is presented in the following sections.

2.1.1. Cooma

Cooma is situated approximately 100 km south of Canberra and is the largest town within the LGA with a population of 6,742 (2016 census). The town was established in 1832 and later grew rapidly in the mid-20th century during construction of the Snowy Mountains Scheme. According to the 2016 census, there is an average of 2.1 people per household and each dwelling has an average of 1.6 motor vehicles. 23% of the population is aged 65 and over and 82% of households speak only English at home. The second-most common languages spoken are German and Italian (both 1% of the population). There are several primary schools and high schools in the town, and a TAFE technical college.

Various creeks, stream and flow paths flow through the township with the most significant being Cooma Creek and Cooma Back Creek. Cooma Creek originates south of Cooma in the foothills of the Monaro Range. It flows through Cooma in a northerly direction before joining Cooma Back Creek in the north-west of town. Cooma Back Creek also originates south of Cooma and is located west of Cooma Creek. Both catchments are steep and relatively free of vegetation with catchment areas of 104 km^2 at their confluence (combined catchment area of 208 km^2). Cooma is also subject to flooding from various minor streams and overland flow paths which flow to Cooma and Cooma Back Creeks. The study area and its features are shown in Figure 2-1.

2.1.2. Bredbo

Bredbo is situated at approximately the halfway point between Cooma (30 km south) and Michelago (30 km north). According to the 2016 census the population of Bredbo is 352, which is up from 169 in 2011 indicating a rapidly growing township, most likely due to its close proximity to Canberra. The town was proclaimed a village in 1888 and functioned as a stop for those crossing the Bredbo River. There is an average of 2.7 people per household and each dwelling has an average of 1.9 motor vehicles. 12% of the population is aged 65 and over and 89% of households speak only English at home. The second-most common language spoken is Greek (1% of the population). There is a single school (primary) in the town.

The Bredbo River originates in the Badja State Forest, and flows predominantly west being joined by seven tributaries, before meeting the Murrumbidgee River approximately 1 km south-east of Bredbo. The catchment of the Bredbo River at Bredbo is approximately 736 km^2. Bredbo is also subject to flooding from overland flows which drain through the township in southerly and westerly directions towards the Bredbo River. The study area and its features are shown in Figure 2-2.

2.1.3. Michelago

Michelago is situated approximately 50 km south of Canberra on the Monaro Highway. Established with a shop and inn for travellers by 1838, in recent years Michelago has been subject to significant developmental pressures due to its proximity to Canberra. According to the 2016 census the population of Michelago is 562. There is an average of 2.9 people per household and each dwelling has an average of 2.3 motor vehicles. 11% of the population is aged 65 and over and 89% of households speak only English at home. The second-most common language spoken is German (1% of the population). There is a single school (primary) in the town.

Michelago Creek flows through Michelago in a north-westerly direction and has a catchment area of approximately 200 km² at its confluence with the Murrumbidgee River. The Creek is a combination of several creeks including Ryries, Booroomba, Margarets and Teatree Creeks which originate in steep mountainous terrain to the east of town. Michelago is also subject to flooding from overland flows which drain through the town towards these creeks. The study area and its features are shown in Figure 2-3.

2.1.4. Berridale

The township of Berridale sits between Cooma and Jindabyne in south east NSW and has a population 1197 according to the 2016 census. Established with a single store in the 1860s, like other towns its early function was as a stop for travellers. There is an average of 2.3 people per household and each dwelling has an average of 1.8 motor vehicles. 18% of the population is aged 65 and over and 92% of households speak only English at home. The second-most common language spoken is German (1% of the population). There is a single school (primary) in the town.

The town is part of the Snowy River Catchment at the regional scale with two smaller catchments in the immediate surrounds. The local Coolamatong (area of 15 km²) and Myack (area of 19 km²) creek catchments are known to have historically caused flooding at Berridale. Coolamatong Creek approaches town from the south-west and flows through town in the northerly direction before meeting Myack Creek downstream of the town. Myack Creek skirts the north-east edge of town. The study area and its features are shown in Figure 2-4.

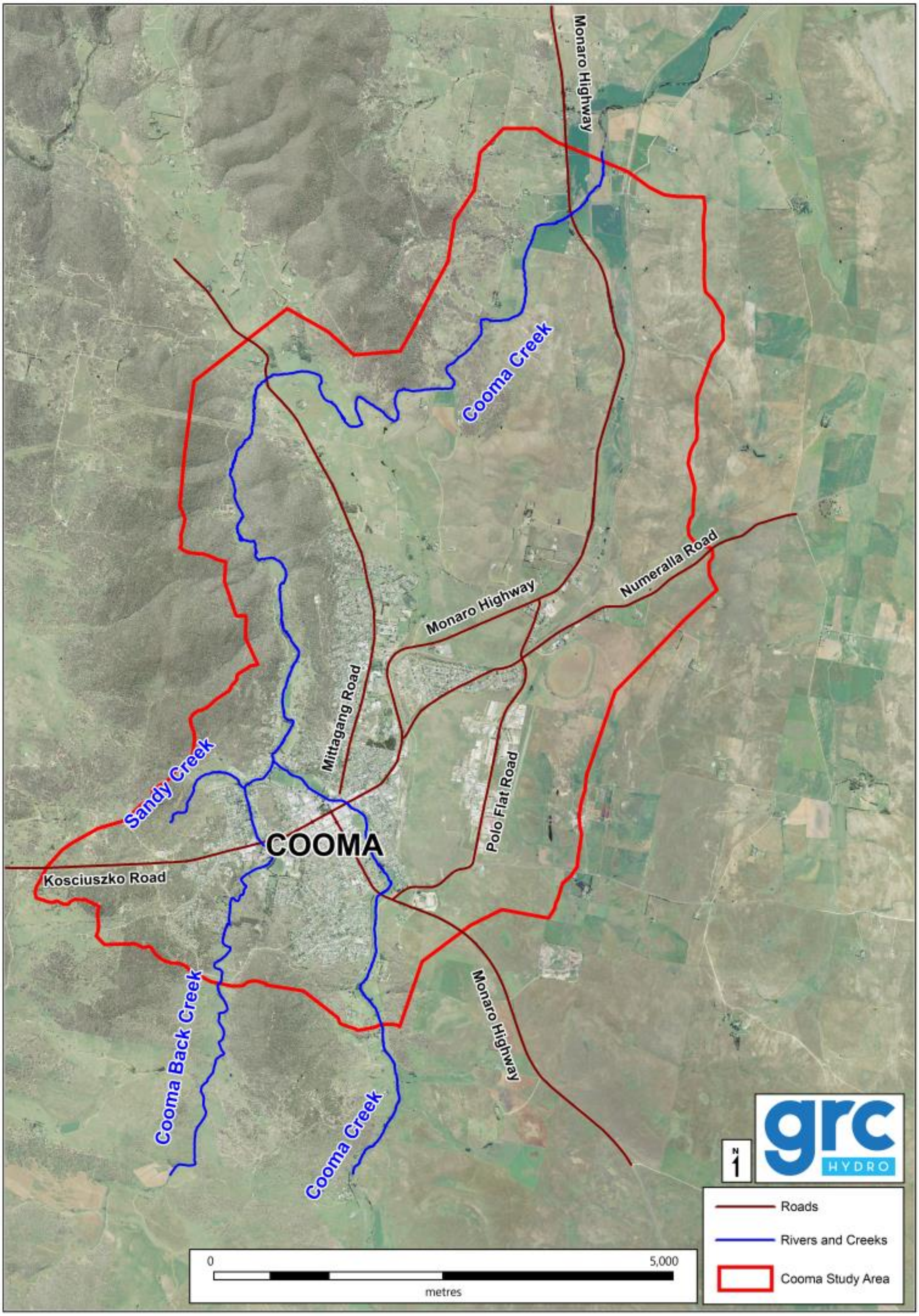


Figure 2-1: Cooma Study Area

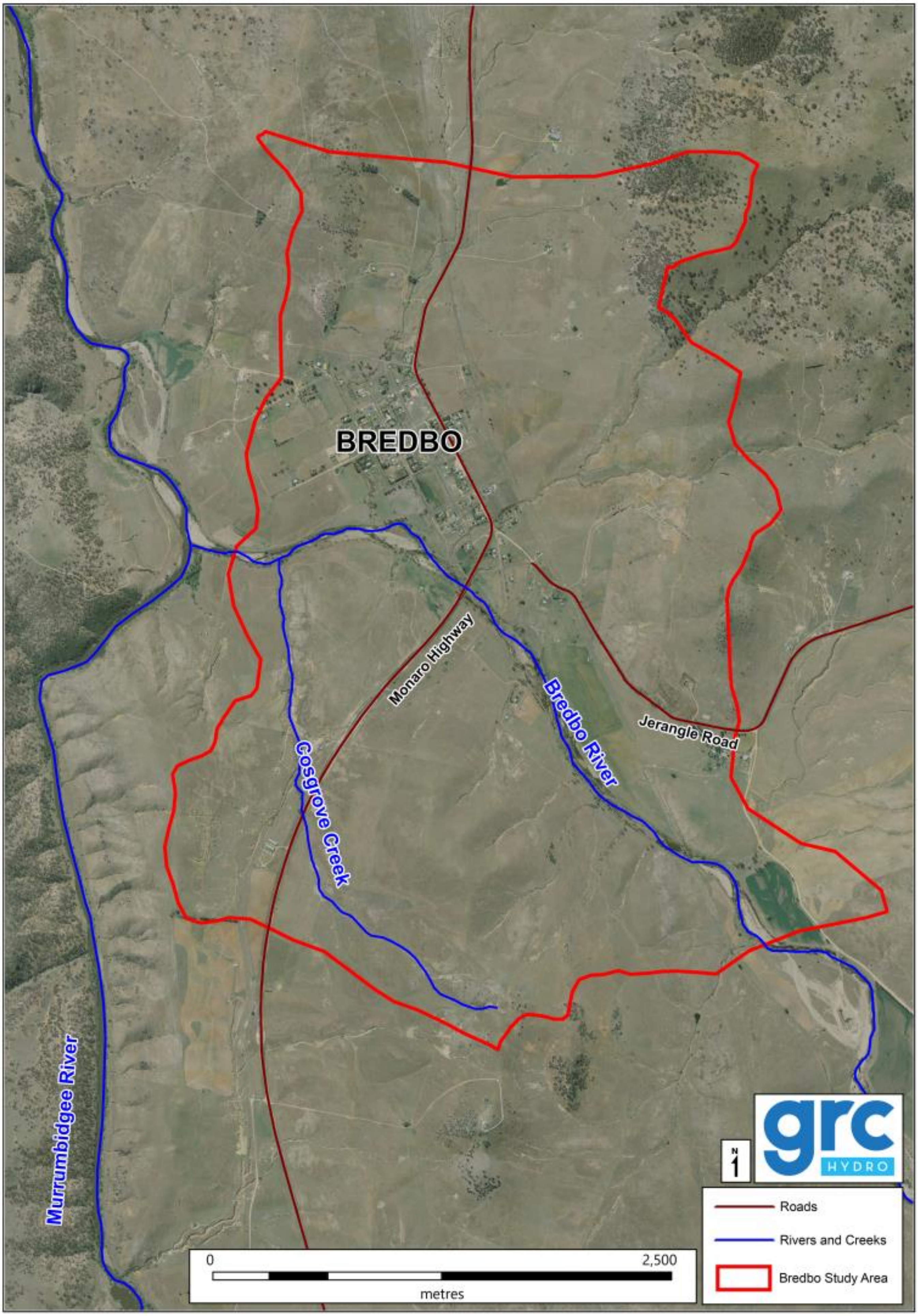


Figure 2-2: Bredbo Study Area

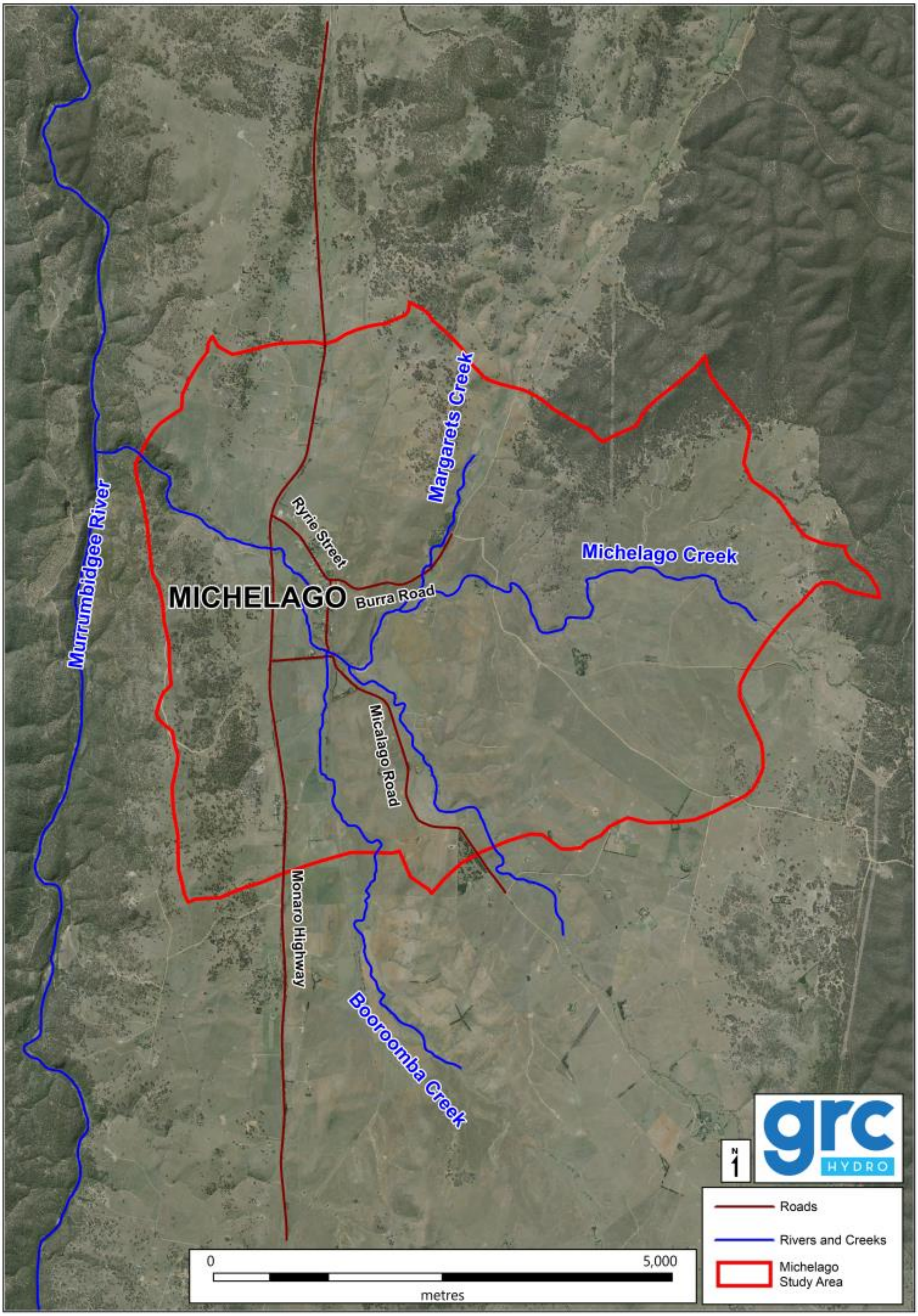


Figure 2-3: Michelago Study Area

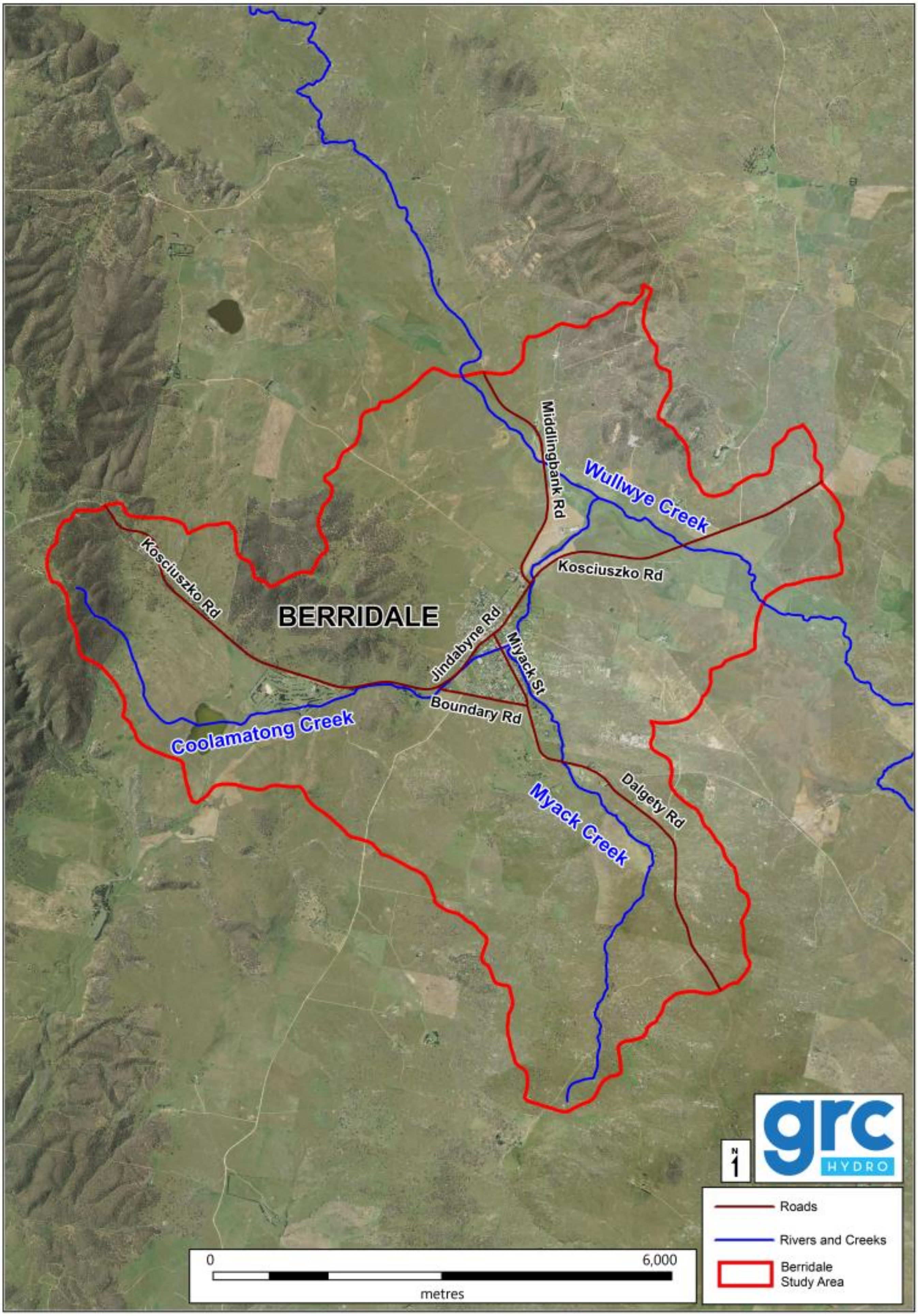


Figure 2-4: Berridale Study Area

2.2. DISCUSSION OF RELEVANT POLICIES, LEGISLATION AND GUIDANCE

2.2.1. Implemented Guidelines and References

Table 3 presents the guidelines, manuals and technical reference documents used for this study. These documents detail best practice in regard to management of flood risk. They cover both best practice about the technical assessment of flood behaviour and flood risk, and, more generally, who has responsibility for managing flood risk and how this management is best achieved in the area.

Table 3: Guidelines and reference documents

Reference	Topic
Australian Emergency Management (AEM) Handbook Series, Managing the floodplain: A guide to best practice in flood risk management in Australia – AEM Handbook 7	Best practice
AEM Handbook 7, Technical flood risk management guideline – Flood Hazard	Flood hazard
AEM Handbook 7, Technical flood risk management guideline – Flood Emergency Response Classification	Emergency response
AEM Handbook 7, Technical flood risk management guideline – Flood risk information to support land-use planning	Land use
AEM Handbook 7, Technical flood risk management guideline – Assessing options and service levels for treating existing risk	Mitigation options and service levels
AEM Handbook 6, National Strategy for Disaster Resilience – community engagement framework	Community engagement
Australian National Committee on Large Dams (ANCOLD) Guidelines	Dam safety
Australian Rainfall & Runoff 2019	Best practice
Section 733 of the Local Government Act, 1993	Liability & indemnity for compliance with the principles in the manual
NSW Government's Floodplain Development Manual (2005)	Flood prone land policy and industry practice
SES requirements from floodplain risk management process	SES requirements
Practical consideration of climate change	Climate change

2.2.2. Relevant Legislation

Council legislation pertaining to flooding in the study areas are the two Local Environment Plans and the two Development Control Plans. There are also a series of state and national plans and policies relevant to flooding. Information on each is presented in the following section.

2.2.2.1. *Local Environmental Plans*

Snowy Monaro Regional Council was formed in May 2016 through a merger of the Bombala, Cooma-Monaro and Snowy River shires. Accordingly, Council's planning policies are still based on the previous shires policies. The policy corresponding to each of the study areas is as follows:

- Cooma, Bredbo and Michelago: Cooma-Monaro Local Environmental Plan (LEP) 2013
- Berridale: Snowy River Local Environmental Plan (LEP) 2013

All three shires have local provisions that control flooding within their LEPs. The Bombala LEP (2012) and Cooma-Monaro LEP (2013) both have clause 6.2 dedicated to 'Flood planning', whilst the Snowy River LEP (2013) has its 'Flood planning' controls defined in clause 7.1. Each of the clauses are similar with the

Snowy River and Cooma-Monaro clauses applying controls 'to land at or below the flood planning level', whilst the Bombala clause applies controls to land at or below the FPL as well as to 'land identified as "Flood planning area" on the Flood Planning Map'. Incorporation of flood planning area maps within an LEP is typically not recommended due to difficulties associated with updating an LEP if a map requires revision. Typically, flood maps presented within a DCP is preferred.

The Cooma-Monaro 'Flood planning' clause has been reproduced below.
Cooma-Monaro Local Environmental Plan 2013

6.2 Flood planning

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

(a) to minimise the flood risk to life and property associated with the use of land,
(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,
(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and
(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
(c) incorporates appropriate measures to manage risk to life from flood, and
(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(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.

(5) In this clause:

flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

Recommendations for Council's flood planning policies are assessed in Section 8.2 of this report.

2.2.2.2. ***Development Control Plans***

Similar to Council's LEPs, the Development Control Plans (DCPs) are still based on the previous shires' policies. All three historic shires have flood policies within their DCPs, the pertinent details of which are presented below. Although the study areas are not covered by Bombala DCP, it has been included as it may be relevant in any potential amalgamation of the policies.

- Bombala DCP (2012), Clause 2.5.2;

  The Bombala DCP (2012) provides minimal guidance on controls for flood affected developments. Controls are based on four 'performance criteria' that reiterate the Bombala LEP (2012) objectives, however limited information is provided around how these controls should be implemented in the context of development.

- Cooma-Monaro DCP (2014), Clause 6.4;

  The Cooma-Monaro DCP (2014) flood policy provides a range of controls via a Flood Risk Precinct Matrix which has been used by numerous Councils throughout NSW. The Flood Matrix approach works by assigning planning controls based upon required proposed development aspects (i.e. floor levels, structure soundness, evacuation/access etc.) and the flood liability of the land on which development is proposed (affected by ≤ 5% AEP, 5%AEP - 1% AEP, 1% AEP - PMF). Generally, the Cooma-Monaro DCP (2014) follows a standard Flood Matrix format which is largely suitable for applying flood related development controls.

Potential issues could arise when trying to enforce planning controls for areas above the 'flood planning level' defined in the Cooma-Monaro LEP (2013). To achieve this, a Floodplain Risk Management Clause contained within Council's LEP is required so that flood controls can be applied up to the level of the PMF. An application to the NSW Department of Planning for inclusion of a Floodplain Risk Management Clause is considered as part of property modification management measures (Section 8.2).

- Snowy River DCP (2013), Section C7, Clause 2;

  The Snowy River DCP (2013) flood policy provides limited controls via a pseudo Matrix approach which considers flood hazard and flood function. The policy does not provide rigorous controls in regards to many types of development with various controls noted to be 'considered on merit'. A merit-based approach is appropriate in some instances, particularly if Council has the resources in place to provide guidance, however it also places decision making responsibilities on Council staff. Other aspects of the DCP discourage the development of land below the flood planning level which is contrary to the FDM (2005) which aims to facilitate the safe development of flood prone land.

Recommendations for Council's flood planning policies are assessed in Section 8.2 of this report.

2.2.2.3. ***State and National Plans and Policies***

Management of flood risk in the four towns is also guided by various state-wide and national policies related to floodplain management in Australia. These have been listed below, including their relevance to the current study:

- Australian Rainfall and Runoff 2019 – sets out hydrological data and procedures to be used for hydrological and hydraulic modelling of flooding in Australia.
- Building Code of Australia - provides a standard for the design and construction of new buildings in Flood Hazard Areas (FHA) with the aim of reducing risk to building occupants.
- NSW Environmental Planning and Assessment Act 1979 – Is the overarching state legislation for local legislation. The Act provides the framework for regulating and protecting the environment and controlling development. Pursuant to Section 9.1 of the EP&A Act, councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. It specifies how councils' LEPs manage flooding.
- NSW Flood Prone Land Policy - aims to reduce the impact of flooding and flood liability on individual landowners and occupiers of flood prone property and to reduce private and public losses resulting from floods via economically positive methods where possible. The NSW Floodplain Development Manual supports the policy.
- NSW Government's Floodplain Development Manual (2005) – Defines the assessment of flood risk in NSW, including flood hazard, hydraulic categories and other variables. More broadly it sets out

the objectives for floodplain development in the state, including description of types of mitigation measure.

- State Environmental Planning Policy (Exempt and Complying Development Codes) (2008) - are environmental planning tools used to address planning issues within NSW. In a flooding context, the SEPP for Exempt and Complying Development Codes 2008 is key for defining:
  - Exempt developments, where development can occur without the need for development consent; and
  - Complying development, where development must be carried out in accordance with a complying development certificate.

  The policy provides further information on where and development of flood-prone land should occur.
- NSW DPIE guidelines relating to flooding. Various guidelines have been published by DPIE for specific aspects of flood risk assessment in NSW. Some specifically related to the study are:
  - Floodway Definition (2007)
  - Practical Consideration of Climate Change (2007)
  - Incorporating 2016 Australian Rainfall and Runoff in studies (2019)
  - Residential Flood Damages (2007)
  - Drainage Behind and Through Levees (2007)
  - SES Requirements from the FRM Process (2007)

2.3. AVAILABLE DATA

All data collected and used by the current study was collected during the 2019 flood study. The majority of data was used for establishment of the hydrologic and hydraulic models for each town, including hydrologic data, LiDAR and other topographic survey, site visit findings and observations of historical floods. The 2019 flood study describes the data collection process in detail. The following section summarises the previous studies, including the recent flood study and the previous flooding assessment, which provide useful context to the remainder of this report.

2.3.1. Cooma, Michelago, Bredbo and Berridale Flood Studies (GRC Hydro and SMEC, 2019)

The flood study was completed in 2019 and provides a comprehensive description of the range of design flood behaviour in each town. The flood study is summarised in Table 4.

Table 4: 2019 Flood Study Overview

Feature	Description	Relevance to FRMS (current study)
Data collection	The following data was collected for the study: • LiDAR data surveyed in 2018 by surveying firm MNG, and in 2011, provided by Council. • Ground survey to validate LiDAR dataset. • Council GIS data including aerial photos, LEP layers, cadastral and road data. • Pit and pipe, culvert and bridge crossing data provided by Council. • Bureau of Meteorology design rainfall data including ARR2019 IFD data. • Rainfall data from 28 pluviometers and 50 daily read stations from BOM/Snowy Hydro, and stream gauge data from 7 stations from WaterNSW. • Previous studies (3 in Cooma, 4 in Berridale)	Data collected by the flood study was used to establish the hydrologic and hydraulic models, used by the current study.

	• Questionnaire responses and newspaper description of historical floods.	
Hydrologic Model	A large-scale WBNM model was established for the upper Murrumbidgee River Catchment and Wullwye Creek Catchment, which was used to define flow hydrographs for the creeks and rivers within each study area and are applied to the upstream boundary of each hydraulic model. The model was calibrated to five historic events and validated via comparison of design flow estimates to flood frequency analysis at five gauges. Additionally, a local WBNM model was established for each of the towns which derives local flows for the hydraulic model within the study areas (i.e. overland flow).	Hydrologic models have been adopted for use in the current study.
Hydraulic Model	A 1D-2D TUFLOW model was established for each town. The sub-surface stormwater network and cross-drainage culverts were included as a 1D model embedded in the model grid. Creeks, rivers and other watercourses were modelled in 2D. Buildings were schematised as impermeable flow obstructions, and breaklines were incorporated to define road crest levels, levee crest levels, road kerbs and creek thalwegs. The downstream boundary was set using a level-time configuration. Each model was calibrated to the March 2012 event and validated to previous studies.	Hydraulic models have been adopted for use in the current study, including in assessment of flood risk in each town and evaluation of management measures.
Design Flood Information	The following results were produced by the study: • Peak flood level, depth, flow and velocity for 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF • Provisional hydraulic hazard for the 5% AEP, 1% AEP, 0.2% AEP and PMF • Sensitivity to climate change, blockages, hydraulic roughness, rainfall losses and model grid size for the 5% AEP, 1% AEP and 0.2% AEP.	The current study uses design flood information in the assessment of flood risk for each town.
Community Consultation	The study involved distribution of a newsletter and questionnaire to residents and business owners in each of the towns. A total of 76 responses were received which provided general information on awareness of flooding and recollection of particular previous floods. A community workshop and one-on-one meetings were held subsequently to gather more specific information regarding flooding in each study area.	Consultation will continue during the current study – see Section 2.4.

Prior to the flood study, investigation of flood and stormwater risk had been undertaken for two of the four study areas (Berridale and Cooma). These studies are summarised in the following sections.

2.3.2. Cooma Floodplain Management Study (SMEC, 1994)

The study carried out an assessment of flood risk in Cooma and was undertaken using ARR87 methods as was considered best practise at this time. Key outputs of the study were the establishment of hydrologic (Regional Storm Water Model, RSWM) and hydraulic (MIKE-11) models. RSWM was calibrated to stream gauge data from the Cooma Creek at Cooma No.2 (410081) station for the January 1992 and July 1991 events, and validated using the June 1991 flood. Flood frequency analysis was undertaken at this gauge and was used to verify design flow estimates. The MIKE-11 was developed using a series of creek and bridge cross-sections and was calibrated using to the 1991 and 1956 flood events.

The study also included a review of emergency response procedures, existing flood mitigation measures and local planning controls. Mitigation measures were assessed, including upgrading and extension of the existing levee, channel modifications along the creeks, vegetation clearing, sediment traps and catchment-wide measures.

The following measures were discussed (the relevance to the current study is included after each):

- A levee upstream of Egan Street – this levee was subsequently constructed. A review of the current levee system is described in Section 3.3.1 and potential upgrades to the levee system are described in Section 8.4.1.
- Visibility improvements for approaches to Commissioner Street causeway – these were subsequent constructed and the issue resolved.
- A new bridge at either Massie Street or Commissioner Street – this has not been built. A bridge at Massie Street is currently being considered by Council, separate to this study.
- Pedestrian access and recreational improvements along Cooma Creek – this has been built and the issue resolved.
- Augmented stormwater drainage around Sharp Street to reduce localised overland flooding (separate to creek flooding).
- Extension of Mulach Street levee beyond confluence of the two creeks – this has been built and flood risk is now limited to overtopping of the levee. Discussion of flood modification measures for Cooma is in Section 8.4.1.
- Raise Vulcan Street at Sandy Creek by at least 1.5 m over 100 m section and increase culvert to have 3 m^2 cross-section area – this was not built. Discussion of road and culvert upgrade is given in Section 8.4.1.2.
- Channelisation works of Cooma Creek and Cooma Back Creek immediately upstream of their confluence – this appears to have been carried out and the issue resolved.
- Vegetation clearing in Cooma Back Creek with focus on willow trees – this has now been implemented. Vegetation management is discussed in Section 8.4.1.
- Sediment traps consisting of 1 m rockfill weirs on Cooma Creek and Cooma Back Creek – these appear to not have been built.

2.3.3. Review of Environmental Factors for the Cooma Flood Mitigation Works (SMEC, 1998)

The study presented the proposed levee upgrade in detail and assessed the potential environmental and social impacts of the works. The upgrade, which was recommended by the 1994 study, was designed to provide protection up to the 1 in 20 year ARI flood, and included channel excavation, construction and raising of earth levees, masonry levee walls, sediment traps and reconstruction of the low-flow channels. Assessment of environmental impacts included those related to general environment, hydrology, water quality, soils, flora and fauna. The following environmental impacts were emphasised as being significant:

- Water quality impacts, and erosion and sedimentation issues during the construction phase, which can be minimised via identified mitigation measures.
- No impact on threatened flora or fauna but removal of five native pine trees to be offset with planting of new trees. Increased sediment at the billabong downstream of the confluence can impact the platypus population.

Social impacts included land use planning, visual amenity, heritage, noise, air quality, traffic and safety. The following social impacts (excluding positive impacts) were emphasised as being significant: visual impact of the works, closure of local roads, land acquisition for affected property owners and residential amenity during construction.

2.3.4. Cooma Flood Mitigation Works, Final Report on Phase 1 and 2 Investigations (SMEC, 2000)

The study was undertaken to assess and evaluate specific aspects of the levee design, including the condition of riffle zones, erosion protection at stormwater outlets, effect on water levels for design alternatives, and sediment trap layout. The study concerns detailed design features of the levee design and is generally not relevant to the current study, which does not relate to detailed design of mitigation works.

2.3.5. Stormwater Management Plan for Jindabyne, East Jindabyne, Tyrolean Village and Berridale (Storm Consulting, 2001)

The report consists of a stormwater management plan carried out for Snowy River Shire Council's urban areas. The study includes a description of the LGA's catchments, land use, and future urban development. The study makes assessment of the area's geology, hydrology, water quality, flora and fauna, and existing stormwater infrastructure. It then sets out objectives for new development, across the planning, construction and post-construction phases. The study identifies several stormwater-related issues in Berridale and lists potential mitigation options for each. The majority of the options relate to stormwater and will have minimal or negligible effect on flooding. The Plan considered a willow tree replacement program on Myack Creek (this has not been implemented, a vegetation management plan is discussed in Section 8.4.1.5). The Plan was reviewed and revised as part of the 2013 Stormwater Management Plan (see below).

2.3.6. Stormwater Management Plan Review 2013 for Snowy River Shire Council (Footprint Sustainable Engineering, 2013)

This report is a list of locations where stormwater issues exist in Berridale, Jindabyne and East Jindabyne, and options for their management. Locations in Berridale include poor drainage between Jindabyne Road and Middlingbank Road, frequent creek flooding between Robert and Park Streets, lack of kerb and gutter on the eastern side of Berridale, and erosion at the outlet apron of the Edward Street crossing of Myack Creek. It recommends a strategic approach to stormwater management is required for future development. As with the previous Plan, most options will have minimal effect on flooding. The relevant recommended options are:

- undertaking a flood study for Berridale – completed in 2015 (see Section 2.3.7 and revised in 2019 by SMEC/GRC Hydro)
- culvert upgrade for Jindabyne Road at Myack Creek
- repair the outlet apron of the Myack Creek culverts at Edwards Street (appears to be William Street, however these were subsequent constructed and the issue resolved)
- prepare a Development Servicing Plan to ensure development in Berridale does not worsen flooding. 2020 status.

2.3.7. Flood Study – Berridale Township (Myack St – Kosciuszko Rd Intersection) (Kleven Spain Survey Consultants, 2015)

The study consisted of a hydrologic and hydraulic assessment of the 100 year ARI flood event in Berridale. The hydrologic model used is not stated, while HEC-RAS appears to be used to determine flood levels and extents. The study recommended the following measures:

- Myack Street walkway bridge be removed.
- Jindabyne Road be lifted and box culverts constructed, to improve access.
- Land between Park Street and Jindabyne Road should be designed as a floodway, including clearing obstructions, reshaping land, and construction of a causeway at the end of Park Street where it turns back to Jindabyne Road.
- Similarly land between James and Myack Streets be reshaped and obstructions removed.

- Kerbs and gutters, sealed pavements and drainage pipes be built in Williams Street to mitigate flooding at a local commercial enterprise. Works also include earthen levees along property boundaries.

The study also recommended two works for Council's consideration:

- Remove all excessive vegetation and obstructions along Coolamatong Creek, reshape the creek bed and replace existing channel with grass or concrete lining, with constant gradient from James Street to Park Street.
- Construct a detention storage upstream of Berridale on Coolamatong Creek, either as part of Coolamatong Lake or as a separate basin downstream of the lake.

These measures were reviewed in preparing measures as part of the current study (see Section 8.4.2.1).

2.3.8. Snowy Monaro Regional Local Flood Plan (NSW SES, 2017)

The Plan sets out all responsibilities, processes and other LGA-wide information before containing town-specific information in its volume 2 and annexes. Information on each of the towns is as follows.

2.3.8.1. *Cooma*

The plan contains information on consequences of flooding, including areas where roads and properties are flooded, based on previous events and previous studies. It also includes description of the Cooma levee system, including its level of protection.

There are two telemetered stream gauges used for flood warning – 'SMEC (Sharp Street)' on Cooma Back Creek near Sharp Street, and 'Koolaroo' on Cooma Creek, also referred to as 'Cooma Creek at Cooma No. 2' in previous studies. The latter is approximately 2.5 km upstream of the Cooma Creek levee system, outside of the town. The Plan states that the BOM provides flood warnings for the two gauges. The minor, moderate and major flood levels, and their consequences have been collated in Table 5. Note this data is from the Local Flood Plan and not the current study. Review and update of the Local Flood Plan is suggested in Section 8.3.4.

Table 5: Summary of Cooma Gauge Information from Local Flood Plan

"SMEC (Sharp Street)" on Cooma Back Creek Gauge Depth	"Koolaroo" on Cooma Creek Gauge Depth	Consequence
	0.5 m	Minor flooding classification
1.8 m	3.8 m	Major flooding classification
1.84 m	3.8 m	10% AEP event, 25 properties flooded above floor
2.38 m	4.4 m	5% AEP event, design height of levee system (note in Plan that levee height requires confirmation)
4.06 m	5.7 m	1% AEP event, 60 properties flooded above ground, TAFE and Council basements flooded

The Plan states that evacuations are likely to be required from low-lying properties near Cooma Creek and Cooma Back Creek when the levee is at risk of overtopping. It also states that the major flood level should be used as a trigger to guide evacuations. It states that warning times are short and there may only be 1-2 hours notice of impending evacuations. It then sets out information for organising the evacuation.

The Plan states that the following locations are suitable for use as evacuation centres:

- Monaro High School, Mittagong Road, Cooma

- St Patrick’s Parish School, Murray Street, Cooma
- Cooma Multifunction Centre, Cromwell Street, Cooma
- Cooma Ex-Serviceman’s Club, Vale Street, Cooma

St Patrick’s Parish School is not flood affected, while Monaro High School has minor overland flow depths of less than 300 mm in the 0.2% AEP event and larger. Cooma Multifunction Centre is located next to Cooma Showground, around 170 m from Cooma Back Creek and is severely flood affected in the PMF. For this reason it should not be used as an evacuation centre during a flood. The Cooma Ex-Serviceman’s Club has some minor overland flow depths around it, in the PMF.

In a PMF event, additional centres will be needed for areas that are cut-off from one of the evacuation centres.

2.3.8.1. ***Bredbo***

For Bredbo, there is no existing flood warning system or flood intelligence specific to the town. The Plan sets out responsibilities and processes for the emergency response during a flood, which is primarily carried out by the SES. The closest SES Regional Operations Centre are located at Geebung Street, Polo Flat. The Plan includes a map of Bredbo and states there may be road closures during a flood, but does not otherwise describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs).

Whilst there is no flood warning system, the BOM does issue a range of warnings related to flooding that may be useful for response preparedness. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning. Flooding of the Murrumbidgee River, which can exacerbate flooding at Bredbo, is included in the warning system but is not described in the Plan in relation to flooding at Bredbo.

2.3.8.1. ***Berridale***

Similarly to Bredbo, at Berridale there is not an existing warning system or flood intelligence specific to the town. The Plan sets out responsibilities and processes for the emergency response during a flood, which is primarily carried out by the SES. The closest SES Regional Operations Centres in the LGA are located at Geebung Street, Polo Flat and on Lee Avenue in South Jindabyne. The Plan does not describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs).

As for other towns in the LGA, the BOM use a network of rainfall gauges and other data to issue a range of warnings related to flooding. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning.

2.3.8.1. ***Michelago***

Similarly to Bredbo and Berridale, there is not an existing warning system or flood intelligence specific to the town. The Plan sets out responsibilities and processes for the emergency response during a flood, which is primarily carried out by the SES. The closest SES Regional Operations Centre in the LGA are located at Geebung Street, Polo Flat. There is another SES unit in Queanbeyan (closer to Michelago) which the Plan states will respond for operations along and north of Michelago Creek. The Plan includes a map of Michelago and states there may be road closures during a flood, but does not otherwise describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs).

Further information on flood warning in each town is given in Sections 3.4 (Cooma), 4.4 (Bredbo), 5.4 (Berridale) and 6.4 (Michelago), emergency response management measures are set out in Section 8.3.

2.4. COMMUNITY CONSULTATION

Community consultation was undertaken as part of the 2019 flood study to inform the community of the study and to collect information relating to previous floods. In addition to these objectives, the consultation was aimed at identifying community concerns and developing the community's confidence in the study through close collaboration. The consultation follows the Community Consultation Plan drafted in December 2017, which included multiple activities, including media release, newsletter/questionnaire, a website and community workshops. Details of the newsletter and questionnaire sent out, as well as the community workshops, one-on-one meetings and meetings with other stakeholders are described in the flood study report.

Further consultation will be undertaken during public exhibition of the draft Floodplain Risk Management Study and Plan (this report). Residents will be contacted to inform them of the flood risk analysis and the recommended management measures. This report will then be updated based on the results of the consultation.

3. COOMA FLOOD RISK

3.1. OVERVIEW

Cooma experiences flooding due to Cooma Creek and Cooma Back Creek once flows exceed channel capacity, as well as overland flow from localised rainfall over the town. The two creeks pass through the centre of Cooma and can cause high hazard flooding of both roads and property. Depths of flooding tend to be greater for creek flooding, also referred to as mainstream flooding, than overland flooding, for which depths are typically less than 0.3 m. The two flooding mechanisms can occur simultaneously or separately. Description of the area's flood risk has been divided into the following sub-sections:

- **Flood Behaviour** (Section 3.2) describes the depth and velocity of floodwaters across the range of design flood events. This section includes flood hazard (Section 3.2.3), which relates depth and velocity to risk posed to pedestrians, vehicles and buildings, and also flood function (Section 3.2.4), which divides the floodplain into the categories of flow conveyance, flood storage and flood fringe.
- **Impact of Flooding** (Section 3.3) describes the consequences of flooding in urban areas. This section includes a review of the function of levee system in Cooma (Section 3.3.1), breakdown of flooding hotspots where flood risk is concentrated (Section 3.3.2), mapping of property flooding across the town (Section 3.3.3), flood liability of critical infrastructure and sensitive land uses (3.3.4) and the economic impact of flooding (Section 3.3.5).
- **Emergency Response** (Section 3.4) describes the flood warning system and operation of emergency services (Section 3.4.1) and the 'flood emergency response classification of communities (Section 3.4.2).

Assessment of land use planning as it relates to flooding, including the cumulative impact of future development on flooding, is described for the four towns in Section 7.

3.2. FLOOD BEHAVIOUR

3.2.1. Background

Cooma has a history of flooding in both Cooma and Cooma Back Creeks, with notable flood events occurring in March 1956, July 1991, January 2007 and February 2012 events. Areas at risk of flooding around the Cooma township include the central business district and low-lying areas adjacent to the creeks. Flooding on both creeks is generally considered to be flash flooding with little warning time and can be deep and fast flowing, posing significant hazard to life (SES, 2017). Nevertheless, creek improvement works, and the construction of the Cooma Creek levee and subsequent upgrades help alleviate some of the flood risks.

Cooma is also subject to flooding from various minor streams and overland flow paths which flow to Cooma Creek and Cooma Back Creek. Further east of the Cooma township there is a separate tributary/swale system adjacent to the Cooma/Polo Flat Airport which also flows in the northerly direction and eventually discharges into Cooma Creek several kilometres downstream. Inundation of some of the adjacent floodplain areas occurs along this tributary.

3.2.2. Design Events Levels and Depths

Table 6 summarises design flood levels for a number of locations in the town while Figure A 1 shows the 1% AEP peak flood depths. Figure A 2 shows the flood profiles for each design event for Cooma Creek and Cooma Back Creek. A full set of design flood mapping is included in the flood study.

Table 6: Cooma Design Flood Levels at Reporting Locations

ID	Location (see Figure A 1)	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	Cooma Creek at Bombala Bridge	792.3	794.6	794.8	795.1	795.4	795.7	796.0	796.3	800.7
2	Cooma Creek at Massie Street	786.1	788.3	788.5	788.7	789.0	789.2	789.4	789.7	796.1
3	Confluence of Cooma Back Creek and Sandy Creek	784.5	787.5	787.7	788.0	788.3	788.5	788.7	788.9	796.1
4	Confluence of Cooma/Cooma Back Creek	781.7	785.1	785.3	785.7	786.1	786.4	786.7	787.1	794.5
5	Behind levee at confluence of Cooma Creek at Cooma Back Creek	785.3	785.5	785.5	785.8	786.1	786.3	786.8	787.2	794.8
6	Campbell Street - Behind Levee	792.6	792.9	793.0	793.2	793.4	793.6	793.8	794.0	799.3
7	Polo Flat channel - U/S of Airstrip Road	815.0	817.0	817.1	817.1	817.2	817.3	817.3	817.4	818.1
8	Holland Road	818.1	818.3	818.4	818.4	818.4	818.4	818.4	818.4	818.7
9	South of railway, near Yareen Road and Woolalla Street	813.1	813.5	813.6	813.7	813.8	813.8	813.9	814.0	814.9
10	Yallakool Road	790.4	791.1	791.2	791.2	791.3	791.3	791.3	791.4	792.0
11	Sharp Street low point (1)	789.3	789.6	789.7	790.1	790.4	790.6	791.0	791.3	798.0
12	Sharp Street low point (2)	789.0	789.2	789.3	789.4	789.9	790.2	790.5	790.7	797.0

Cooma experiences significant flood affectation in events greater than the 10% AEP, with areas of significant inundation in the vicinity of the levee on Cooma Creek. The peak flood depths figures show the following areas of affectation:

- In the 5% AEP, approximately 10 properties between Campbell and Denison Streets are flooded (although not all have dwellings), with another cluster around Sharp Street adjacent to the levee also affected in that event.
- In the 1% AEP event, the area around the Cooma Creek levee and immediately upstream has some properties with depths of 1-2 m, with severe property flooding also occurring near Sharp and Commissioner Streets in the vicinity of the levee.
- In the 5% AEP, Cooma Back Creek is largely confined to the channel, except for breakout upstream of Kerwan Street (which results in the significant flooding of a number of properties) and to the west of the Cooma Bowling Club. In the 1% AEP event, there is severe flooding of properties upstream and downstream of Kerwan Street, as well as around Tumut Street, and immediately upstream of Sharp Street.
- Downstream of the two creeks' confluence, creek flow is contained in the 20% AEP, while the 5% AEP extent expands into the adjacent park area. In the 1% AEP, there is significant flooding of a handful of properties immediately west of the confluence at Mulach Street. While the flow width expands to greater than 100 m downstream of the confluence, the majority is confined to channel and the cleared paddocks on either side.
- On both sides of Mittagong Road, between Boona Street and Baroona Avenue, properties are affected by overland flood in the 5% AEP event with depths of up to 0.3 m.

- In Polo Flat, there is minor flooding in the vicinity of the area's drainage channel in the 20% AEP and flooding of Geebung Street which restricts access to the Cooma SES Unit. In the 5% AEP, there are large areas of flooding on some properties in the vicinity of the channel, with around 0.4 m depth of flooding. In the 1% AEP there is significant flooding of numerous properties, particularly in the north of the suburb, with depths of between 0.5 and 1 m.

3.2.3. Flood Hazard

Flood hazard is defined as the threat that the hydraulic characteristics of flooding will pose to human activity. It is initially calculated based on the flood's depth and velocity in each model grid cell, as part of the flood study stage. It is finalised during the floodplain risk management stage by considering other factors not covered by the depth-velocity calculation. The calculation is based on the Australian Emergency Management Handbook 7 guideline (reference in Table 3), which considers the threat to types of people (children, adult) and activity (pedestrian, vehicle and within a building). More information on its derivation is given in Section E.1.

There are six categories of flood hazard, specifically:

- H1 – Generally safe for people, vehicles and buildings
- H2 – Unsafe for small vehicles
- H3 – Unsafe for vehicles, children and the elderly
- H4 – Unsafe for people and vehicles
- H5 – Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

Hazard categories for Cooma are presented on Figure A 3 to Figure A 6, for the 5%, 1% and 0.2% AEP, and the PMF. The figures show the following areas of hazard:

- In the 5% AEP, nearly all areas of H2 – H6 are located in and adjacent to Cooma Creek and Cooma Back Creek. Other areas of overland flow are predominantly categorized as H1. Along the creeks, there are areas of H2-H5 outside the channel itself, for example upstream of the Cooma Creek levee. This hazard does not directly affect dwellings, save for one location on Albert St. There are areas of H2 hazard in Polo Flat, with Geebung Street affected by H4 hazard.
- In the 1% AEP, there are large sections of H5 hazard adjacent to the Cooma Creek channel. The flooded areas between Murray and Sharp Streets is mostly H2-H4. Residential areas on Cooma Back Creek downstream of Sharp Street are affected by flood up to H5 hazard. Polo Flat has large areas of H2 and H3 outside of the drainage channel.
- In the 0.2% AEP, large sections of the floodplains of the two creeks are H3-H5, including parts of the commercial area in the town centre. In the PMF, a large proportion of the town is H6, fringed by H1-H5.

Areas noted to experience a significant degree of flood hazard, including flooded roads, are discussed in detail in Section 3.3.2, Flood Hotspots.

3.2.4. Flood Function

Flood function is a processed model output that classify floodwaters into flow conveyance (previously call floodway), flood storage or flood fringe. These categories describe the function of flow in a particular area of the floodplain and are commonly used by town planners to understand flood behaviour in an area of potential development. Areas of flow conveyance are generally incompatible with development aside from parks or recreational facilities, while areas of flood storage can generally be developed, if the loss of storage or other impacts are managed. Flood fringe is areas of shallow flooding that, if developed, have minimal effect on the overall function of the floodplain.

Further information on flood function including its derivation for the study area is given Section E.2.

The flood function categories of flow conveyance, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP, 0.2% AEP and PMF events and are shown in Figure A 7 to Figure A 10.

The figures show that in the 1% AEP, the majority of the mainstream flood extent is flow conveyance, as would be expected based on the well-defined channels and limited overbank. Small areas of flood storage and fringe on the periphery. There are some smaller flow conveyance areas caused by overland flooding. The rest of the town is mostly flood fringe. Areas outside the town, are typically affected by overland flooding with a flood fringe classification.

In the 5% AEP, the flow conveyance is typically confined to the mainstream channels while there is a much larger flow conveyance area, beyond the main channel, in the 0.2% AEP. As with the 1% AEP, overland flooding is mostly classified as flood fringe. In the PMF, the majority of all flooded areas are classified as flow conveyance, with flood storage and fringe on the periphery.

3.3. IMPACT OF FLOODING

3.3.1. Review of Cooma Flood Mitigation Scheme Levee

The Cooma Flood Mitigation Scheme protect parts of the town from small Cooma Creek flood events, while being overtopped or circumvented by floodwaters in larger events. There are three earth embankment levees (see Figure A 1), one on both the east/west banks of Cooma Creek, and another at the Cooma Creek / Cooma Back Creek confluence.

The analysis undertaken herein considers both the crest level and estimated design height of the levee. It should be noted that in most instances, the design height of the levee is below the levee's crest level. This is because a crest height of the levee typically incorporates a freeboard which is used as a factor of safety to ensure that the selected level of protection for the levee is reasonably achieved and uncertainties in the design are accounted for. In a flooding context, a freeboard is used to account for design variables such as uncertainties in design flood level estimates, wind and wave action, localised hydraulic effects, climate change and post construction settlement and levee defects. It is important to note that during an actual flood event, if the design height of the levee is exceeded, it may not be the case that the levee is overtopped. The design freeboard of the Cooma levee system was 0.5 m.

The levee on the east side of Cooma Creek is approximately 750 m long with a crest level varying between 789.8 and 793.2 mAHD, and design level between 789.3 and 792.7 mAHD (based on the SMEC, 2000 study discussed in Section 2.3.4). It starts north from Sharp Street and goes around the corner between Denison Street and Victoria Street, where it ends. The first area of overtopping is likely to be at a low point halfway between Sharp Street and Commissioner Street. At this location, the 10% AEP flood level is slightly higher than the design level (i.e. crest level minus 0.5 m freeboard). Figure 3-1 shows the levee crest level and design compared to the range of design flood events.

The levee on the west side has a length of approximately 1030 m with a crest level varying between 789.2 and 793.7 mAHD. It starts north from Sharp Street and ends south from Victoria Street. The levee to the west is likely to first be overtopped around Sharp Street in a 5% AEP event. Figure 3-2 shows the levee crest level compared to the range of design flood events.

At Mulach Street, the levee is approximately 330 m long with a crest level varying between 787.8 and 786.3 mAHD. Assuming a freeboard of 0.5 m, it is first overtopped near the confluence of Cooma Creek and Cooma Back Creek in the 2% AEP event.

The levee system was also analysed for its overall effect on flooding. The function and limitations of a levee are sometimes not well-understood, including the concept of freeboard, the potential for flood events that overtop the levee, and the area that the levee protects. The area protected by the Cooma levee system can be understood by mapping the increase in flooding were the levee to be completely removed, as shown on Figure 3-3. The figure shows that in a 5% AEP flood, the main levee system protects an area on either side of the creek, extending around 50-60 m away from the creek. Without the levee, the largest area of different would be deeper flooding of Rotary Oval, which continues as a flowpath through Commissioner Street and Sharp Street. The figure also shows the Mulach Street levee does not significantly affect flooding in the 5% AEP event. This is because the residential lots are on naturally higher ground and it's only in the larger flood events (e.g. 2% AEP) that the levee prevents creek flooding at that location.

More information on the flood behaviour, hazard and property flooding is given in the flooding hotspots section (Section 3.3.2).

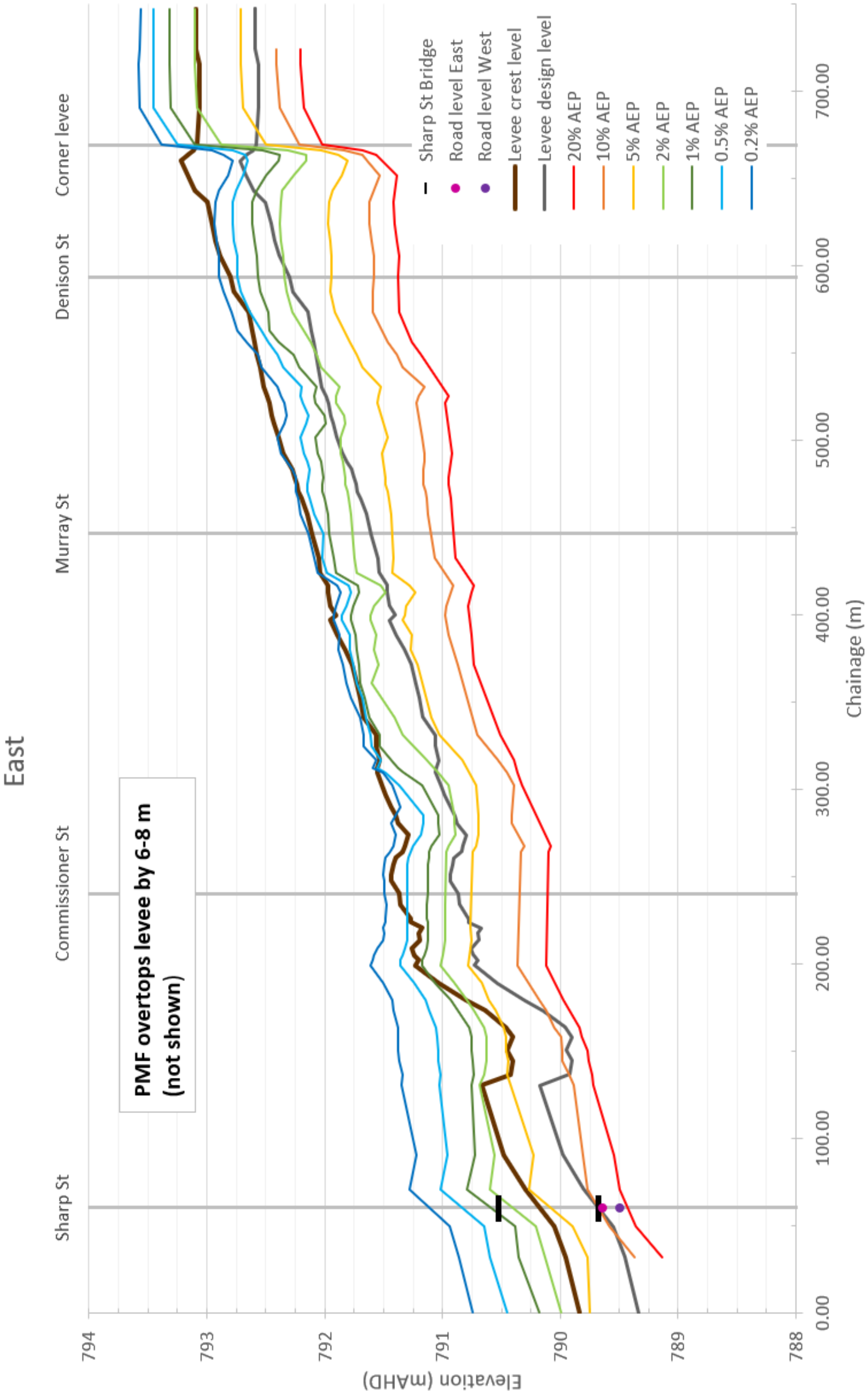


Figure 3-1: Design flood levels compared to levee crest level – Cooma Creek east side

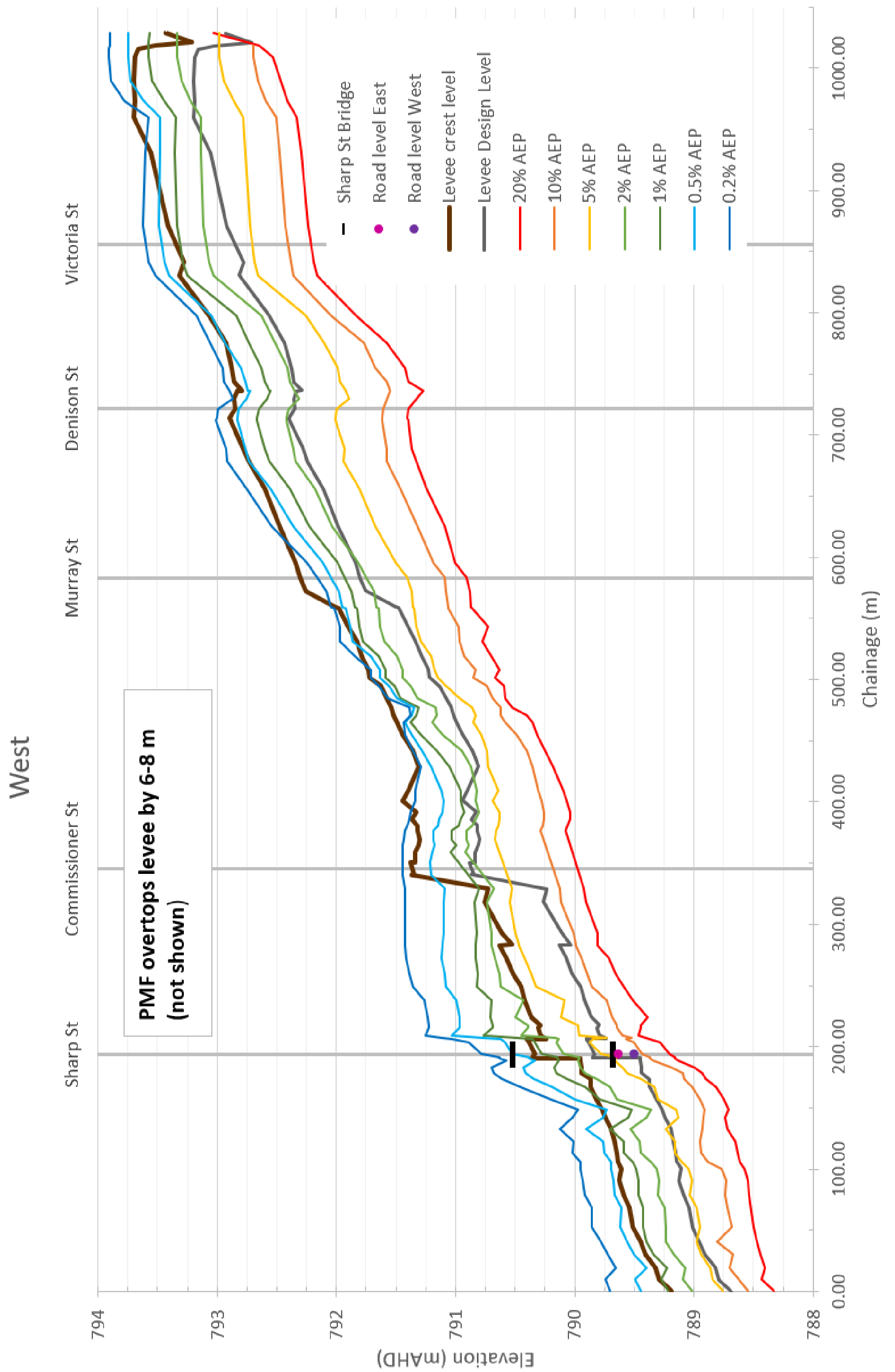


Figure 3-2: Design flood levels compared to levee crest level - Cooma Creek west Side

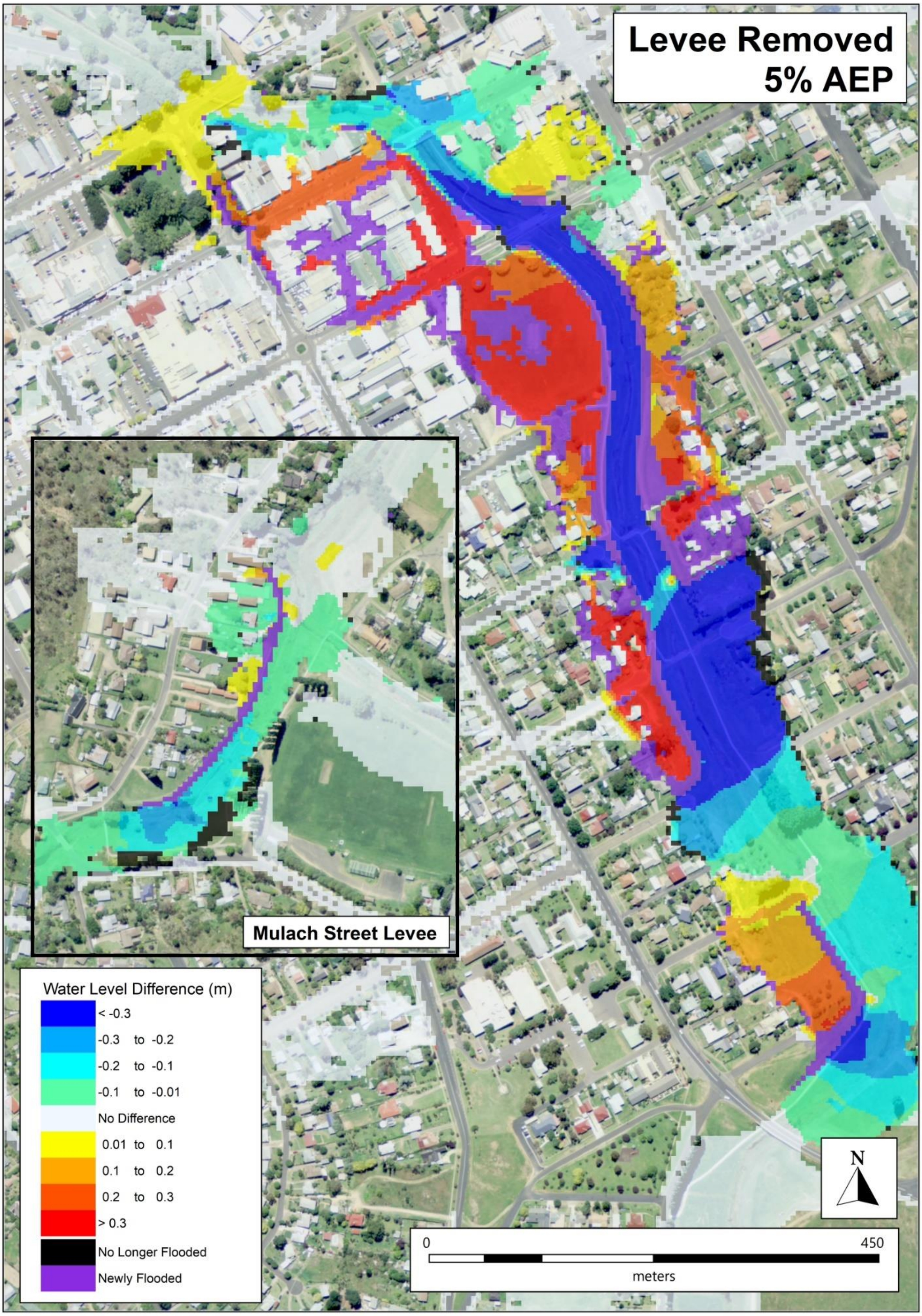


Figure 3-3: Area of increased flooding if the levee system is removed, in the 5% AEP flood event

3.3.2. Flooding Hotspots

Cooma contains several areas of concentrated flood risk, due to a combination of road and property flooding. These include the section of Cooma Creek from Church Road to Amos Street, the section of Cooma Back Creek from Sharp Street to the confluence with Cooma Creek, Sandy Creek near Vulcan Street, and in part of Polo Flat near the drainage channel through that area. The majority of the town's flood risk relates to mainstream flooding of these various watercourses. Areas of significant overland flooding are present but tend to have lower risk. In the following section, each hotspot has been described with regards to properties and roads inundated, and the depth and hazard of floodwaters for a range of events. Some areas have been separated into multiple hotspots for ease of presentation.

Summary of Cooma's Hotspots is presented in Table 7, with further details presented in Sections 3.3.2.1 to 3.3.2.8. The location of the various hotspots are presented in Figure A 1.

Table 7: Cooma Hotspots

Hotspot #	Location	Risk Factors
1	Cooma Creek at Church Road	Road flooding and evacuation/isolation issues
2	Cooma Creek Levee	Road and property flooding, overland flow trapped behind levee and hazardous flow overtopping levee.
3	Tumut Street	Road flooding and property flooding
4	Cooma Back Creek around Kerwan Street	Property flooding
5	Sandy Creek at Vulcan Street	Road flooding and evacuation/isolation issues
6	Cooma Back Creek levee at Mulach Street	Road and property flooding, overland flow trapped behind levee and hazardous flow overtopping levee.
7	Overland flow in Polo Flat	Road flooding and property flooding
8	Geebung Street	Road and property flooding, impeded access to SES unit

3.3.2.1. ***Hotspot 1 - Cooma Creek at Church Road***

The northern end of Church Road, upstream of Snowy Mountains Highway, may become flooded when Cooma Creek exceeds its channel capacity. The road, which is on the west side of the creek, is around 2.5-3 m higher than the channel, while the residential lots are on sloped ground, around 1-1.5 m higher than the road. This means that above-floor flooding only occurs in rare events and that hazardous flow on the road is the primary flood risk in the hotspot. In addition, a number of properties on Church Road to the north of Culey Avenue can become isolated as well as rural areas to the south of town, however alternative access routes are available for the surrounding urban areas.

Table 8 describes the area's flood behaviour and flood risk.

Table 8: Cooma Creek at Church Road Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, up to 0.6m at Church Road in the sag between Sellar Street and Culey Avenue. Around 0.2 m in other parts of the road. • In 1% AEP, 1.0m at Church Road in the sag between Sellar Street and Culey Avenue. Around 0.7 m in other parts of the road.

Flood Hazard	• In 5% AEP, majority of road is of H1, however road sags are H2-H3 • In 1% AEP, majority of road is of H3-H4, some properties are H2
Properties flooded	• 0 in 5% AEP • 5 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Properties adjacent to flooded areas of Church Road will have rising road access to evacuate before the road is flooded, and overland escape routes once the road is cut off.
Duration	Depending on the length of the storm event, flooding likely to last one or several hours.
Additional Risk Factors	The road is both an important access route for properties to the south, and adjacent to highly hazardous flow in Cooma Creek. Flooding of the road can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event. There is risk of a vehicle being swept into the creek in 5% AEP and rarer events.
Gauge levels	The road has H2 hazard when Cooma Creek gauge reaches 804.4mAHD (3.8m level at gauge) and 790.3mAHD at hypothetical gauge (see Section 8.3.5), equivalent to a 5% AEP event.

3.3.2.2. ***Hotspot 2 - Cooma Creek Levee***

The Cooma Creek levee system is first overtopped in the 10% AEP event at localised low spots, and then over wide sections in the 5% AEP and greater. A description of the levee's overtopping and level of protection is given in Section 3.3.1. The levee protects the residential area south-east of the town centre from flooding, as well as the town centre itself on Sharp Street. The levee both confines the creek flow in a flood event and blocks the overland flow from the adjacent urban areas that naturally drains to the creek. This overland flow discharges through stormwater drainage that passes through or underneath the levee, but this will be impeded once the creek water level is high, which can cause ponding and flooding from overland flow on the 'dry' side of the levee.

Table 9 describes the area's flood behaviour and flood risk.

Table 9: Cooma Creek Levee Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of exceeding 0.5 m are common behind the levee, with depths of up to 1.0 m at some locations (e.g. eastern bank levee at Sharp Street). • In 1% AEP, water depths of exceeding 1.0 m are common behind the levee, with depths of up to 1.5 m at some locations (e.g. western bank between Sharp Street and Commissioner Street)
Flood Hazard	• In 5% AEP, areas of overtopping are mostly H2-H3, as well as overland flow trapped behind the levee. H5 is limited to the Bombala/Massie St intersection. There is H2-H3 flow on Sharp St caused by levee overtopping. • In 1% AEP, areas of overtopping have sections of H4-H5, but most flow is H2-H3. Flow breakouts at Sharp Street results in H5 flooding to the west of the bridge, posing a significant risk to vehicles and pedestrians. The flow breakout then turns north and becomes H4 on Bombala Street, meaning that there is a risk that vehicles and pedestrians could be swept into Cooma Creek at Massie Street The flooding in this area is associated with significant risk to life during rare to extreme flood events.
Properties flooded	• 92 in 5% AEP • 150 in 1% AEP

Properties flooded above floor (approx.)	• 18 in 5% AEP • 42 in 1% AEP
Evacuation	Most properties around the Cooma Creek levee can evacuate through rising road escape routes, if required. The exception are the properties located at Sharp Street which may become isolated due to flows along this road and through Bombala Street may isolate properties before they are able to evacuate. Due to the fast rate of rise associated with levee overtopping/failure, even properties with rising road access may become isolated due to high hazard flooding surrounding individual buildings.
Duration	Depending on the length of the storm event, flooding is likely to last several hours. Inundation due to overland flow trapped behind the levee may be present for several days if Cooma Creek levels remain elevated.
Additional Risk Factors	• The majority of the levee is an earth embankment, so there is some risk of levee failure due to the crest rapidly eroding. • Overtopping of the levee can occur at multiple points simultaneously and unpredictably, as there is not a well-defined spillway section. • Overland flow may be trapped behind the levee when the creek is high, potentially leading to properties affectation
Gauge levels	First overtopping of levee when existing gauge at Cooma Creek reaches 803.9mAHD (3.3m gauge depth) and 789.7mAHD at the hypothetical gauge (see Section 8.3.5), equivalent to a 10% AEP event. Generalised overtopping of levee when existing gauge at Cooma Creek reaches 804.4mAHD (3.8m deep at gauge) and 790.3mAHD at proposed gauge, equivalent to a 5% AEP event.

3.3.2.3. *Hotspot 3 - Tumut Street*

The watercourse that goes underneath of West Street, Hill Street, and Lambie Street, partly through a series of culverts, has its capacity exceeded at Lambie Street in relatively common flood events, with flow overtopping the road and continuing through Tumut Street. Flood risk exists in the form of hazardous flooding on the roads, and risk to dwellings in the affected area.

Table 10 describes the area's flood behaviour and flood risk.

Table 10: Tumut Street Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.2m are present at the front of properties, 0.6-2.1 m at the rear. • In 1% AEP, water depths of up to 0.3m are present at the front of properties, 1.2-2.8 m at the rear.
Flood Hazard	• In 5% AEP, H1 is prevalent across the area, and some small portions of H2, the watercourse to the rear of the properties has H2-H5. • In 1% AEP, H2 is prevalent across the area. The watercourse has H2-H5.
Properties flooded	• 11 in 5% AEP • 16 in 1% AEP
Properties flooded above floor (approx.)	• 1 in 5% AEP • 2 in 1% AEP
Evacuation	Residents are able to evacuate through the road for events of up to 5% AEP, in larger events the road may become hazardous for smaller vehicles. To the south of Tumut Street residents may still be able to evacuate through the footpath for events up to 1% AEP, but residents on the northern side may become isolated within their homes due to high hazard flooding surrounding the properties.

Duration	Flooding is likely to last one hour or less, but could potentially be longer in some flood events.
Additional Risk Factors	-
Gauge levels	Overland flow catchments are too small to use flow or level gauges.

3.3.2.4. ***Hotspot 4 - Cooma Back Creek around Kerwan Street***

From Sharp Street to near Kerwan Street, Cooma Back Creek overtops its banks and floods the surrounding properties for events as small as the 10% AEP event. The creek in this area is heavily vegetated and consists of a well-define channel, several metres deep, with residential dwellings immediately adjacent on the out-of-bank area. Flood risk relates to high hazard flow, in close vicinity to the main channel, directly affecting dwellings and their occupants.

Table 11 describes the area's flood behaviour and flood risk.

Table 11: Cooma Back Creek around Kerwan Street Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, 0.1-0.2 m in most areas outside the channel, up to 0.4 m at low points • In 1% AEP, 0.7-0.9 m in most areas outside the channel, up to 1.2 m at low points
Flood Hazard	• In 5% AEP, outside of the creek channel, H1-H2 on most affected properties and up to H4 at some low points. • In 1% AEP, H4 and H5 flow across several lots, including against buildings, and H2-H3 in other areas.
Properties flooded	• 12 in 5% AEP • 24 in 1% AEP
Properties flooded above floor (approx.)	• 2 in 5% AEP • 12 in 1% AEP
Evacuation	While there is rising road access to flood free land to the east and west of the creek, however, in large floods some lots are surrounded by breakout flowpaths and will not be able to safely evacuate due to high hazard flows surrounding dwellings.
Duration	Flooding is likely to last one hour or less, but could potentially be longer in some flood events.
Additional Risk Factors	As there have not been any major flood events in recent times, there is likely to be low awareness of flooding in the area, especially the severity of large flood events. There is potential for vehicles or pedestrians to be swept into Cooma Back Creek.
Gauge levels	Information on the Cooma Back Creek gauge was not available at the time of writing.

3.3.2.5. ***Hotspot 5 - Sandy Creek at Vulcan Street***

In the 5% AEP and larger flood events, Sandy Creek overtops Vulcan Street when the capacity of the 0.75 m diameter culvert under the road is exceeded. It is unlikely to cause significant property damage, but it does isolate the residents at Mulach Street hindering access and egress. Alternate access to the area is via the causeway at Creek Street, but this access is likely to also be cut due to flooding on Cooma Back Creek. Flood risk relates to residents who try to cross the flooded road (Vulcan Street) and isolation of Mulach Street, although it is not likely to last more than several hours.

Table 12 describes the area's flood behaviour and flood risk.

Table 12: Sandy Creek at Vulcan Street Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, shallow high hazard flow with water depths of up to 0.1m over centreline of Vulcan Street, higher depths on the side of the road. • In 1% AEP, water depths of up to 0.4m over centreline of Vulcan Street, higher depths on the side of the road.
Flood Hazard	• Up to H4 on the road in the 5% AEP • Up to H5 on the road in the 1% AEP
Properties flooded	• 2 in 5% AEP • 2 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Residents at Mulach Street are unable to evacuate as both of the area's access routes (Vulcan Street and the Creek Street causeway) becomes too hazardous for vehicles and people to cross during a flood event. Isolation can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event.
Duration	Flooding is likely to last one hour or less, but could potentially be longer in some flood events.
Additional Risk Factors	There is risk of people and vehicles being swept into Cooma Back Creek if either road crossing is attempted during hazardous flow. Vehicles entering floodwaters can pose a significant risk to life.
Gauge levels	The Sandy Creek catchment does not contain any stream or level gauges.

3.3.2.6. ***Hotspot 6 - Cooma Back Creek Levee at Mulach Street***

The levee located between Cooma Back Creek and Mulach Street may be overtopped during events as small as the 2% AEP event. Further, overland flows within the levee may cause property flooding during frequent events if the region cannot drain due to elevated Cooma Creek levels.

Table 13 describes the area's flood behaviour and flood risk.

Table 13: Cooma Back Creek Levee at Mulach Street Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.6m behind the levee due to ponding overland flow • In 1% AEP, water depths of up to 1.0m behind the levee due to levee overtopping and inundation from Cooma Creek
Flood Hazard	• Localised H2-H3 behind the levee in the 5% AEP event • Widespread H2-H3 behind the levee in the 1% AEP event
Properties flooded	• 21 in 5% AEP • 24 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 2 in 1% AEP
Evacuation	Residents affected by trapped overland flow are able to evacuate to higher grounds away from the creek, but may be isolated due to flooding of Vulcan Street at Sandy Creek and Barrack Street at Cooma Back Creek.

Duration	Depending on the length of the storm event, flooding likely to last several hours. Shallow inundation may be trapped for several days if Cooma Creek levels remain elevated, or drains are blocked.
Additional Risk Factors	A levee failure scenario could lead to a hazardous surge of water affecting properties in this area.
Gauge levels	Overland flow catchments are too small to use flow or level gauges.

3.3.2.7. ***Hotspot 7 - Overland flow in Polo Flat***

Numerous properties in the industrial area of Polo Flat are affected by overland flows as they have floor levels at or just above surrounding ground levels. Minor drains and swales exist in the area, however the capacity of these systems are quickly exceeded during major rain events. Above floor property affectation is noted to start in events as frequent as the 20% AEP. Flooding can occur due to areas west of Polo Flat Road being slightly slower than the road, which causes shallow flow to be trapped by the road, and stormwater pits to surcharge when the Polo Flat watercourse is high. Flood risk relates to low hazard but widespread flooding causing damage to buildings in the area.

Table 14 describes the area's flood behaviour and flood risk.

Table 14: Overland Flow in Polo Flat Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of typically < 0.2m at most affected properties • In 1% AEP, water depths of typically < 0.3m at most affected properties
Flood Hazard	• The area has a hazard level of H1 in the 5% AEP event • The area has a hazard level of H1 in the 1% AEP event
Properties flooded above ground	• 13 in 5% AEP • 14 in 1% AEP
Properties flooded above floor (approx.)	• 7 in 5% AEP • 9 in 1% AEP
Evacuation	Flood hazard in the area is low and evacuation may not be necessary, but if required, people are able to evacuate the area through the roads
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	Flooding of industrial areas may result in the inundation and distribution of hazardous materials.
Gauge levels	No applicable stream gauge.

3.3.2.8. ***Hotspot 8 - Geebung Street***

Flooding can occur at Geebung Street when the capacity of the 1.8m diameter pipe which passes through the area is exceeded. Flood risk in the area relates to above-floor flooding of properties, and high hazard flows at the location of the Geebung Street crossing of the swale that runs parallel to Polo Flat Road. The swale poses a risk to vehicles and pedestrians.

Table 15 describes the area's flood behaviour and flood risk.

Table 15: Geebung Street Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• Up to 0.5m on Geebung Street in the 5% AEP • Up to 0.8m on Geebung Street in the 1% AEP
Flood Hazard	• Hazard level H1-H2 at properties, and H3 at Geebung Street crossing the swale • Hazard level H1-H3 at properties, and H3-H5 at Geebung Street crossing the swale
Properties flooded above ground	• 9 in 5% AEP • 15 in 1% AEP
Properties flooded above floor (approx.)	• 7 in 5% AEP • 10 in 1% AEP
Evacuation	Properties at Geebung Street becomes isolated as the swale crossing the streets makes it too hazardous for vehicles to cross
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	The SES and RFS are located at Geebung Street and may become isolated, lose power and become ineffective during a flood event
Gauge levels	The Polo Flat catchment does not contain any stream or level gauges.

3.3.2.9. ***Flooded Roads – Cooma***

Hazardous flooding of roads occurs when there is sufficient flow to knock over pedestrians or transport cars off the road due to buoyancy effects. In Australia, vehicles attempting to cross flooded roads is one of the largest causes of injury and fatality during a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at small flow speeds (this corresponds to H2 hazard). The following roads have been identified as experiencing hazardous flow (H2 or above) in a 5% AEP event. Many of these crossing experience hazardous flows in even more frequent events.

- Geebung Street (most of the street has some flooding, higher flow is near the road culverts around 60 m east of Polo Flat Road)
- Carlaminda Road at watercourse that traverses Polo Flat, around 720 m west of Polo Flat Road
- Church Road at three locations (30 m south of Sellar Street, 100 m north of Sellar Street, and around 400 m south of Culey Avenue).
- Vulcan Street where it crosses Sandy Creek
- Numeralla Road where it crosses Polo Flat watercourse (around 240 m north-east of Cooma Monaro Race Club)
- Yallakool Road at crossing with watercourse west of intersection with Tillabudgerry Road
- Massey Street and Commissioner Street (these crossings have manually closed gates)
- West Street, Lambie Street and Hill Street where they cross the Cooma Back Creek tributary

These locations have also been listed in Section 8.3.1, which recommends warning signage. Note that other road locations may also be flooded in a 1% AEP event and larger events (see hazard maps).

3.3.2.10. ***Other Areas for Consideration - Cooma***

Aside from the hotspots described, there are various scattered instances of over floor flooding in the town (based on the analysis presented in Section 3.3.3). The following section describes property flood liability. Areas of flooding include:

- Wangie Street and Walla Street
- Area near Boundary Road and Mary Street
- Area between Boundary Road and Florence Street
- Gungarlin Street near Poplar Street

These properties may be affected by shallow flows associated with minor drainage.

3.3.3. Property Flood Liability

Properties across the study area may experience inundation during a flood event, with affectation focussed along the watercourses and overland flowpaths. As part of the economic damages assessment, the flood affectation on a per property level was assessed by comparison of each lot's ground level and habitable floor level to the design flood levels at the property. The comparison is made at a point location on each lot, usually at the visible entry (i.e. front door). The floor level at each lot is an estimate based on visual inspection and not a surveyed level. This assessment allows an overall estimate of where properties are flooded above floor level, as shown on Figure A 15, which colour codes each property for the flood event it is first flooded above floor level. The map also shows the 1% AEP hazard.

The map should be interpreted as an overall representation of above-floor flood liability, and as an estimate only for determination for any particular property. This is because the floor level was estimated from visual inspection, which is less accurate than survey, and secondly because minor landscaping drainage features within a lot are sometimes not accurately captured in the model which is assessing an area of 44 km^2. The latter tends to exaggerate above-floor flooding in areas of shallow overland flow. Where properties in H1 hazard are shown as flooded above floor in relatively frequent floods, this indicates that the property simply has a low floor level and that shallow flow depths could potentially cause above-floor flooding. However, in practise, often local landscaping/drainage may ameliorate the risk of above floor flooding.

3.3.4. Critical Infrastructure and Sensitive Land-Uses

Critical infrastructure is located throughout the area and if inundated during a flood, can significantly impact the functioning of the town. The following section describes the flood liability of various critical infrastructure. The section also describes the exposure of facilities particularly sensitive to inundation, including childcare, schools and aged care.

3.3.4.1. *Electricity*

The Cooma substation is situated on the northern side of the Monaro Highway between Polo Flat Road and Thurrung Street. The substation is supplied via two 132 kV transmission lines from the Canberra/Williamsdale area, providing electricity to the town of Cooma and its surroundings (inclusive of Bredbo, Berridale and Michelago), the NSW alpine region and the NSW far south coast.

The substation is noted to be above the level of the PMF and thus not subject to inundation.

Essential Energy have been contacted for comment however have not responded at the time of writing.

3.3.4.2. *Wastewater Treatment*

Cooma's wastewater treatment plant is located on Glen Road, approximately 3.5 km downstream of the Cooma/Cooma Back Creek confluence.

The plant, including its sewage treatment ponds, are not expected to be flooded until events larger than the 0.2% AEP event, indicating limited risk of spillage and downstream contamination.

3.3.4.3. *Hospital and Ambulance*

Cooma Hospital is situated on the corner of Victoria and Bend Streets. The hospital services Cooma and the surrounding areas (inclusive of Bredbo and Michelago) and provides 24 hour Accident and Emergency.

The hospital is noted to be above the level of the PMF and thus not subject to inundation. However, flooding of roads surrounding the Hospital may lead to reduced access during times of flood. This is discussed further in Section 3.2.3.

Cooma Ambulance Station (located in the Southern Sector of the NSW Ambulance Goulburn Area) is located on the same block as Cooma Hospital with access from Bombala Street. The ambulance station services Cooma and surrounding areas including Bredbo, Berridale and Michelago. Due to their proximity, Berridale may also be serviced by the Jindabyne Ambulance Station, and Michelago by the Queanbeyan Ambulance Station (as per liaison with NSW Ambulance).

The station is noted to be above the level of the PMF and thus not subject to inundation, however flooding of Bombala Streets during extreme events (approaching the PMF) may impact ambulance access. Further, flooding of roads in the region may lead to difficulties reaching the Ambulance Station due to roads being cut. Road closures around each of the towns is discussed further in their flood hotspots sections, however flooding of major arterial roads including, Snowy Mountains Highway, Kosciusko Road and Jindabyne Road are also likely during major storm events and would restrict regional ambulance access during major flood events. Details around flooding of these major arterial roads are limited as large stretches of these roads are situated outside of the current study, study areas.

3.3.4.4. ***State Emergency Service (SES)***

The Cooma SES Unit is located at 11 Geebung St, Polo Flat. The Unit services Cooma and the surrounding areas (including Michelago and Bredbo). The site is flood affected in events as small as the 5% AEP event, with flooding of Geebung Road reducing access to the site for events as small as the 20% AEP event.

3.3.4.5. ***Schools and Childcare Centres***

A review of schools and childcare centres at Cooma is presented in Table 16. The analysis found very little flood liability of the schools, with only minor flood affection (< 300 mm depth, H1 hazard) during extreme events approaching the magnitude of the PMF.

Table 16: Cooma Schools and Childcare Centres

Name	Location	First Flooded	Comments
Cooma Public School	Corner of Commissioner and Vale Street	Not flood affected	-
Saint Patrick's Parish School Secondary Campus	Cnr Vale St &, Murray St,	Not flood affected	-
The Alpine School	12 Mittagang Rd	> 0.2% AEP	Minor overland flow depths of less than 150mm
Snowy Mountains Christian School	Baroona Ave near Binalong Street	> 0.2% AEP	Minor overland flow depths of less than 150mm
Cooma North Public School	35 Baroona Ave near Mittagang Rd	Not flood affected	-

Monaro High School	Mittagang Rd near Baroona Ave	> 0.2% AEP	Minor overland flow depths of less than 300mm
St Patrick' Parish School - Primary	Cnr Vale St &, Murray St, Cooma NSW 2630	Not flood affected	-
Milestones Early Learning Cooma	43 Campbell St	Not flood affected	-
Cooma Lambie Street Preschool Inc	Lambie Street near its intersection with Vulcan Street	> 0.2% AEP	-

3.3.4.6. ***Aged and Vulnerable Care***

A review of aged/vulnerable persons care centres at Cooma is presented in Table 17. The analysis found very little flood liability of the care centres, with only minor flood affection (< 300 mm depth, H1 hazard) during extreme events approaching the magnitude of the PMF.

Table 17: Cooma Aged and Vulnerable Care

Name	Location	First Flooded	Comments
Sir William Hudson Memorial Centre Nursing Home	19 Buchan Parade	Not flood affected	-
Monaro Retirement Villas	7 Fachin Ave	Not flood affected	Access to the site may be impacted in events > 0.2% AEP
Sir William Hudson Memorial Centre	8 Fachin Ave	> 0.2% AEP (overland flow)	Access to the site may be impacted in events > 0.2% AEP
Monaro Early Intervention Service	6 Hill St	Not flood affected	-
Yallambee Lodge	1 Binalong St	> 0.2% AEP (overland flow)	Minor overland flow depths of less than 300mm
Monaro Retirement Villas	1 Brown Cl	> 0.2% AEP (overland flow)	Minor overland flow depths of less than 150mm

3.3.5. Economic Impact of Flooding

A flood damages assessment is used to quantify the economic impact of flooding on the community. The assessment equates the depth experienced at each property to an economic cost. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed management measures and by the state government in prioritising resources. More information on flood damages, including how they are derived, is provided in Section E.3. For Cooma, both residential and non-residential (commercial, industrial, public properties) damages were estimated.

Table 18 describes the residential flood damages estimate for Cooma, Table 19 shows non-residential flood damages, and Table 20 has the combined damages estimate. The combined Average Annual Damage is estimated as $4.68 million.

Table 18: Cooma Flood Damages - Residential

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	23	10	$3,141,400	34%	$28,600
10% AEP	31	18	$3,637,100	24%	$28,900
5% AEP	45	34	$4,376,900	14%	$29,600
2% AEP	75	58	$6,524,900	12%	$31,100
1% AEP	90	80	$9,012,400	6%	$36,200
0.5% AEP	109	96	$12,777,100	4%	$43,900
0.2% AEP	122	116	$15,946,100	3%	$50,100
PMF	437	310	$40,121,400	4%	$91,000
Average Annual Damages (AAD)			$ 1,405,000		$3,200

Table 19: Cooma Flood Damages – Non-residential

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	110	29	$6,511,800	30%	$88,000
10% AEP	125	37	$6,902,800	20%	$90,800
5% AEP	147	44	$10,665,800	13%	$107,700
2% AEP	203	68	$20,164,000	14%	$146,100
1% AEP	243	97	$27,719,000	7%	$182,400
0.5% AEP	286	138	$36,469,600	5%	$226,500
0.2% AEP	312	174	$46,332,400	4%	$280,800
PMF	167	166	$156,110,900	6%	$897,200
Average Annual Damages (AAD)			$3,274,700		$18,800

Table 20: Cooma Flood Damages - Combined

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	133	39	$9,653,200	31%	$52,500
10% AEP	156	55	$10,539,900	22%	$52,200
5% AEP	192	78	$15,042,700	14%	$60,900
2% AEP	278	126	$26,689,000	13%	$76,700
1% AEP	333	177	$36,731,500	7%	$91,600
0.5% AEP	395	234	$49,246,600	5%	$109,000
0.2% AEP	434	290	$62,278,500	4%	$128,900
PMF	604	476	$196,232,300	5%	$319,100
Average Annual Damages (AAD)			$4,679,700		$7,600

The tables show that there is significant flood affectation in Cooma in the full range of flood events, with increasing exposure in the 2% AEP and larger. In the 20% and 10% AEP events, around 40-50 properties are estimated to be flooded above floor, of around 150 flooded above ground. These are largely the result of overland flow, which causes widespread but shallow flooding in locations across Cooma. In the 5% AEP and larger there is greater property affectation along Cooma Creek and Cooma Back Creek, especially once the main levee is significantly overtopped around the 5%-2% AEP floods.

The results show that frequent events are responsible for over half the AAD figure. The standard residential flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $9.6m in 20% AEP). This is likely an over-estimate of the actual damage cost for the reasons described in Section 3.3.3. In rarer events, the number flooded above floor level increases significantly, and there is a corresponding increase in the event damages, with $36.7 million in the 1% AEP.

The separation of residential and non-residential damages shows that non-residential properties, which includes factories, warehouses, shops and schools, have significantly higher damage estimates on a per property basis. This is due to the higher damage curve values for non-residential properties, and its incorporation of costs per m^2. There are also a greater number of non-residential properties flooded in most events, for example 37 flooded above floor in a 10% AEP event, versus 18 residential.

3.4. EMERGENCY RESPONSE

3.4.1. Flood Warning and Emergency Response

Understanding of the available flood warning and emergency response in Cooma are largely understood from information provided in the Local Flood Plan, which is summarised in Section 2.3.8. Cooma has an existing flood warning system based on a series of rainfall and stream gauges in the Cooma Creek and Cooma Back Creek catchments, with the Local Flood Plan summarising the flood levels at the gauges and the consequences regarding road and property flooding. It states that warning times are short and there may only be 1-2 hours notice of impending evacuations.

Analysis of four historical flood events indicates Cooma has a warning time of 0-1 hours. Comparison of the end of the peak rainfall burst with the peak flood level showed a difference of 1 hour or less for most events. There is minimal travel time between the Cooma Creek gauge and the town centre near Sharp Street.

The BOM use a network of rainfall gauges and other data to issue a range of warnings related to flooding. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning. These warnings are typically issued for a large area containing multiple towns.

For the warnings issued for the two gauges, liaison with the BOM indicates that their warning system uses three data inputs – forecast rainfall, observed rainfall and observed water level – to automatically and continuously monitor the likelihood of a flood occurring. When certain triggers are met, a flood warning is issued, with a target lead time of 1 hour. This would very likely be preceded by previous more general warnings and alerts for flooding in the area, to assist emergency services.

Overall, Cooma experiences flash flooding and the small available warning time leads to a high flood risk in the town. Flash floods are difficult to forecast as the rainfall is very localised, which forecast models can less accurately predict than wider rainfall events. The short warning time means that in a large flood, emergency services must evacuate several separate areas and manage potentially reluctant or slow residents. Emergency services are also likely to experience access issues due to flooded roads. The BOM warning system that incorporates various data input reduces the risk by increasing the warning time, but will ultimately only issue the warning, with no guarantee of successful evacuation.

Discussion of improvements to the flood warning system is given in the flood risk management measures section (Section 8.3).

3.4.2. Flood Emergency Response Classification of Communities

Flood Emergency Response Classification refers to categorising parts of the floodplain based on their evacuation constraints. Mapping of evacuation constraints across the study area assist the SES and other emergency responders in planning where assistance, evacuation or rescue is needed for individual properties. The categories have been mapped for three design events (5% AEP, 1% AEP and PMF) to understand how evacuation constraints vary between different-sized floods. The categories have been determined in accordance with DPIE's 'Flood Emergency Response Planning Classification of

Communities' guideline. The categories are shown on Figure Figure A 11 (5% AEP), Figure A 12 (1% AEP) and Figure A 13 (PMF).

The figures show that:

- In the 5% AEP, most flood-prone urban areas are classified as Rising Road Access. Some areas, for example Sharp Street immediately west of Cooma Creek, are a mixture of Low Flood Island and High Trapped Perimeter. There is a Low Flood Island along Cooma Back Creek downstream of Sharp Street.
- In the 1% AEP, most categories are unchanged from the 5% AEP. Areas of difference include a Low Flood Island at the south end of the west bank of the levee system, a larger Low Flood Island along Cooma Back Creek including the Tumut Street flowpath, and a large area centred on Mulach Street classified as a High Trapped Perimeter area.
- In the PMF there is H6 hazard along both creeks, extending around 100 to 150 m either side of the channel. This forms a very deep and fast moving flow path that is extremely hazardous to vehicles, pedestrians and buildings. While all major roads will be completely blocked by flooding, there is still high ground available for short-term evacuation (see PMF hazard map).

4. BREDBO FLOOD RISK

4.1. OVERVIEW

Bredbo experiences flooding due to the Bredbo River, overland flow and the Murrumbidgee River during extreme flood events. Bredbo River joins the Murrumbidgee River downstream of the town, and the Murrumbidgee River can exacerbate flooding at Bredbo if both rivers are high. Bredbo River does not flood most of the town in most flood events, but in rare and extreme events it will cover large parts of the town with significant flooding. A small watercourse passes through part of the town, and some other locations also experience overland flow flooding. Description of the area's flood risk has been divided into the following sub-sections:

- **Flood Behaviour** (Section 4.2) describes the depth and velocity of floodwaters across the range of design flood events. This section includes flood hazard (Section 4.2.3), which relates depth and velocity to risk posed to pedestrians, vehicles and buildings, and also flood function (Section 4.2.4), which divides the floodplain into the categories of flow conveyance, flood storage and flood fringe.
- **Impact of Flooding** (Section 4.3) describes the consequences of flooding in urban areas. This section includes a breakdown of flooding hotspots where flood risk is concentrated (Section 4.3.1), mapping of property flooding across the town (Section 4.3.2), flood liability of critical infrastructure and sensitive land uses (0) and the economic impact of flooding (Section 4.3.4).
- **Emergency Response** (Section 4.4) describes the flood warning system and operation of emergency services (Section 4.4.1) and the 'flood emergency response classification of communities (Section 4.4.2).

Assessment of land use planning as it relates to flooding, including the cumulative impact of future development on flooding, is described for the four towns in Section 7.

4.2. FLOOD BEHAVIOUR

4.2.1. Background

Bredbo River is the main watercourse flowing through the Bredbo township though the main mechanism of flooding was found to originate from the minor tributaries entering the river from the north. Some sections of the town are affected by overland flow flooding which drains through the township in southerly or westerly directions towards the Bredbo River. Local flooding in Bredbo town can be exacerbated when there is coincidental mainstream flooding on the Murrumbidgee River. The Murrumbidgee River can also be responsible for flooding in Bredbo during extreme events.

There is little data available describing previous floods in Bredbo. Residents reported floods of various sizes, including 1991, 2007, 2012, 2014/15 and 2016. These generally aligned with high rainfall events recorded in the region, including February 2012, December 2014 and June 2016.

4.2.2. Design Events

Table 21 summarises design flood levels for a number of locations in the town. Locations are shown on Figure B 1 which also shows the 1% AEP peak flood depth. Figure B 2 shows the flood profiles for each design event for Bredbo River. A full set of design flood mapping is included in the flood study.

Table 21: Bredbo Design Flood Levels at Reporting Locations

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
13	Bredbo River northwest of intersection with Monaro Hwy	696.5	699.1	699.7	700.4	701.3	702.2	703.2	704.5	718.6
14	Bransby Street near Clifford Street	699.3	699.7	699.8	700.3	701.2	702.2	703.2	704.4	718.6
15	Monaro Hwy near Clifford Street	702.8	703.5	703.5	703.5	703.5	703.5	703.5	704.4	718.6
16	North Street near Walker Street	706.6	706.8	707.3	707.5	707.6	707.7	707.9	708.1	718.6
17	Walker Street and Bunyan Street	703.8	704.0	704.0	704.0	704.0	704.1	704.1	704.4	718.6

Bredbo experiences significant flood affectation in events greater than the 20% AEP, with significant areas of inundation around Clifford and Bransby Streets. The peak flood depths figures show the following areas of affectation:

- In the 10% AEP, the channel running north to south through the west side of town has a flow width of approximately 30 m, with corresponding inundation on a number of properties and on several streets (Swan Street, Bunyan Street, North Street and the end of Clifford Street). In the 1% AEP, this width increases to around 40 m.
- There is a large area of ponding water in the vicinity of Clifford and Bransby Streets due to both local overland flows and Bredbo River flooding, with up to 1 m depth in the 10% AEP. In the 1% AEP this expands to completely inundate the area to a depth of between 1.5 and 3 m. A number of properties are significantly flood affected during the 1% AEP event by the Bredbo River.
- There is shallow flooding (<0.5 m) around the east end of Clifford Street in the relatively small floods (20% to 5% AEP), which increases to the majority of the street being inundated in the 1% AEP, with large areas of ponding between Clifford and Bunyan Streets.
- Railway Gully, which passes under the highway at the south end of the town, is contained to its channel in all design events up to the 0.2% AEP event.
- In the PMF, the entire town is flooded to depths of 15-20 m. This is due to the very large peak flow occurring on the Murrumbidgee River (approximately 10 times the 1% AEP flow), during which the town becomes part of the Murrumbidgee floodplain.

4.2.3. Flood Hazard

Background on the concept and derivation of flood hazard is given in Section E.1.

Hazard categories for Bredbo are presented on Figure B 3 to Figure B 6, for the 5%, 1% and 0.2% AEP, and the PMF. The figures show the following areas of hazard:

- In the 5% AEP, there is an area of H3 fringed by H1-H2 from Bredbo River up to Clifford Street and Bransby Street that affects around three properties, while in the 1% AEP a similar but larger area is H5 fringed by H1-H4. In the 0.2% AEP event, there is a large H6 area fringed by H1-H5 area that extends past Bunyan Street and the Monaro Highway. Numerous houses are flooded by high hazard flooding during the 1% AEP event and larger.
- Apart from these high hazard areas, flooding of H4-H6 is confined within the Murrumbidgee River, Bredbo River, Railway Gully and the creek that crosses Bredbo in a north-south direction

past Swan Street and Bunyan Street in the 5% AEP. The H4-H6 area further extends into the town at Bredbo River upstream of Monaro Highway in the 1% AEP.

- Patches of H2-H3 areas are scattered through the town, such as the east end of Clifford Street, upstream of culvers under the railway, and sections of Bunyan Street in the 1% AEP.
- The majority of the town is classified as H6 in the PMF.

4.2.4. Flood Function

Background on the concept and derivation of flood hazard is given in Section 3.2.4 and E.2

The hydraulic categories of flow conveyance, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP, 0.2% AEP and PMF events and are shown in Figure B 7 to Figure B 10. The figures show that in the 1% AEP, the majority of the mainstream flood extent is flow conveyance, with large areas of flood storage and small areas of fringe in the town centre and downstream of the confluence of Murrumbidgee River and Bredbo River. Overland flow leads to some smaller flow conveyance areas and larger areas of flood fringe in the town centre.

In the 5% AEP, the flow conveyance again occupies the majority of the floodplain, but the storage areas are smaller in the town centre. In the 0.2% AEP a big part of the town centre is flood storage with some smaller areas of flood fringe. There are only very small areas of flood fringe left in the PMF. The majority of the flood extent is flow conveyance with the majority of the town centre being flood storage.

4.3. IMPACT OF FLOODING

4.3.1. Flooding Hotspots

Bredbo contains areas of concentrated flood risk, however most of the town is not affected by flooding during more frequent flood events. There are areas of localised flooding along small watercourses and overland flow through the town, and these are generally related to stormwater drains being exceeded. In larger events, Bredbo River flooding occurs in some areas, and this can be exacerbated by high Murrumbidgee River flow. In very large events, both rivers flood a large portion of the town with hazardous flow.

Summary of Bredbo Hotspots is presented in Table 22, with further details presented in Sections 4.3.1.1 to 4.3.1.3. The location of the various hotspots are presented in Figure B 1.

Table 22: Bredbo Hotspots

Hotspot #	Location	Risk Factors
9	Bredbo River floodplain	Road flooding and evacuation/isolation issues
10	Monaro Highway	Road flooding and property flooding
11	Watercourse through Bredbo	Road flooding and evacuation/isolation issues

4.3.1.1. ***Hotspot 9 - Bredbo River Floodplain***

Bredbo River floods a large area on the southern edge of the town, centred on the oval on Clifford Street but also affecting properties in the vicinity. This flooding can be exacerbated by Murrumbidgee River flooding. During extreme events, or potentially failure of Tantangara Dam, large areas of Bredbo may be flood affected by high hazard flow. Flood risk relates to property damage and risk to life for persons occupying their homes during major flood events, particularly near the oval, and on Clifford and Bransby Streets.

Table 23 describes the area's flood behaviour and flood risk.

Table 23: Bredbo River Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.5-0.7 m near intersection of Bransby and Clifford St • In 1% AEP, water depths of up to 2.0 – 2.5 m near intersection of Bransby and Clifford St
Flood Hazard	• In the 5% AEP, H3 in area around Bransby and Clifford Streets • In the 1% AEP, H5 in same area, extending further east and north.
Properties flooded above ground	• 11 in 5% AEP • 32 in 1% AEP
Properties flooded above floor (approx.)	• 1 in 5% AEP • 19 in 1% AEP
Evacuation	Generally, affected residents are able to evacuate through rising road access, but some access routes may be cut off due to overland flow approaching the river (see following hotspots).
Duration	Depending on the length of the storm event, flooding likely to several hours to days.
Additional Risk Factors	Failure of Tantangara Dam could potentially pose a significant risk to Bredbo. Dam breach analysis is recommended to better understand exposure and risk to life.
Gauge levels	A gauge has been proposed for the area (see Section 8.3.7), but the relationship in gauge levels and flooding at the town has not been established.

4.3.1.2. ***Hotspot 10 - Monaro Highway***

There is a localised flooding hotspot at Monaro Highway near the intersection with Clifford Street, where flooding occurs when the 0.525m diameter culvert under the highway is full and flow passes overland. Overtopping at the highway is generally of low hazard, however there is some property affectation in the area.

Table 24 describes the area's flood behaviour and flood risk.

Table 24: Monaro Highway Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.6m at upstream of culvert, up to 0.05m over the road and up to 0.2m in adjacent lots. • In 1% AEP, water depths of up to 0.7m at upstream of culvert, up to 0.1m over the road and up to 0.25m in adjacent lots.
Flood Hazard	• In the 5% AEP, H1 at affected properties and on the highway. • In the 5% AEP, H1 at affected properties and on the highway.
Properties flooded above ground	• 6 in 5% AEP • 6 in 1% AEP
Properties flooded above floor (approx.)	• 3 in 5% AEP • 5 in 1% AEP
Evacuation	The area generally has low hazard flooding and should not present any risks to people or vehicles if evacuation is needed.

Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	-
Gauge levels	Overland flow catchments are too small to use flow or level gauges.

4.3.1.3. *Hotspot 11 - Watercourse through Bredbo*

A watercourse runs from the north of the town towards Bredbo River and passes through various properties and streets. The watercourse itself does not cause any property affectation but it does isolate the western side of the town as it becomes too hazardous to cross by foot or vehicle.

Table 25 describes the area's flood behaviour and flood risk.

Table 25: Watercourse through Bredbo Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 1.2m at North Street crossing • In 1% AEP, water depths of up to 1.5m at North Street crossing
Flood Hazard	• In the 5% AEP, hazard of up to H5 at road crossings • In the 1% AEP, hazard of up to H6 at road crossings
Properties flooded above ground	• 21 in 5% AEP • 21 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	All road crossing are low level and subject to frequent flooding resulting in isolation of areas to the west of the watercourse Isolation can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event.
Duration	Depending on the length of the storm event, flooding likely to last several hours. Shallow inundation may be trapped for several days after a flood.
Additional Risk Factors	Frequently flooded crossings increase the chance that vehicles will enter flood waters which can pose a significant risk to life.
Gauge levels	The watercourse does not have a flow or level gauge.

4.3.1.4. *Flooded Roads – Bredbo*

Hazardous flooding of roads occurs when there is sufficient flow to knock over pedestrians or transport cars off the road due to buoyancy effects. In Australia, vehicles attempting to cross flooded roads is one of the largest causes of injury and fatality in a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at small flow speeds (this corresponds to H2 hazard). The following roads have been identified as experiencing hazardous flow (H2 or above) in a 5% AEP event.

- North Street at causeway to the west of intersection with Walker Street
- Swan Street at causeway
- Bunyan Street at causeway
- Clifford Street at intersection with Bransby Street

These locations have also been listed in Section 8.3.1, which recommends warning signage. Note that other road locations may be flooded in a 1% AEP event and larger events (see hazard maps).

4.3.2. Property Flood Liability

Properties across the study area experience inundation in a flood event, with affectation focussed along the watercourses and overland flowpaths. As part of the economic damages assessment, the flood affectation on a per property level was assessed by comparison of each lot's ground level and habitable floor level to the design flood levels at the property. The comparison is made at a point location on each lot, usually at the visible entry (i.e. front door). The floor level at each lot is an estimate based on visual inspection and not a surveyed level. This assessment allows an overall estimate of where properties are flooded above floor level, as shown on Figure B 15, which colour codes each property for the flood event it is first flooded above floor level. The map also shows the 1% AEP hazard.

The map should be interpreted as an overall representation of above-floor flood liability, and as an estimate only for determination for any particular property. This is because the floor level was estimated from visual inspection, which is less accurate than survey, and secondly because minor landscaping drainage features within a lot are sometimes not accurately captured in the model which is assessing an area of 23 km^2. The latter tends to exaggerate above-floor flooding in areas of shallow overland flow. Where properties in H1 hazard are shown as flooded above floor in relatively frequent floods, this indicates that the property simply has a low floor level and that shallow flow depths could potentially cause above-floor flooding. However, in practise, often local landscaping/drainage may ameliorate the risk of above floor flooding.

4.3.3. Critical Infrastructure and Sensitive Land-Uses

Critical infrastructure is located throughout the area and if inundated during a flood, can significantly impact the functioning of the town. The following section describes the flood liability of various critical infrastructure. The section also describes the exposure of facilities particularly sensitive to inundation, including childcare, schools and aged care.

4.3.3.1. ***Hospital and Ambulance***

Bredbo is serviced by the Southern Sector of the NSW Ambulance Goulburn Area. Ambulance access to Bredbo from Cooma may be impacted due to flooding of various road crossings during frequent flood events. In the event of major flooding in the Cooma region, access from the Queanbeyan Ambulance Station to Bredbo may be preferred due to flooding of key access roads.

Council should notify the Southern Sector of the NSW Ambulance Goulburn Area, any reports of road closures associated with flooding between Cooma and Bredbo. This will allow Ambulances to be directed from Queanbeyan if necessary.

4.3.3.2. ***State Emergency Service (SES)***

The Cooma-Monaro SES Unit services Bredbo. Access to Bredbo by emergency services is likely to be impacted due to flooding of various road crossings during frequent flood events. Assistance from the SES is likely to be significantly affected if the township to Bredbo is impacted by flooding.

Access from the NSW SES Queanbeyan Unit may be preferred during major flood events in the Cooma region and/or reports of roads closures. Council should notify the NSW SES South East Zone Headquarters of any reports of road closures associated with flooding between Cooma and Michelago. This will emergency services to be directed from Queanbeyan if necessary.

4.3.3.3. ***Schools and Childcare Centres***

Bredbo Public School is located on the northern side of the Monaro Highway near Bunyan Street. The school is affected by shallow overland flow (<300 mm, H1 hazard) flooding for a range of events as small as the 20% AEP. During events larger than the 0.2% AEP, the school may become significantly inundated and subject to H6 hazard. Evacuation of the school is required during extreme Bredbo and Murrumbidgee River flood events.

4.3.4. Economic Impact of Flooding

A flood damages assessment is used to quantify the economic impact of flooding on the community. The assessment equates the depth experienced at each property to an economic cost, based on data from historical floods. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed management measures and by the state government in prioritising resources. More information on flood damages, including how they are derived, is provided in Section E.3.

The flood damages assessment for Bredbo estimated an Average Annual Damage of $161,900. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 26.

Table 26: Bredbo Flood Damages

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	5	1	$91,100	8%	$18,200
10% AEP	15	4	$405,100	15%	$27,000
5% AEP	18	5	$488,300	14%	$27,100
2% AEP	21	9	$ 823,500	12%	$39,200
1% AEP	37	24	$2,075,000	9%	$56,100
0.5% AEP	58	48	$4,610,400	10%	$78,100
0.2% AEP	96	89	$9,492,800	13%	$98,900
PMF	132	131	$19,699,300	18%	$149,200
		Average Annual Damages (AAD)	$161,900		$1,200

The table shows that there is minimal property flooding in Bredbo in frequent events, however in the 1% AEP and larger, there is a significant number flooded, including above floor. In frequent events, flooding tends to occur where overland flowpaths interact with buildings, with around 15-20 properties affected. In the 1% AEP this is nearly double and the event damages is over $2 million. In the PMF, when a large portion of the town experiences very high flood depths, the damages increases to $20 million.

The results show that frequent events are responsible for around a third of the AAD figure. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $91k in 20% AEP). This is likely an over-estimate of the actual damage cost.

4.4. EMERGENCY RESPONSE

4.4.1. Flood Warning and Emergency Response

Understanding of the available flood warning and emergency response in Bredbo is understood from information provided in the Local Flood Plan, which is summarised in Section 2.3.8 and analysis as part of the current study. The Plan includes a map of Bredbo and states there may be road closures during a flood, but does not otherwise describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs). There is not an existing flood warning system in Bredbo.

Like other towns in the LGA, the BOM use a network of rainfall gauges and other data to issue a range of warnings related to flooding. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning. Flooding of the Murrumbidgee River, which can exacerbate flooding at Bredbo, is included in the warning system but is not described in the Plan in relation to flooding at Bredbo. While warnings may be issued that alert residents to potential flooding, Bredbo does not have a flood warning system relating river levels to road and property flooding.

Analysis of four historical events for the Strike-a-light River stream gauge indicates that there is around 6-7 hours between a flood-producing rainfall burst occurring and the peak flood level at Bredbo. Further analysis of the Strike-a-light gauge found 3-4 hours between burst and peak flow at the gauge, and an estimated travel time from the gauge to Bredbo of 3 hours. This time of concentration indicates that, given the significant flood risk to properties in rare to extreme flood events in Bredbo, a flood warning system for the town is feasible and warranted. Any such system would require additional stream gauges, as the Strike-a-light gauge only captures ~30% of the town's catchment area. Further discussion of a possible system is provided in Section 8.3.7.

4.4.2. Flood Emergency Response Classification of Communities

Flood Emergency Response Classification refers to categorising parts of the floodplain based on their evacuation constraints. Mapping of evacuation constraints across the study area assist the SES and other emergency responders in planning where assistance, evacuation or rescue is needed for individual properties. The categories have been mapped for three design events (5% AEP, 1% AEP and PMF) to understand how evacuation constraints vary between different-sized floods. The categories have been determined in accordance with DPIE's 'Flood Emergency Response Planning Classification of Communities' guideline. The categories are shown on Figure B 11 (5% AEP), Figure B 12 (1% AEP) and Figure B 13 (PMF).

The figures show that:

- The evacuation constraints are effectively the same in the 5% and 1% AEP in Bredbo. In both events, the area to the west of the flowpath through the town is a High Trapped Perimeter area, as the access roads are flooded. Flooded areas in the remainder of the town are Rising Road Access. While there is significantly more hazard in the 1% AEP event, the evacuation constraints for the worst-flooded areas around Clifford and Bransby Streets is the same.
- In the PMF, virtually the entire town is classified as H6 hazard and all roads including the highway will be impassable.

5. BERRIDALE FLOOD RISK

5.1. OVERVIEW

Berridale experiences flooding due to high flow on Myack Creek and Coolamatong Creek that exceeds the channel capacity, as well as overland flow from localised rainfall over the town. Coolamatong Creek passes through the centre of Berridale and Myack Creek is to the east of the town centre. Both can cause high hazard flooding of both roads and property. Depths of flooding tend to be greater for creek flooding, also referred to as mainstream flooding, than overland flooding, for which depths are typically less than 0.3 m. The two flooding mechanisms can occur simultaneously or separately. Description of the area's flood risk has been divided into the following sub-sections:

- **Flood Behaviour** (Section 5.2) describes the depth and velocity of floodwaters across the range of design flood events. This section includes flood hazard (Section 5.2.3), which relates depth and velocity to risk posed to pedestrians, vehicles and buildings, and also flood function (Section 5.2.4), which divides the floodplain into the categories of flow conveyance, flood storage and flood fringe.
- **Impact of Flooding** (Section 5.3) describes the consequences of flooding in urban areas. This section includes a breakdown of flooding hotspots where flood risk is concentrated (Section 5.3.1), mapping of property flooding across the town (Section 5.3.2), flood liability of critical infrastructure and sensitive land uses (5.3.3) and the economic impact of flooding (Section 5.3.4).
- **Emergency Response** (Section 5.4) describes the flood warning system and operation of emergency services (Section 5.4.1) and the 'flood emergency response classification of communities (Section 5.4.2).

Assessment of land use planning as it relates to flooding, including the cumulative impact of future development on flooding, is described for the four towns in Section 7.

5.2. FLOOD BEHAVIOUR

5.2.1. Background

There are two main creek systems which traverse the Berridale town centre, i.e. Coolamatong Creek and Myack Creek. Flood affected areas within the Berridale town are generally found along Coolamatong Creek and the adjacent low-lying floodplain south of Jindabyne Road. Roads crossing Coolamatong Creek are found to be overtopped in floods such as the February 2012 event due to a combination of undersized cross drainage and road crests almost at-grade with the creek.

On the east side of Berridale town, floodwaters are generally confined within Myack Creek with the William Street crossing creating a significant control causing backwater upstream. Some of the properties along the western side of Myack Creek are flood-affected due to their proximity to the creek flood extent.

Various parts of Berridale township are also subject to flooding from overland flow paths which drain to the two main creeks.

There is some data available describing previous floods in Berridale. There was high awareness of flooding amongst those who responded to questionnaire during the flood study, with reports of flooding in 2012, 2014, 2015, and January and October 2017. These generally aligned with high rainfall events recorded in the region, including February 2012, December 2014, April 2015 and October 2017.

5.2.2. Design Events

Table 27 summarises design flood levels for a number of locations in the town. Locations are shown on Figure C 1 which also shows the 1% AEP peak flood depth. Figure C 2 shows the flood profiles for each design event for Myack Creek and Coolamatong Creek. A full set of design flood mapping is included in the flood study.

Table 27: Berridale Design Flood Levels at Reporting Locations

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
18	Myack Creek at William Street	857.6	858.5	859.0	859.5	860.0	860.1	860.1	860.1	861.6
19	Myack Street near Jindabyne Road	858.0	858.5	858.7	858.8	859.0	859.0	859.1	859.2	860.8
20	Mary Street near James Street	866.3	NF*	NF*	NF*	866.5	866.6	866.6	866.6	866.8
21	Confluence of Myack Creek and Coolamatong Creek	852.5	854.0	854.3	854.6	854.7	854.8	855.0	855.0	856.6
22	Near Mackay Street and Cecil Street	879.4	879.9	879.9	879.9	879.9	880.0	880.0	880.0	880.2
23	Woolway Creek at Kosciuszko Road	832.9	835.2	835.3	835.4	835.6	835.7	835.8	835.9	838.2
24	Coolamatong Creek at Boundary Street	869.3	869.7	869.7	869.8	869.9	869.9	870.0	870.0	871.4
25	North end of Morrice Street	862.2	862.3	862.4	862.5	862.6	862.7	862.8	862.9	864.3
26	Southern Cross Drive	850.3	850.7	850.9	851.0	851.2	851.3	851.4	851.4	853.1
27	Gungarlin Street low point, near Highdale Street	864.6	864.7	864.8	864.8	864.9	865.0	865.1	865.2	865.5

* NF = Not Flooded

Berridale experiences significant flood affectation in events greater than the 10% AEP, with areas of significant inundation in the vicinity of Coolamatong Creek and Myack Creek. The peak flood depths figures show the following areas of affectation:

- Coolamatong creek has an ill-defined channel, which leads to wide shallow flood affectation. Residential areas near the creek are inundated in the 20% AEP, expanding to greater areas in the 5% AEP event. Additionally, the creek overtops Jindabyne Road upstream of its confluence with Myack Creek in the 10% AEP and larger.
- Myack Creek overtops Dalgety Road in the 20% AEP and larger; overtops Kosciuszko Road in the 5% AEP and larger; and floods a small number of properties upstream of William Street in the 20% AEP, expanding to larger area in the 2% AEP event.
- Wullwye Creek overtops the northern end of Middlingbank Bridge in the 1% AEP event and larger.
- In the 20% AEP, a flow path is present to the west of the intersection of Boundary Road and Rockwell Road, causing inundation of a small number of properties upstream of its confluence with Coolamatong Creek.

5.2.3. Flood Hazard

Background on the concept and derivation of flood hazard is given in Section E.1.

Hazard categories for Berridale are presented on Figure C 3 to Figure C 6, for the 5%, 1% and 0.2% AEP, and the PMF. Berridale figures show an additional type of hazard as a hatched overlay – ‘High’ and ‘Low’ hazard as defined by the NSW Floodplain Development Manual (Reference 1). This type of hazard is based on a similar depth-velocity calculation and is explicitly referred to in Berridale's DCP, hence the inclusion on the figure. The figures show the following areas of hazard:

- Areas of high hazard and of H3-H6 categories are localised within Coolamatong Creek, Myack Creek, Wullwye Creek and other smaller flow paths outside of town in the 0.2% AEP.
- A number of properties boarding Myack Creek experience H2-H4 hazard yard flooding in the 5% AEP.
- Residential areas around Coolamatong Creek are typically H1 to H2 category in the 5% AEP, increasing in extent as event magnitude increases, with a few areas reaching H3. In the PMF, the H5 to H6 hazard areas affect much of the town.

5.2.4. Flood Function

Background on the concept and derivation of flood hazard is given in Section 3.2.4 and E.2

The hydraulic categories of flow conveyance, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP, 0.2% AEP and PMF events and are shown in Figure C 7 to Figure C 10.

The figures show that in the 1% AEP, the majority of the mainstream flood extent is flow conveyance, with small areas of flood storage and flood fringe on the periphery and some larger flood fringe areas close to the confluence of Myack Creek and Wullwye Creek. Overland flow is mostly classified as flood fringe with some flow conveyance areas along flowpaths.

In the 5% AEP, the flow conveyance again occupies the majority of the floodplain with islands of flood fringe and storage between the flow conveyance areas. The flood categories in the 0.2% AEP are similar to the 1% AEP, though slightly larger. In the PMF the flow conveyance increased significantly with some flood storage and flood fringe areas on the periphery. Overland flow in the PMF leads to several overland flow conveyance areas.

5.3. IMPACT OF FLOODING

5.3.1. Flooding Hotspots

Flood risk in Berridale is primarily related to flooding of road crossing of Coolamatong Creek and Myack Creek. There are also a number of properties that are flood affected by both creeks.

Summary of Berridale Hotspots is presented in Table 28, with further details presented in Sections 5.3.1.1 to 5.3.1.6. The locations of the various hotspots are presented in Figure C 1.

Table 28: Berridale Hotspots

Hotspot #	Location	Risk Factors
12	Dalgety Road at Myack Creek crossing	Road flooding and evacuation/isolation issues
13	Koscuiszko Road, west of Wullwye Creek bridge	Road flooding
14	Short Street causeway at Myack Creek	Road flooding and evacuation/isolation issues
15	William Street crossing over Myack Creek	Road and property flooding and evacuation/isolation issues
16	Coolamatong Creek	Road flooding and property flooding
17	Snowy River Hostel	Property flooding

5.3.1.1. *Hotspot 12 - Dalgety Road at Myack Creek Crossing*

The Dalgety Road crossing of Myack Creek has a box culvert (2.8 m x 0.6 m) that are noted to have previously been subject to significant blockage during flooding. Flood risk at the location relates to overtopping of Dalgety Road resulting in hazardous flow over the road that can pose a significant risk to pedestrians and vehicles.

Table 29 describes the area's flood behaviour and flood risk.

Table 29: Dalgety Road and Myack Creek Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.3m over the road • In 1% AEP, water depths of up to 0.4m over the road
Flood Hazard	• In the 5% AEP, hazard level is of H2-H5 at road • In the 1% AEP, hazard level is predominantly H5 at road
Properties flooded above ground	• 3 in 5% AEP • 3 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Access to the south of Berridale is cut-off when the road is flooded, to roads including Bobundara Road, Hickory Dale Road and towards Dalgety in the south. For Berridale residents, open areas exist for evacuation that are flood-free in the PMF (e.g. Baanya Showground). However, isolation can have implications for emergency

	vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event.
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	Frequently flooded crossings increase the chance that vehicles will enter flood waters which can pose a significant risk to life.
Gauge levels	There is no gauge on Myack Creek.

5.3.1.2. ***Hotspot 13 - Kosciuszko Road, west of Wullwye Creek bridge***

Koszciuszko Road is overtopped to the west of the Wullwye Creek crossing when the capacity of four 4 m x 1 m box culverts are exceeded. Koszciuszko Road is the main arterial road for the region providing access from Cooma to Berridale and NSW Ski Fields. The road is first overtopped in the 10% AEP, although it is not until the 5% AEP event that H2 hazard is present.

Table 30 describes the area's flood behaviour and flood risk.

Table 30: Kosciuszko Road Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depth of up to 0.1m is present at the road • In 1% AEP, water depth of up to 0.3m is present at the road
Flood Hazard	• In the 5% AEP, hazard level of up to H2 is present on the road • In the 1% AEP, hazard level predominantly H4-H5 on the road
Properties flooded above ground	• 0 in 5% AEP • 0 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Flooding over the road prevents road access between Berridale and Cooma
Duration	Depending on the length of the storm event, flooding likely to last several hours.
Additional Risk Factors	Kosciuszko Road is the main arterial road for the region and services a significant amount of traffic which increases the chance that vehicles will enter flood waters. Flooding of the road could resulting in isolation which can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event
Gauge levels	There is no gauge upstream of Kosciuszko Road

5.3.1.3. ***Hotspot 14 - Short Street Causeway at Myack Creek***

The Short Street causeway over Myack Creek is likely to be frequently flooded and experiences flow that is hazardous to vehicles and pedestrians. Access to a handful of dwellings is cut-off during creek flooding. There is no above floor property affectation associated with the hotspot.

Table 31 describes the area's flood behaviour and flood risk.

Table 31: Short Street Causeway at Myack Creek Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.9 m is present at the causeway • In 1% AEP, water depths of up to 1.2 m is present at the causeway
Flood Hazard	• In the 5% AEP, hazard level of up to H5 is present at the causeway

	• In the 1% AEP, hazard level of up to H5 is present at the causeway
Properties flooded above ground	• 7 in 5% AEP • 7 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Residents at Short Street becomes isolated during a flood event and no alternative route exists to evacuate. Isolation can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	Frequently flooded crossings increase the chance that vehicles will enter flood waters which can pose a significant risk to life.
Gauge levels	There is no gauge on Myack Creek.

5.3.1.4. *Hotspot 15 - William Street Crossing over Myack Creek*

Similar to previous hotspots, William Street's crossing over Myack Creek experiences hazardous flooding and will cut-off access to the O'Brien Avenue to the area to the east. The crossing has three 3.05 m x 1.52 m box culverts, which are noted to have previously been subject to significant blockage during flooding. Property flooding also occurs at the hotspot for lots backing onto Myack Creek.

Table 32 describes the area's flood behaviour and flood risk.

Table 32: William Street at Myack Creek Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 1.9m at upstream of culvert, and no flow over the road • In 1% AEP, water depths of up to 2.5m at upstream of culvert, and 0.3 m over the road
Flood Hazard	• In the 5% AEP, hazard of up to H4-H5 is predominant in the creek, no hazard at road • In the 1% AEP, hazard of up to H5 is predominant in the creek, up to H4 at road crossing
Properties flooded above ground	• 12 in 5% AEP • 13 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 1 in 1% AEP
Evacuation	Residents of O'Brien Avenue are isolated when William Street is overtopped. Isolation can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	There is risk of vehicles and pedestrians being swept into Myack Creek. Future development in the O'Brien Avenue area may increase the number of people using the William Street crossing of Myack Creek which could increase flood risk.
Gauge levels	There is no gauge on Myack Creek.

5.3.1.5. *Hotspot 16 - Coolamatong Creek*

Coolamatong Creek crosses several roads in Berridale on its way towards Myack Creek, and runs approximately parallel to Jindabyne Road. Flooding of the creek can result in property flooding and reduced access to due to hazardous flow affecting a number of roads.

Table 33 describes the area's flood behaviour and flood risk.

Table 33: Coolamatong Creek Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.3m at Oliver Street, up to 0.5m at Bolton Street, and up to 0.7m at Myack Street. • In 1% AEP, water depths of up to 0.4m at Oliver Street, up to 0.7m at Bolton Street, and up to 0.9m at Myack Street.
Flood Hazard	• In the 5% AEP, hazard level of up to H4-H5 at creek • In the 1% AEP, hazard level of up to H4-H5 at creek
Properties flooded above ground	• 35 in 5% AEP • 52 in 1% AEP
Properties flooded above floor (approx.)	• 9 in 5% AEP • 13 in 1% AEP
Evacuation	Access to Jindabyne Road from the east is reduced by flooding of Coolamatong Creek. One exception is the bridge at Robert Street which is relatively high, although blockage of the bridge structure can lead to overtopping. Areas to the east of Jindabyne Road become isolated during relatively frequent events. Isolation can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event
Duration	Depending on the length of the storm event, flooding may last several hours.
Additional Risk Factors	Frequently flooded crossings increase the chance that vehicles will enter flood waters which can pose a significant risk to life.
Gauge levels	There is no gauge on Coolamatong Creek

5.3.1.6. *Hotspot 17 - Snowy River Hostel*

This hotspot is an aged care facility (Snowy River Hostel) that experiences overland flooding. Flood risk is higher than at similar lots due to the property's use as an aged care facility. Overland flows originate to the north-west as sheet flow on the cleared land, with flow then directly hitting the hostel buildings. There are no stormwater features (e.g. drains) in the area that take the flow. Flow rates are generally small (around 0.5 m^3/s in the 1% AEP).

Table 34 describes the area's flood behaviour and flood risk.

Table 34: Snowy River Hostel Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 0.3m at Snowy River Hostel • In 1% AEP, water depths of up to 0.4m at Snowy River Hostel
Flood Hazard	• In the 5% AEP, hazard of up to H2 at Snowy River Hostel • In the 1% AEP, hazard of up to H3 at Snowy River Hostel
Properties flooded above ground	• 3 in 5% AEP • 3 in 1% AEP
Properties flooded above floor (approx.)	• 1 in 5% AEP • 1 in 1% AEP

Evacuation	Shallow, localised, low hazard flooding in areas surrounding the property may occur, indicating that evacuation is possible if required, however, evacuation may be complicated by residents with limited mobility.
Duration	Flooding is likely to dissipate relatively rapidly (less than 1 hour).
Additional Risk Factors	The property is an aged care facility. Unplanned/abrupt evacuation of aged care facilities is associated with increased mortality rates in vulnerable people. Measures should be implemented to reduce risk to life.
Gauge levels	Overland flow catchments are too small to use flow or level gauges.

5.3.1.7. ***Flooded Roads – Berridale***

Hazardous flooding of roads occurs when there is sufficient flow to knock over pedestrians or transport cars off the road due to buoyancy effects. In Australia, vehicles attempting to cross flooded roads is one of the largest causes of injury and fatality in a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at small flow speeds (this corresponds to H2 hazard). The following roads have been identified as experiencing hazardous flow (H2 or above) in a 5% AEP event.

- Boundary Street to the east of intersection with Kosciuszko Road
- Oliver Street to the east of intersection with Kosciuszko Road
- Bolton Street to the east of intersection with Kosciuszko Road
- Myack Street to the east of intersection with Kosciuszko Road
- Park Street to the east of intersection with Kosciuszko Road
- Short Street at Myack Creek

These locations have also been listed in Section 8.3.1, which recommends warning signage. Note that other road locations may be flooded in a 1% AEP event and larger events (see hazard maps).

5.3.1.8. ***Other Areas for Consideration - Berridale***

Aside from the hotspots described, there are various scattered instances of over floor flooding in the town. The following section describes property flood liability. Areas of flooding include:

- Cecil Street
- Area near Boundary Road and Mary Street
- Area between Boundary Road and Florence Street
- Gungarlin Street near Poplar Street

These properties may be affected by shallow flows associated with minor drainage.

5.3.2. Property Flood Liability

Properties across the study area experience inundation in a flood event, with affectation focussed along the watercourses and overland flowpaths. As part of the economic damages assessment, the flood affectation on a per property level was assessed by comparison of each lot's ground level and habitable floor level to the design flood levels at the property. The comparison is made at a point location on each lot, usually at the visible entry (i.e. front door). The floor level at each lot is an estimate based on visual inspection and not a surveyed level. This assessment allows an overall estimate of where properties are flooded above floor level, as shown on Figure C 15, which colour codes each property for the flood event it is first flooded above floor level. The map also shows the 1% AEP hazard.

The map should be interpreted as an overall representation of above-floor flood liability, and as an estimate only for determination for any particular property. This is because the floor level was estimated from visual inspection, which is less accurate than survey, and secondly because minor landscaping drainage features within a lot are sometimes not accurately captured in the model which is assessing an area of 22 km^2. The latter tends to exaggerate above-floor flooding in areas of shallow overland flow. Where properties in H1 hazard are shown as flooded above floor in relatively frequent floods, this indicates that the property simply has a low floor level and that shallow flow depths could potentially cause above-floor flooding. However, in practise, often local landscaping/drainage may ameliorate the risk of above floor flooding.

5.3.3. Critical Infrastructure and Sensitive Land-Uses

Critical infrastructure is located throughout the area and if inundated during a flood, can significantly impact the functioning of the town. The following section describes the flood liability of various critical infrastructure. The section also describes the exposure of facilities particularly sensitive to inundation, including childcare, schools and aged care.

5.3.3.1. ***State Emergency Service (SES)***

Berridale may be serviced by the NSW SES Snowy River and Cooma-Monaro Units. Access to Berridale by emergency services is potentially impacted due to flooding of various road crossings during moderate to major flood events. Assistance from the SES may be significantly affected if the township to Berridale is impacted by flooding.

Council should notify the NSW SES South East Zone Headquarters of any reports of road closures associated with flooding between Cooma and Jindabyne. This will allow the NSW SES to determine unit to direction emergency services from.

5.3.3.2. ***Schools and Childcare Centres***

Berridale Public School is situated on Oliver Street between Florence and Mary Streets. The school is noted to be above the level of the PMF and thus not subject to inundation, however flooding of Jindabyne and Dalgety Roads may lead to reduced access during times of flood.

Berridale Little Stars Preschool & Childcare Centre. Little Stars Preschool is located on Pryce Street. The preschool may experience minor drainage issues during rare flood events, however even during the PMF, flood depths are shallow (< 300mm) and classified as H1 hazard. Access to the preschool is likely to be restricted during times of flood due to flooding of Jindabyne Road.

5.3.3.3. ***Aged and Vulnerable Care***

Snowy River Hostel is situated at 7 Jindalee St. The site may become flooded during relatively frequent rainfall events and be flood affected by shallow overland flow (< 300 mm, H1-H2 classification). Due to the Hostels exposure to flooding, frequent evacuation/response activities are likely required. Unplanned/abrupt evacuation of aged care facilities is associated with increased mortality rates in vulnerable people.

5.3.4. Economic Impact of Flooding

A flood damages assessment is used to quantify the economic impact of flooding on the community. The assessment equates the depth experienced at each property to an economic cost, based on data from historical floods. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed management measures and by the state government in prioritising resources. More information on flood damages, including how they are derived, is provided in Section E.3.

The flood damages assessment for Berridale estimated an Average Annual Damage of $256,000. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 35.

Table 35: Berridale Flood Damages

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	23	0	$279,100	17%	$12,100
10% AEP	34	4	$570,900	17%	$16,800
5% AEP	48	14	$1,149,400	18%	$23,500
2% AEP	71	23	$2,102,700	20%	$28,400
1% AEP	86	32	$ 2,870,600	10%	$33,000
0.5% AEP	97	41	$ 3,535,700	7%	$36,100
0.2% AEP	97	42	$3,672,800	4%	$37,500
PMF	173	130	$11,771,500	6%	$67,300
		Average Annual Damages (AAD)	$243,200		$1,400

The table shows that property flooding in Berridale steadily increases with larger flood events, with significant above-floor flooding in rarer flood events. In frequent events, flooding tends to occur where overland flowpaths interact with buildings, with around 20-30 properties affected. In the 1% AEP this is more than doubled and the event damages is close to $3 million.

The results show that frequent events are responsible for around half of the AAD figure. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $280k in 20% AEP). This is likely an over-estimate of the actual damage cost.

5.4. EMERGENCY RESPONSE

5.4.1. Flood Warning and Emergency Response

Understanding of the available flood warning and emergency response in Berridale is understood from information provided in the Local Flood Plan, which is summarised in Section 2.3.8, and analysis as part of the current study. The Plan sets out responsibilities and processes for the emergency response during a flood, which is primarily carried out by the SES. The closest SES Regional Operations Centre in the LGA are located at Geebung Street, Polo Flat. There is another SES unit on Lee Avenue in South Jindabyne which may assist in Berridale. The Plan does not describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs).

As for other towns in the LGA, the BOM use a network of rainfall gauges and other data to issue a range of warnings related to flooding. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning.

Analysis of the catchment size and characteristics indicates Berridale has minimal warning time. The catchment response time is approximately 0-1 hours for Cooma and the Berridale creek catchments are around six times smaller than the Cooma Creek catchment. Berridale can therefore be characterised as experiencing flash flooding and the small to negligible available warning time leads to a high flood risk in the town. Flash floods are difficult to forecast as the rainfall is very localised, which forecast models can less accurately predict than wider rainfall events. The short warning time means that in a large flood, emergency services must evacuate several separate areas and manage potentially reluctant or slow residents.

Discussion of response modification measures is given in the flood risk management measures section (Section 8.3).

5.4.2. Flood Emergency Response Classification of Communities

Flood Emergency Response Classification refers to categorising parts of the floodplain based on their evacuation constraints. Mapping of evacuation constraints across the study area assist the SES and other emergency responders in planning where assistance, evacuation or rescue is needed for individual properties. The categories have been mapped for three design events (5% AEP, 1% AEP and PMF) to understand how evacuation constraints vary between different-sized floods. The categories have been determined in accordance with DPIE's 'Flood Emergency Response Planning Classification of Communities' guideline. The categories are shown on Figure C 11 (5% AEP), Figure C 12 (1% AEP) and Figure C 13 (PMF).

The figures show that:

- In the 5% AEP, most flood-prone urban areas are classified as Rising Road Access. Some areas, for example on Coolamatong Creek immediately north of Myack Street, are classified as High Trapped Perimeter area as Park Street is flooded. There is also a Low Flood Island further north between Myack Creek and Jindabyne Road.
- In the 1% AEP, most categories in the Berridale urban area are unchanged from the 5% AEP. Areas of difference include more of the caravan park off Jindabyne Road being High Trapped Perimeter, and the entire area east of Myack Creek being High Trapped Perimeter area, due to the creek flooding the access roads.
- In the PMF there is a wide H5-H6 flowpath along both creeks that directly impacts much of the town and cuts off all major roads. There are areas in the south and west of the town that are relatively safe for short term evacuation (see PMF hazard figure).

6. MICHELAGO FLOOD RISK

6.1. OVERVIEW

Michelago Creek flooding does not affect the majority of the town in most flood events, although very rare and extreme events will flood a number of roads and properties. Flood risk in the town is largely related to several overland flowpaths that impact road and properties in different parts of the town. The two flooding mechanisms can occur simultaneously or separately. Description of the area's flood risk has been divided into the following sub-sections:

- **Flood Behaviour** (Section 6.2) describes the depth and velocity of floodwaters across the range of design flood events. This section includes flood hazard (Section 6.2.3), which relates depth and velocity to risk posed to pedestrians, vehicles and buildings, and also flood function (Section 6.2.4), which divides the floodplain into the categories of flow conveyance, flood storage and flood fringe.
- **Impact of Flooding** (Section 6.3) describes the consequences of flooding in urban areas. This section includes a breakdown of flooding hotspots where flood risk is concentrated (Section 6.3.1), mapping of property flooding across the town (Section 6.3.2), flood liability of critical infrastructure and sensitive land uses (0) and the economic impact of flooding (Section 6.3.4).
- **Emergency Response** (Section 6.4) describes the flood warning system and operation of emergency services (Section 6.4.1) and the 'flood emergency response classification of communities (Section 6.4.2).

Assessment of land use planning as it relates to flooding, including the cumulative impact of future development on flooding, is described for the four towns in Section 7.

6.2. FLOOD BEHAVIOUR

6.2.1. Background

Several creeks and tributaries converge south of the Michelago town centre including Michelago Creek, Margarets Creek, Ryries Creek, Booroomba Creek and Teatree Creek. Some sections of the town and surrounds are affected by overland flow flooding which drains towards these creeks, with minor roads like Tinderry Road reported to experience flooding (SES, 2017).

There is little data available describing previous floods in Michelago. Residents reported floods of various sizes, including 2010, 2012 and 2017. These generally aligned with high rainfall events recorded in the region, including February 2010, February 2012 and October 2017.

6.2.2. Design Events

Table 36 summarises design flood levels for a number of locations in the town. Locations are shown on Figure D 1 which also shows the 1% AEP peak flood depth. Figure D 2 shows the flood profiles for each design event for Michelago Creek.

Table 36: Michelago Design Flood Levels at Reporting Locations

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
28	Michelago Creek at Monaro Highway Bridge	685.7	687.7	688.1	688.4	688.8	689.0	689.3	689.6	698.4

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event							
			20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
29	Michelago Creek near railway bridge	691.8	693.3	693.6	693.8	694.2	694.4	694.7	695.1	699.9
30	Near Ryrie Street and Burra Road	694.9	695.1	695.1	695.2	695.2	695.2	695.2	695.2	698.5
31	Near Monaro Highway and Ryrie Street	690.6	691.0	691.2	691.3	691.3	691.3	691.3	691.4	698.5
32	Mount View Street	698.4	698.6	698.6	698.6	698.6	698.7	698.7	698.7	699.0
33	Micalago Rd near creeks' confluence	692.9	693.0	693.4	693.4	693.4	693.5	693.5	693.6	698.8
34	Booroomba Creek close to confluence with Michelago Creek	692.1	693.3	693.4	693.6	693.9	694.0	694.2	694.4	698.8
35	Near Monaro Highway and Ryrie Street	700.6	701.7	702.0	702.0	702.1	702.1	702.2	702.2	702.5

Michelago experiences less flood affectation than the other three towns. There is localised flood affectation at the intersection of Ryrie Street and Monaro Highway, and in the vicinity of the intersection Ryrie Street and Burra Road. The peak flood depths figures show the following:

- Michelago Creek remains confined to its channel until the 2% AEP event where it starts to spread out of bank downstream of its confluence with Booroomba Creek.
- There is a section of inundation of Micalago Road approximately 400 m to the east of Monaro Highway. Depths are around 0.7 m in the 10% AEP and increasing to 1.4 m in the 1% AEP.
- A flow path is present in the 20% AEP that joins into Mount View Street, inundation an area of land with depths between 0.2 m and 0.3 m.
- Several other flow paths leading towards Michelago creek are also present. Currently, there is little risk posed by the flow paths where they are away from roads and property.

6.2.3. Flood Hazard

Background on the concept and derivation of flood hazard is given in Section E.1.

Hazard categories for Michelago are presented on Figure D 3 to Figure D 6, for the 5%, 1% and 0.2% AEP, and the PMF. The figures show the following areas of hazard:

- The area to the east of the intersection of Monaro Highway and Ryrie Street, Mount View Street, and the area to the west of the intersection of Ryrie Street and Burra Road are categorised as H2-H4 in the 5% AEP.
- Nearly all the H3-H6 areas are localised within creeks and other minor flow paths in events up to and including 0.2% AEP, indicating the town has relatively low flood risk.
- In the PMF, a large proportion of the town is categorised as H5-H6 fringed by H1-H4, including sections of the Monaro Highway.

6.2.4. Flood Function

Background on the concept and derivation of flood hazard is given in Section 3.2.4 and E.2

The hydraulic categories of flow conveyance, flood storage and flood fringe have been derived for the 5% AEP, 1% AEP, 0.2% AEP and PMF events and are shown in Figure D05 to Figure D08. As described in Section E.2, the categories are used by town planners and other stakeholders to understand flood risk. Areas of flow conveyance are generally incompatible with development aside from parks or recreational facilities, while areas of flood storage can generally be developed, if the loss of storage or other impacts are managed. Flood fringe is areas of shallow flooding that, if developed, have minimal effect on the overall function of the floodplain.

The figures show that in the 1% AEP, the majority of the mainstream flood extent is flow conveyance, with some large areas of flood storage and flood fringe on the periphery. Overland flow leads to some smaller flow conveyances and large areas of flood fringe.

In the 5% AEP, the flow conveyance again occupies the majority of the floodplain, with some areas of flood fringe and small areas of flood storage on the periphery. The 0.2% AEP is similar to the 1% AEP, with slight increases in flow conveyance and flood storage. In the PMF most of the flood extent is flow conveyance with large areas of flood storage, including the town centre. Overland flow leads to some smaller flow conveyance areas and areas of flood fringe.

6.3. IMPACT OF FLOODING

6.3.1. Flooding Hotspots

Michelago does not experience significant flooding from Michelago Creek in most flood events; however, creek flooding can cause access issues for properties south of the town, when Micalago Road is inundated. There are also multiple overland flowpaths that cause localised minor flooding in the town.

Summary of Michelago Hotspots is presented in Table 37, with further details presented in Sections 6.3.1.1 and 6.3.1.2. The location of the various hotspots are presented in Figure D 1: Peak Flood Depth and Level - 1% AEP Michelago.

Table 37: Michelago Hotspots

Hotspot #	Location	Risk Factors
18	Ryrie Street near intersection with Monaro Highway	Road flooding and evacuation/isolation issues
19	Micalago Road at train tracks	Road flooding and evacuation/isolation issues

6.3.1.1. *Hotspot 18 - Ryrie Street near intersection with Monaro Highway*

This hotspot is the area in the vicinity of the Ryrie Street petrol station near the highway, which becomes flooded when the culverts under Ryrie Street (Two 0.9 m diameter) have their capacity exceeded. Inundation of the petrol station and surrounding area occurs due to backwatering, while Ryrie Street is also overtopped. Road flooding is low hazard (category H1) for events up to the 0.2% AEP event.

Flood risk at the location is generally low but it has been included as a hotspot due to being the only access road to Michelago from the highway.

Table 38 describes the area's flood behaviour and flood risk.

Table 38: Ryrie Street and Monaro Highway Hotspot Description

Flood Risk Characteristic	Description

Depth of flooding	• In 5% AEP, water depths of up to 1.4 m is present just upstream of culvert. Flooding of around 0.5 m around the petrol station. • In 1% AEP, water depths of up to 1.4 m is present just upstream of culvert. Flooding of around 0.6 m around the petrol station.
Flood Hazard	• In 5% AEP, hazard level of H1-H2 on the road, H1-H3 at the area north of the road • In 1% AEP, hazard level of H1-H2 on the road, H1-H3 at the area north of the road
Properties flooded above ground	• 1 in 5% AEP • 1 in 1% AEP
Properties flooded above floor (approx.)	• 1 in 5% AEP • 1 in 1% AEP
Evacuation	Hazard level at Ryrie street is low and affected residents can evacuate if needed.
Duration	Depending on the length of the storm event, flooding may several hours.
Additional Risk Factors	-
Gauge levels	Overland flow catchments are too small to use flow or level gauges.

6.3.1.2. *Hotspot 19 - Micalago Road at train tracks*

The section of Micalago Road near Ryrie Street and the now-defunct train tracks is affected by flooding of Michelago and Booroomba Creeks. Flooding occurs when the Booroomba Creek culverts (two 1.2 m diameter) are overtopped, and when the Michelago Creek inundates the road near the rail bridge. Flood risk is related to vehicles crossing hazardous flow on the road, and isolation of the area Micalago Road services.

Table 39 describes the area's flood behaviour and flood risk.

Table 39: Micalago Road at Train Tracks Hotspot Description

Flood Risk Characteristic	Description
Depth of flooding	• In 5% AEP, water depths of up to 1.2m is present on the road, near the culverts • In 1% AEP, water depths of up to 1.8m is present on the road, near the culverts
Flood Hazard	• Hazard level of around H4-H5 on the road in the 5% AEP • Hazard level of H5 on the road in the 1% AEP
Properties flooded above ground	• 3 in 5% AEP • 3 in 1% AEP
Properties flooded above floor (approx.)	• 0 in 5% AEP • 0 in 1% AEP
Evacuation	Micalago Road is the main access road for a number of properties to the west of the rail line. There is an alternative route (Ryrie Hill Road) but it is also likely to be flooded during major storm events. Flooding of the road will result in isolation which can have implications for emergency vehicle access such as ambulances which increases the risk to life if there is a medical emergency during a flood event
Duration	Depending on the length of the storm event, flooding likely to last several hours to days.
Additional Risk Factors	The crossing is expected to be trafficable during events smaller than the 20% AEP. Frequently flooded crossings increase the chance that vehicles will enter flood waters which can pose a significant risk to life.
Gauge levels	No available gauge

6.3.1.3. ***Flooded Roads – Michelago***

Hazardous flooding of roads occurs when there is sufficient flow to knock over pedestrians or transport cars off the road due to buoyancy effects. In Australia, vehicles attempting to cross flooded roads is one of the largest causes of injury and fatality in a flood. The ability of flow to move or completely float a car is often underestimated, with as little as 0.3 m (30 cm) depth enough to move a small car, even at small flow speeds (this corresponds to H2 hazard). The following roads have been identified as experiencing hazardous flow (H2 or above) in a 5% AEP event.

- Ryrie Street near Monaro Highway and petrol station
- Micalago Road at Booroomba Creek
- Micalago Road at Michelago Creek

These locations have also been listed in Section 8.3.1, which recommends warning signage. Note that other road locations may be flooded in a 1% AEP event and larger events (see hazard maps).

6.3.1.4. ***Other Areas for Consideration - Michelago***

Aside from the hotspots described, there are various scattered instances of over floor flooding in the town. The following section describes property flood liability. Areas of flooding include:

- Ryrie Street north-west of intersection with Burra Road. There is a 2x0.45m diameter culvert under Ryrie Street but flooding occurs on the northern side of the road as the culvert is not at the low point.
- Ryrie Street between Burra Road and Micalago Road

These properties may be affected by shallow flows associated with minor drainage flows rather than flooding.

6.3.2. Property Flood Liability

Properties across the study area experience inundation in a flood event, with affectation focussed along the watercourses and overland flowpaths. As part of the economic damages assessment, the flood affectation on a per property level was assessed by comparison of each lot's ground level and habitable floor level to the design flood levels at the property. The comparison is made at a point location on each lot, usually at the visible entry (i.e. front door). The floor level at each lot is an estimate based on visual inspection and not a surveyed level. This assessment allows an overall estimate of where properties are flooded above floor level, as shown on Figure D 15, which colour codes each property for the flood event it is first flooded above floor level. The map also shows the 1% AEP hazard.

The map should be interpreted as an overall representation of above-floor flood liability, and as an estimate only for determination for any particular property. This is because the floor level was estimated from visual inspection, which is less accurate than survey, and secondly because minor landscaping drainage features within a lot are sometimes not accurately captured in the model which is assessing an area of 21 km². The latter tends to exaggerate above-floor flooding in areas of shallow overland flow. Where properties in H1 hazard are shown as flooded above floor in relatively frequent floods, this indicates that the property simply has a low floor level and that shallow flow depths could potentially cause above-floor flooding. However, in practise, often local landscaping/drainage may ameliorate the risk of above floor flooding.

6.3.3. Critical Infrastructure and Sensitive Land-Uses

Critical infrastructure is located throughout the area and if inundated during a flood, can significantly impact the functioning of the town. The following section describes the flood liability of various critical infrastructure. The section also describes the exposure of facilities particularly sensitive to inundation, including childcare, schools and aged care.

6.3.3.1. ***Hospital and Ambulance***

Michelago is serviced by the Southern Sector of the NSW Ambulance Goulburn Area. Ambulance access to Michelago from Cooma may be impacted due to flooding of various road crossings during frequent flood events. In the event of major flooding in the Cooma region, access from the Queanbeyan Ambulance Station to Michelago may be preferred due to flooding of key access roads.

Council should notify the Southern Sector of the NSW Ambulance Goulburn Area, any reports of road closures associated with flooding between Cooma and Michelago. This will allow Ambulances to be directed from Queanbeyan if necessary.

6.3.3.2. ***State Emergency Service (SES)***

According to the Local Flood Plan, the Queanbeyan SES Unit service Michelago. Access to Michelago by emergency services is likely to be impacted due to flooding of various road crossings during frequent flood events. Assistance from the SES is likely to be significantly affected if the township to Michelago is impacted by flooding.

Access from the NSW SES Queanbeyan Unit may be preferred during major flood events in the Cooma region and/or reports of roads closures. Council should notify the NSW SES South East Zone Headquarters of any reports of road closures associated with flooding between Cooma and Michelago. This will emergency services to be directed from Queanbeyan if necessary.

6.3.3.3. ***Schools and Childcare Centres***

Michelago Public School is situated at 20 Ryrie St. The school is flood free for events up to and including the 0.2% AEP event, however, is affected by flood depths exceeding 2 m with an associated H5 flood hazard during the PMF event. Evacuation of the school is required during extreme Michelago Creek flood events.

6.3.4. Economic Impact of Flooding

A flood damages assessment is used to quantify the economic impact of flooding on the community. The assessment equates the depth experienced at each property to an economic cost, based on data from historical floods. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed management measures and by the state government in prioritising resources. More information on flood damages, including how they are derived, is provided in Section E.3.

The flood damages assessment for Michelago estimated an Average Annual Damage of $137,000. The results of the assessment, including properties flooded above floor per design event, and corresponding cost, is presented in Table 26.

Table 40: Michelago Flood Damages

Event	No. Properties Affected	No. Flooded Above Floor	Total Damages for Event	% Contribution to AAD	Avg. Damage per Flood Affected Property ($)
20% AEP	9	5	$331,700	36%	$36,900
10% AEP	9	5	$401,900	27%	$44,700
5% AEP	10	5	$450,500	16%	$45,000
2% AEP	11	5	$462,600	10%	$42,100

1% AEP	14	6	$529,500	4%	$37,800
0.5% AEP	15	8	$709,200	2%	$47,300
0.2% AEP	18	8	$767,400	2%	$42,600
PMF	34	33	$4,259,500	4%	$125,300
Average Annual Damages (AAD)			$136,700		$4,000

The table shows that there is minimal property flooding in Michelago in most flood events, with only the PMF causing more than 10 properties to be flooded above floor. In frequent events, flooding tends to occur where overland flowpaths interact with buildings, with around 10 properties affected. In the 1% AEP there is only slightly more than damage than more frequent events. In the PMF, the damages increases to $4.3 million.

The results show that frequent events are responsible for more than half of the AAD figure. The standard flood damages estimation includes a cost of around $10,000 for below-floor flooding, which results in large damages for frequent events (e.g. $332k in 20% AEP). This is likely an over-estimate of the actual damage cost.

6.4. EMERGENCY RESPONSE

6.4.1. Flood Warning and Emergency Response

Understanding of the available flood warning and emergency response in Michelago is understood from information provided in the Local Flood Plan, which is summarised in Section 2.3.8, and analysis as part of the current study. The Plan includes a map of Michelago and states there may be road closures during a flood, but does not otherwise describe the consequences of flooding at the town (i.e. historical events or river levels at which road or property flooding occurs).

As for other towns in the LGA, the BOM use a network of rainfall gauges and other data to issue a range of warnings related to flooding. These include Severe Thunderstorm Warning, Severe Weather Warning for Flash Flooding, and Flood Warning.

Analysis of four historical flood events indicates Michelago has a warning time of 1-2 hours. Michelago can therefore be characterised as experiencing flash flooding and the lack of available warning time can exacerbate risk in the town. Flash floods are difficult to forecast as the rainfall is very localised, which forecast models can less accurately predict than wider rainfall events. The short warning time means that in a large flood, emergency services must evacuate several separate areas and manage potentially reluctant or slow residents. While a replication of the BOM system at Cooma, which uses forecast rainfall and other inputs, may be possible for Michelago, it is not considered warranted given the comparative flood risk.

Discussion of response modification measures is given in the flood risk management measures section (Section 8.3).

6.4.2. Flood Emergency Response Classification of Communities

Flood Emergency Response Classification refers to categorising parts of the floodplain based on their evacuation constraints. Mapping of evacuation constraints across the study area assist the SES and other emergency responders in planning where assistance, evacuation or rescue is needed for individual properties. The categories have been mapped for three design events (5% AEP, 1% AEP and PMF) to understand how evacuation constraints vary between different-sized floods. The categories have been determined in accordance with DPIE's 'Flood Emergency Response Planning Classification of Communities' guideline. The categories are shown on Figure D 11 (5% AEP), Figure D 12 (1% AEP) and Figure D 13 (PMF).

The figures show that:

- In the 5% AEP and 1% AEP, the town is classified as High Trapped Perimeter area. This is due to the access to Monaro Highway, which is via Ryrie Street, being restricted by a small flowpath over Ryrie Street near the petrol station. The flow over the road is relatively minor but there is some H2 hazard flow which motorists would be advised against crossing.
- In the PMF, nearly all properties on the creek side of Ryrie Street are affected by H5 and H6 flooding, as are several properties on the other side of the road. All major roads are cutoff by hazardous flooding. The northwest corner of the town is relatively safe and can be used for short term evacuation (see PMF hazard map).

7. LAND USE PLANNING AND FLOODING

7.1. CUMULATIVE IMPACT ASSESSMENT

Cumulative impact assessment refers to the impact on flood behaviour by future development. It is a measure of how widespread development across the study area may lead to worse flooding, due to changes in the catchment characteristics. Specifically, urban areas have lower rainfall losses than undeveloped areas, and lower hydraulic roughness than areas of thick vegetation, both due to the increase in impermeable surfaces (i.e. roofs, footpaths, roads). The areas of future development were taken from the current LEP zoning areas based on discussion with Council. It is noted that these do not denote any currently proposed development areas. The impact is then determined by comparing the existing 5%, 1% and 0.2% AEP design flood levels and the 'fully developed' scenario. This scenario has the following modifications from the existing case:

- All fully-developed residential areas are treated as suburban residential lots, with 30% imperviousness in the hydrologic model (as per the existing case). This reduces the rainfall losses, which leads to increased runoff.
- Similarly, industrial/commercial zoned areas are set at 80% imperviousness (only applies to Cooma).
- Currently undeveloped areas have hydraulic roughness parameters set as per the roughness applied for urban areas based on the land zoning.

The 'fully developed' area is shown on Figure 8-24 to Figure 8-27 in Appendix E.

The impact assessment found that the 'fully developed' scenario will have negligible effect on existing flood behaviour, save for some localised areas where there is a minimal increase in flood levels. The results for each of the study areas is as follows:

- **Cooma** showed no increase in peak flood level in Cooma Creek or Cooma Back Creek across the three design events. In the Polo Flat watercourse, around 1.5 km from Numeralla Road, there was an increase of around 0.18 m in the 1% AEP event and 0.12 m in the 5% AEP event. The impact was contained within the main channel of the watercourse. There was no impact in the 0.2% AEP.
- **Bredbo, Berridale and Michelago** showed no increase in peak flood level, across the three design events.

While the reduced rainfall losses did lead to increased runoff in each of the simulations, the increase in flow occurred prior to the larger upstream catchment flood peak, and thus there was a negligible impact on peak flows and flood levels for the design events being examined. In some double burst rainfall events, it could occur that flood flows are increased due to the increase in imperviousness. This situation may occur when a secondary rainfall burst occurs at the time flood flows from a primary bust were passing through a proposed developed area. This situation is likely to be relatively rare and not lead to significant increases in flood levels.

The results indicate that development controls in relation to On-Site Detention (OSD) are not required to manage the cumulative impact on flooding from future development. In fact, in some situations, implementation of OSD may exacerbate flooding by slowing down discharge from developed areas which may then better align with the upstream catchment flood peak (thus increasing flood levels). This should be considered when developing on OSD strategy.

However, OSD controls also provide benefits for reasons other than flooding. They can be used to manage the change in runoff from frequent rainfall events thus reducing the risk of downstream erosion, as well as be implemented in conjunction with water quality strategies. For these reasons, an OSD policy is potentially appropriate for new development areas in each of the towns, however, it would not be categorised as a floodplain risk management measure.

7.2. FLOOD PLANNING AREA

The process of deriving the FPA varies depending on the dominant flood mechanism in a study area, with areas of creek flooding (also referred to as mainstream flooding) using a different approach to areas of overland flow. For some parts of the four study areas, there were also small unnamed creeks and gullies in rural areas with minimal flow (e.g. 5 m^3/s in the 1% AEP) that would likely be considered overland flow were the area to be developed. The range of flood mechanisms meant that the final FPA is a combination of different techniques, as described below. Overall, the FPA incorporates the risk of flood levels increasing in the main creeks and rivers, by including a freeboard of 0.5 m (as per NSW FDM), while also acknowledging that overland flow has less risk of covering a large area and so a 0.5 m freeboard is not suitable.

The methodology used to define the FPA in each town is as follows:

1. For the main creeks and rivers, which are defined here as those with >10 m^3/s peak flow in the 1% AEP, the FPA is defined by raising the 1% AEP level by 0.5 m and increasing the flood extent accordingly[1]. In each town these main creeks and rivers are:
    - **Cooma**: Cooma Creek, Cooma Back Creek, Sandy Creek, the unnamed creek that crosses Yallakool Road near Tillabudgerry Road and joins Cooma Creek 4.5 km north of the town centre, the creek/drainage channel that runs south to north through the Polo Flat area, and the small creek that joins Cooma Back Creek just downstream of Tumut Street
    - **Michelago**: Lenanes Creek, Margarets Creek, Michelago Creek, Booroomba Creek, Ryries Creek
    - **Bredbo**: Murrumbidgee River, Cosgrove Creek, Railway Gully and some smaller creek joining with Railway Gully, Bredbo River, Murrumbucca Creek, small creek that joins Bredbo River after Railway Gully and before Cosgrove Creek
    - **Berridale**: Woolway Creek, Coolamatong Creek, Myack Creek including two tributaries of Myack Creek
2. For lots within the urban areas (i.e. lot size of ~0.25 acres or smaller), but not overlapping with the mainstream FPA defined in step 1, the process is to first select all lots with at least 0.2 m depth in 10% of their lot (based on the 1% AEP event). Then, lots with localised, spurious depths resulting from DEM artefacts (particularly surrounding a building) are excluded, while any additional properties with significant flow are included. 'Significant flow' in this instance is defined as where there is 1% AEP flow conveyance.
3. For all other areas in the study area (i.e. larger rural or rural-residential lots), the FPA defined in Step 1 is extended to include the small creeks that have between 2 and 10 m^3/s peak flow in the 1% AEP. These are small unnamed creeks and gullies that are tributaries of the larger creeks. Their FPA was defined as the flood extent of the 0.2% AEP event, with depths of <0.2 m excluded. The 0.2% AEP was always less than 0.5 m above the 1% AEP event, and therefore did not overestimate the FPA area. For smaller flowpaths (i.e. <2 m^3/s), these were not included in the FPA and it is assumed that any development would manage this runoff via basic stormwater infrastructure.
4. For Cooma, which has an extensive urban area and stormwater system, lots were included in the FPA if they were traversed by stormwater drainage of 600 mm diameter or greater. These drains tend to follow natural flow paths in the urban area.

[1] This is achieved by using the flood level contours of a larger event (either 0.5% AEP or PMF), updating each contour with the 1% AEP level + 0.5 m, and then generating a surface from the contours, with the FPA occurring where the surface is above the ground level.

The Flood Planning Level (FPL) is then the 1% AEP level at the area of interest, plus 0.5 m. For lots affected solely by overland flooding, the FPL may be lower, depending on what is set in Council's LEP and DCP (see Section 8.2.2).

8. FLOOD RISK MANAGEMENT MEASURES

8.1. BACKGROUND

Assessment of flood risk management measures is one of the two key outputs of the current study, along with assessment of the villages' flood risk. Flood risk management measures are broadly defined as interventions that Council or other stakeholders can implement that will reduce, or otherwise manage, the risk of flooding in each town. There is a wide range of measures that can be used to manage flood risk, from large-scale structural works (e.g. a new levee) to non-structural interventions (e.g. planning control for new development). To determine which are best suited to a particular area, the range of measures is considered and evaluated against the nature of the flood risk. The investigation then determines whether a measure is feasible and ranks the feasible measures for implementation priority. The recommended measures are summarised in the Floodplain Risk Management Plan, including timing, responsibility and indicative costing.

Management measures are chosen from three categories set out in the NSW Floodplain Development Manual (2005), as follows:

1. **Property Modification Measures** are those that modify existing properties to manage their flood risk. This includes planning-related measures such as minimum floor levels and zoning based on a locality's flood risk. They also include house raising, and in cases of high flood risk, voluntary purchase schemes.
2. **Response Modification Measures** are those that improve the ability of people to plan for and react to flood events. They often involve emergency services and can be targeted at different phases of a flood, e.g. preparation, warning, response and recovery.
3. **Flood Modification Measures** are those that change the depth, level, flow or velocity of floodwaters, via structural measures. They are often used to exclude flow from an area (e.g. a levee bank) or to reduce the peak flow (e.g. detention basin).

All measures will have different effects for different sizes of flood. For example, measures that give benefit in the 10% AEP flood may have negligible benefit in the 1% AEP event and vice versa.

Table 41 gives an overview of typical measures in each category and their advantages and disadvantages, based on the NSW Floodplain Development Manual.

Table 41: Overview of mitigation measure types

	Measure	Areas of Application	Advantages	Disadvantages
Property Modification	**Land-use Planning**	Can be used in any area of development on flood-prone land but is particularly effective where new areas of development are planned.	In areas of new development, can avoid large-scale flood risk by incorporating flood risk mitigation into the development process.	Limited use when development is not planned as controls or zoning are not enforced. In such cases will only be effective in the long term. Stringent controls on development may not be accepted by community.
Property Modification	**Voluntary Purchase**	Where residential properties are exposed to high hazard flow that poses risk to life or high financial cost.	Can significantly reduce flood risk by removing people from high risk flooding.	Often expensive relative to other options and requires consent of each residence.
Property Modification	**Voluntary House Raising**	Where residential properties are exposed to low hazard and localised flow that can be avoided with higher floor levels.	Can significantly reduce cost of flooding in an area by reducing above-floor flooding. Avoids relocation of people.	Only suitable for low hazard flow. Not all house types are suitable for raising.

	Flood Access	Where isolation during a flood event is considered hazardous.	Can reduce risk to life by provision of access routes out of a flooded area.	Does not reduce damage to built assets. Limited to areas with isolation and access issues.
Response Modification	**Flood Education, community readiness**	Where a community's knowledge of flooding can be improved in order to reduce their flood risk.	Can equip community with best response/recovery plan for flooding, often cost-effective	Hard to ensure 100% of community is reached, limited benefit in particularly high hazard areas.
Response Modification	**Flood Prediction and Warning**	Where rainfall and flooding in a catchment can be forecast or measured and warning sent to downstream areas.	Can be used to initiate complete evacuation or other preparation measures.	Limited use in small catchments, warnings may be misinterpreted, does not reduce risk to fixed assets (e.g. houses).
Response Modification	**Recovery Planning**	Where recovery from a flood can be significantly improved	Designate responsibilities between agencies involved including Council, SES, community and insurers.	Focuses on the aftermath of a flood event so generally used in conjunction with other measures.
Flood Modification	**Flood Mitigation Dams**	Where a larger creek or river has available land to detain flood flow.	Can completely remove instance of common floods.	Often severe environmental impacts, requires large areas of land.
Flood Modification	**Retarding Basins**	Where an overland flowpath or small creek can be detained before it enters an urban area.	Reduces the flood peak and therefore flood levels in urban areas.	Requires large area of land, can be hazardous during a flood if a multi-use space.
Flood Modification	**Levees**	Where a creek or river can be blocked from a developed area.	Can protect against a range of floods, can be straightforward design and construction	Level of protection often overestimated, can be overtopped and fail. Often impacts properties outside the levee.
Flood Modification	**Bypass Floodways**	Where there is land available with suitable topography to create a bypass channel for a creek or river	Can reduce flooding in an urban area by diverting flow during a flood.	Requires large area of land and only suited to some floodplain topographies. May impact areas downstream.
Flood Modification	**Channel Modifications**	Where a creek or river is particularly constricted or otherwise inefficient in conveying floodwaters	Can reduce peak flood level by improving conveyance along a section of channel	Often significant impacts on environment and natural amenity. May impact areas downstream.

As described previously, all measures have a common disadvantage of having limited benefit in extreme floods, or in floods larger than their design event. Similarly, all measures must be maintained, either physically in the case of built measures, or renewed and updated in the case of flood education, planning controls and other interventions.

The structure of the remainder of the section is:

- Property Modification Measures – All Towns
- Response Modification Measures – All Towns
- Flood Modification Measures
    - Cooma Flood Modification Measures
    - Bredbo Flood Modification Measures
    - Berridale Flood Modification Measures
    - Michelago Flood Modification Measures

8.2. PROPERTY MODIFICATION MEASURES – ALL TOWNS

Property modification measures are those that directly deal with existing and future development to manage its flood risk. While such measures do not change the flood behaviour itself, over time they can remove dwellings and other buildings from the most hazardous flooding and ensure the remaining flood-prone areas are well-equipped to deal with flooding. Such measures are particularly suited to areas where flood modification measures are either not available or prohibitively expensive. In most cases property modification measures are implemented via Council policies, which can be used to stipulate where and how development can occur in the floodplain.

8.2.1. Adopt updated Flood Planning Area for each town (PM01)

The Flood Planning Area (FPA) defines properties that are subject to flood related development controls and is a key planning tool for managing and mitigating flood risk in an LGA. The process used to determine the FPA for each town is given in Section 7.2.

The FPA for Cooma is shown in Figure A 14, for Bredbo in Figure B 14, for Berridale in Figure C 14 and for Michelago in Figure D 14.

Adoption of the updated FPAs can be made in the short-term, while changes to the LEPs and DCPs may take slightly longer (see following measures). Adoption of this Floodplain Risk Management Study and Plan by Council can be used to formally adopt the new planning areas and supersede the existing planning areas.

Recommendation: Adopt an updated Flood Planning Area for each town

8.2.2. Local Environment Plan Amendments (PM02)

The Local Environment Plans (3) are the overarching policy document that sets requirements for managing flood risk in the LGA. There are currently three LEPs as the three pre-amalgamation councils each had separate plans. Section 2.2.2.1 describes what each of the LEPs contain in regard to flooding, in their respective flood clauses.

The following amendments to Council's LEP are recommended:

- A single LGA wide LEP be developed based on the Standard Instrument LEP with the following adjustments;
    - The Standard Instrument LEP, Subclause 2a is removed as is any reference to a flood planning area map. Incorporation of flood planning area maps within an LEP is typically not recommended due to difficulties associated with updating an LEP if a map requires revision. By removing the map from the LEP, updating the map (which can be in the DCP or individual FRMS instead) is relatively simple. Having the clause refer to a map in the LEP means that the map cannot be updated (as is required if results change or a levee is upgraded, for example) without a Planning Proposal.
    - The Standard Instrument LEP, Subclauses 4 and 5 need not be considered as they pertain to sea level rise.
- An example draft clause that can be used as a basis for Council's future LEP is presented below.
- A Floodplain Risk Management Clause should be introduced to the LEP so that flood planning controls can be applied between the Flood Planning level and the PMF. A draft Floodplain Risk Management Clause that can be used as a basis for Council's future LEP is presented below.

Whilst Council are developing their revised LEP, Clause 6.2 of the Cooma-Monaro Local Environmental Plan (2013) should be used for all areas of the LGA.

Council should include a revised Flood Planning clause in future Planning Proposals for LEP revision. A Floodplain Risk Management Clause should also be used so that controls can be applied to sensitive land uses above the Flood Planning Level. The draft LEP clauses presented below can be used as the basis of Councils proposal.

Draft LEP clauses

7.1 Flood planning

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

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account floodplain risk management studies and plans adopted by the Council and projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding, and

(f) is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual.

(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 in 2005, unless it is otherwise defined in this Plan.

(5) In this clause:

flood planning level means the level of a 1% AEP (Annual Exceedance Probability) flood event plus 0.5 metre freeboard, or a freeboard specified in the Snowy Monaro Regional Council Development Control Plan (published in 2020).

7.1A 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, but does not apply to land at or below the flood planning level.

(3) Development consent must not be granted to development for any of the following purposes on land to which this clause applies unless the consent authority is satisfied that the development is consistent with any relevant floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual, and will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land—

(a) centre-based child care facilities,

(b) correctional centres,

(c) emergency services facilities,

(d) group homes,

(e) hospitals,

(f) residential care facilities,

(g) respite day care centres,

(4) In this clause—

probable maximum flood has the same meaning as it has in the Floodplain Development Manual. Note. The probable maximum flood is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation.

Recommendation: A planning proposal be prepared for development of a new Snowy Monaro Regional Council Local Environmental Plan with inclusion of Flood Planning and Floodplain Risk Management Clauses as discussed above.

The Cooma-Monaro Local Environmental Plan (2013) should be used for all areas of the LGA, as an interim measure while the LEPs are being updated.

8.2.3. Advice on Land-use Zoning Considering Flooding (PM03)

Future Zoning Proposals

The Floodplain Development Manual (2005) states that '*Land use planning limits and controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately*'. Council should therefore give due consideration to selecting appropriate zones and related provisions when flood prone land is being rezoned as an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors and should not unjustifiably restrict development simply because land is flood prone (FDM, 2005).

Recommendation: Council to ensure that future zoning applications consider the flood risk of the land to reduce risk to life and property due to flooding.

Land Use Zone Types

The Cooma LEP has a range of Land Use types ranging from rural and environmental to residential, business and industrial land uses. A notable exclusion that is commonly implemented by Councils is 'Zone W1 Natural Waterways'. Zone W1 is a suitable zoning for the various creeks and rivers that impact the four towns and provides appropriate limitations on development in these areas.

Recommendation: A planning proposal be prepared for development of a new Snowy Monaro Regional Council Local Environmental Plan with inclusion of 'Zone W1 Natural Waterways' land use zone.

Existing Land Use Zonings

A review of land use zones that considers local flood characteristics has been undertaken for each of the towns.

The Australian Disaster Resilience Handbook Collection (Handbook 7) states that risk management can be achieved by informing land zonings through consideration of flood function, flood hazard, emergency response limitations, and vulnerability of difference development types. Consideration of these characteristics has been undertaken to identify potential appropriate adjustments to land use zonings.

To reduce future flood risk potential due to development pressures, undeveloped lots situated in high hazard (H3 or greater), flow conveyance areas and areas with significant evacuation constraints, are considered hazardous and should be considered for downzoning to a land use type that does not permit residential, business or industrial land uses.

A summary of the review is presented below. The analysis identified lots that met the above criteria and are considered hazardous and suitable for downzoning:

- Cooma - 37 undeveloped lots were considered to pose a significant flood risk if developed due to being located in 1% AEP high hazard/flow conveyance areas with limited evacuation potential due to lack of available warning time. The lots had a range of land zonings (R1, R2, B2, B3 and B4) and were all located on either Cooma Creek or Cooma Back Creek.
- Bredbo - 22 undeveloped lots were considered to pose a significant flood risk if developed due to being located in 1% AEP high hazard areas, with limited evacuation potential during extreme events due to a 'Low Trapped Perimeter Area' evacuation classification. The lots were predominantly zoned as RU1 with two R1 zoned properties. The properties are flooded by the Bredbo River and the creek which flows through Bredbo from the north.
- Berridale - 9 undeveloped lots were considered to pose a significant flood risk if developed due to being located in a 1% AEP high hazard area, with limited evacuation potential due to lack of available warning time. All lots were situated in RU5 zoned land and are affected by either Myack or Coolamatong Creeks.
- Michelago – no properties are suggested for downzoning.

Recommendation: Council consider downzoning undeveloped lots that are subject to hazardous flood conditions, to a land use type that does not permit residential, business or industrial land uses.

8.2.4. Updated Flood Planning Controls in the Development Control Plan(s) (PM04)

The Development Control Plans (3) are the second main policy document that sets requirements for development in flood prone areas of the LGA. While the LEP sets the overarching objectives, the DCP contains controls such as minimum floor levels, flood compatible construction, and which types of development can occur in different degrees of flood risk. Section 2.2.2.2 describes what each of the DCPs contain in regard to flooding.

It is understood that the NSW government will be releasing a standardised DCP for councils to use and that this will include a section on flooding. When this occurs, the new document will be a chance to combine the towns into one document, and to update the flood planning controls so as to be consistent across the LGA. As an interim measure, the current Cooma Monaro DCP 2014 (specifically Section 6.4 Flood Prone Land) should be used for setting flood controls across the LGA.

In general, the DCP should achieve the following:

- Provide clear and prescriptive controls for development on flood-prone land that are consistent with the LEP flood clause. The controls for a particular development on a particular site should be straightforward to understand by Council staff and the public.
- Incorporate the significant differences in flood risk that exist between mainstream flooding (generally creeks and rivers) and overland flow.
- Allow for a range of land use types in flood prone areas, with greater controls for more sensitive or critical uses.

To this end, the following modifications are recommended for updating the current Cooma Monaro DCP Section 6.4:

- Under 6.4.2.1 Flood Assessment, flood studies are required as part of the DA process for lots in the 1% AEP extent. The current study produces a much larger 1% AEP extent due to its inclusion of overland flooding, much of which is shallow, low risk and would not normally warrant a site-specific flood study. The requirement should be updated to apply to all lots in the Flood Planning Area, which, aside from mainstream flooding areas, only includes lots affected by significant overland flow.
- Similarly, 6.4.2.2 and 6.4.2.3 set minimum floor level requirements for residential and commercial development, using a freeboard above the 1% AEP or 5% AEP flood level. This freeboard is suitable for mainstream flooding and can be decreased to 0.3 m for overland flooding if significant scaling of flood levels is not noted for larger events.
- Sections 6.4.3-6 describe the flood studies and other information available for each town. These should be updated with reference to the current study and 2019 flood study.

Recommendation: Update DCP flooding controls during development of LGA-wide DCP based on the NSW government standardised DCP.

As an interim measure, apply Cooma Monaro DCP 2014 flood controls to the LGA.

8.2.5. Voluntary Purchase and Voluntary House Raising in Cooma (PM05)

Voluntary purchase requires the purchase of properties that experience high hazard flooding that cannot be otherwise mitigated. House raising involves lifting the house above a design flood level, and is generally only possible with non-brick houses (i.e. timber frame or similar) in low hazard areas.

House raising does not remove a house from the hazardous flooding and there is risk of occupants not evacuating which can exacerbate flood risk. In comparison, purchase of the property aims to remove the flood risk altogether by removing all buildings and re-zoning it as a park or environmental land. Both measures have been used across various instances in NSW where there are houses in areas of high hazard flooding. Both are voluntary and so are only pursued following consent of the landowner.

A voluntary purchase option has been discussed with Council for parts of Cooma. Further details are not provided here due to the sensitive nature of the option.

8.3. RESPONSE MODIFICATION MEASURES – ALL TOWNS

Response modification measures are those that improve the ability of people to plan for and react to flood events. Across the four study areas, flooding generally occurs with minimal warning time and is of short duration. Response modification measures are therefore focussed on improving general awareness of flooding and its consequences, additional warning signage particularly for roads with high hazard flooding, and improvements to the existing flood warning system.

8.3.1. Warning Signage at Hazardous Road Crossings (RM01)

This option consists of installing warning signage at roads in each town to reduce the incidence of motorists attempting to cross hazardous flood flow. Across Australia, the most common cause of fatality during a flood is drowning from attempting to cross a flooded bridge or road. As described in each town's hotspots section, there are roads in each town that have hazardous flooding in relatively frequent floods (H2 and above is hazardous for vehicles). Signage at flood-prone roads typically includes a warning sign (e.g. 'Road Subject to Flooding, Indicators Show Depth') and depth markers on both approaches. These can be cost-effective in managing flood risk, especially for areas where a bridge/culvert upgrade is not feasible. Recent research has found that static signage tends be ignored by drivers and that dynamic signage is more effective at warning against crossing hazardous flooding. Dynamic signage adds an electronic sign above the standard warning sign, that lights up to indicate when the road is flooded. A recent project using flashing signs that are automatically triggered has had early success in Queensland[2], and cost $500,000 for 21 signs.

Depth markers are already present at some roads in the four towns, and some road crossings in Cooma have manually operated gates that prevent road crossing during times of significant creek flow.

The following locations experience hazardous flow in a 5% AEP flood event and would benefit from depth markers and warning signage (* indicates they already have some signage but have been included for completeness):

- Cooma
  - Geebung Street (most of the street has some flooding, higher flow is near the road culverts around 60 m east of Polo Flat Road)
  - Carlaminda Road at watercourse that traverses Polo Flat, around 720 m west of Polo Flat Road
  - Church Road at three locations (30 m south of Sellar Street, 100 m north of Sellar Street, and around 400 m south of Culey Avenue).
  - Vulcan Street where it crosses Sandy Creek
  - Numeralla Road where it crosses Polo Flat watercourse (around 240 m north-east of Cooma Monaro Race Club)
  - Yallakool Road at crossing with watercourse west of intersection with Tillabudgerry Road
  - Massey Street and Commissioner Street (these crossings have manually closed gates)
  - West Street, Lambie Street and Hill Street where they cross the Cooma Back Creek tributary
- Bredbo
  - North Street at causeway to the west of intersection with Walker Street
  - Swan Street at causeway*
  - Bunyan Street at causeway*
  - Clifford Street at intersection with Bransby Street

[2] https://www.governmentnews.com.au/qld-council-expands-smart-flood-warning-system/

- Berridale
    - Boundary Street to the east of intersection with Kosciuszko Road
    - Oliver Street to the east of intersection with Kosciuszko Road
    - Bolton Street to the east of intersection with Kosciuszko Road
    - Myack Street to the east of intersection with Kosciuszko Road
    - Park Street to the east of intersection with Kosciuszko Road
    - Short Street at Myack Creek
- Michelago
    - Micalago Road at Booroomba Creek
    - Micalago Road at Michelago Creek

Recommendation: Install flood warning signage and depth markers for identified road flooding locations in each town

8.3.2. Automatic Boom Gates for Key Flooded Roads (RM02)

Automatic boom gates should be considered for frequently used low level crossing. Road such as Massie Street in Cooma, currently rely on Council staff to manually close the road once the crossing becomes inundated. This can result in a period when the road crossing is hazardous for vehicles, but not yet closed by Council. This situation occurred during a storm event in late 2019 where heavy localised rainfall over Cooma lead to flooding of Massie Street with delayed notification to Council.

There are various types of automatic boom gates, for example some may close due to a trigger level being reached at an upstream gauge (pre-existing gauges could be used), whilst others trigger due to the water level at the location of the road crossing. However, the objective remains the same, with the pressure and responsibility of rapid road closures reduced for Council staff.

It is worth noting that frequently flooded low level crossings that experience high traffic volumes are typically also suitable for road raising works to reduce flood liability. Road raising is the preferred method of mitigating risk to high hazard low level crossing, however, may not be financially feasible. In circumstances where road raising is not feasible, or unlikely to occur for many years, automatic booms gates should be considered.

Recommendation: Install automatic boom gates for frequently flooded low level crossings that experience high traffic volumes.

8.3.3. Community Flood Education (RM03)

The level of awareness of flooding in a community is an important indicator of how well the community can prepare for, respond to and then recover from a flood event. Beyond general awareness that flood risk exists in a particular town, flood education is most effective when it facilitates resilience to flooding in a community. This encompasses understanding of the types of flood risk, the available warning systems, measures that can be taken in preparation for a flood event, personal safety and protection of assets during a flood, and recovery from a severe flood event. In each of the four towns, the level of engagement and awareness will vary significantly between those with high flood risk and those who are only indirectly affected by flooding.

Flood education should be tailored to each area and carried out across a range of methods. Materials used in education should consist of:

- information on previous floods including photos
- design flood information as described in the flood risk sections of this report
- SES information on preparing for a flood, common hazards during a flood, and the recovery phase (see Figure 8-1 below as an example)

The range of communication methods adopted should cover different demographics and groups within the community. Available methods include:

- SES and Council stall at local events, with fact sheets, maps and SES staff available to talk to interested residents.
- Flood depth markers showing the height reached by historical floods. These can be attached to telegraph poles or other infrastructure.
- Periodic articles in press and social media, which describe the history of flooding and useful information on the current flood risk, and available resources.
- Council website with various information on flooding available in one location
- Education packages for primary schools and secondary schools. See https://www.ses.nsw.gov.au/for-schools/ for examples.

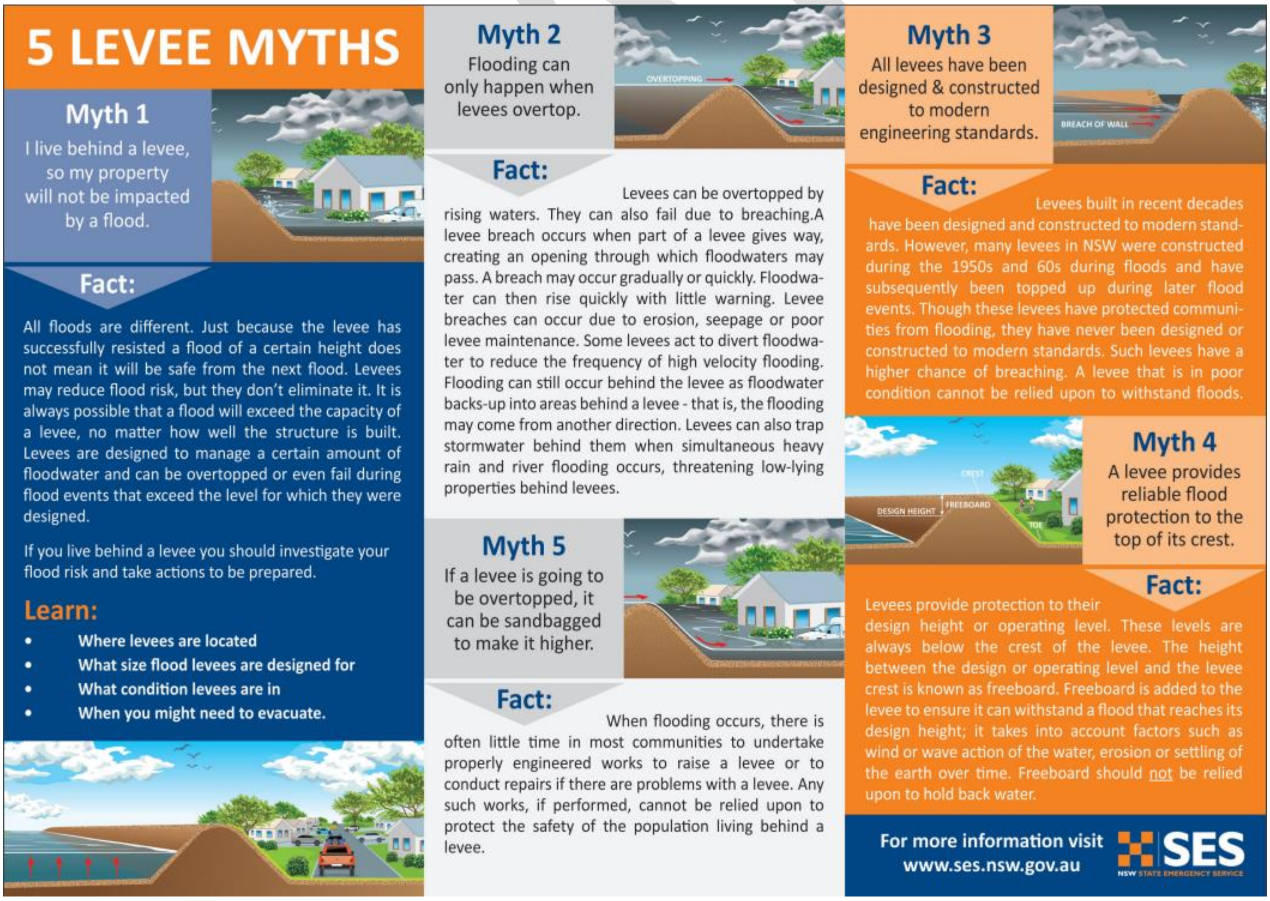


Figure 8-1: Example of a flood education fact sheet (source: NSW SES)

Recommendation: Implement a community flood education program for each town

8.3.4. Update Local Flood Plan and Flood Intelligence Cards (RM04)

The measure consists of updating information on flooding in the Snowy Monaro Regional Local Flood Plan and Flood Intelligence Cards for the two Cooma warning gauges. The Plan, which is summarised in Section 3.4.1 for Cooma, currently provides quite detailed information on flooding in Cooma based on the previous flooding assessments in 1994 and 1998 (see Section 2.3.1). There is minimal information on flooding in the other three towns. The plan can therefore be updated to provide information on flooding in each town, including the most recent flood risk assessment for Cooma. Pertinent information from this report and the Flood Study (2019) should be gleaned and incorporated into the Plan. A number of recommendations for amendments to the Plan are made below:

1. Expand the 'Landforms and River Systems' section to include description of Michelago Creek, Myack Creek, Coolamatong Creek and Wullwye Creek. Description of each is included in the 2019 flood study.
2. Update the 'Characteristics of Flooding' section with:
    a. The design flood estimates in paragraph 1.5.5 (the paragraph states 2.38 m at SMEC gauge estimated at 5% AEP, which is still accurate, while 4.4 m at Koolaroo is estimated as 5% AEP. 4.4 m is now closer to 2% AEP (4.55 m at the gauge))
    b. Add sections for Michelago Creek, Bredbo River, and the three creeks in Berridale. General description of each can be taken from the Flood Risk Assessment section for each town in this report.
    c. Confirm the Flash Flood Alerts section is up to date with the Bureau of Meteorology.
3. Expand the 'Flood History' section to include historical events in Michelago, Bredbo and Berridale, as described in the 2019 flood study.
4. Update the 'Flood Mitigation Systems' section for Cooma to be consistent with the information presented in Sections 3.3.1 and 3.3.2.2 of this report, including gauge height information.
5. Update the 'Extreme Flooding' to include the latest 1% AEP flood level at the gauge and the latest 1% design flood maps (depth and hazard may both be useful). Also include description of large and extreme floods in the other three towns using the Flood Risk Assessments or Overview of Flood Behaviour sections of this report, including the relevant maps.
6. Update the Specific Risk Areas – Flood section to be consistent with information presented in the Flood Risk Assessments section of this report, including adding information on the three other towns.
    a. Consider developing site-specific Flood Emergency Response Plans for three properties in Berridale that experience H5 hazard flooding from Coolamatong Creek.
7. Update Annex 1: Facilities at Risk of Flooding and/or Isolation with updated design flood extents and affected facilities in each of the four towns.
8. Describe flooded roads that lie outside the study areas which may block emergency services from accessing a particular community. This will primarily describe low-points on the highway that may be flooded, but will also include any particular access roads that service a collection of houses.
9. Develop Flood Intelligence Cards for Cooma and Bredbo to provide an understanding of flood consequence for flood events of varying magnitudes and the rapid dissemination of flood information by the SES during an event.

10. Nominate evacuation centres to be used during flooding in Bredbo, Michelago and Berridale. These should be located above the PMF, or if within the PMF, then ensure hazard is not higher than H1.
11. Include a section describing the new warning system at Bredbo, if measure RM07 is implemented.

Recommendation:

- Update the Local Flood Plan; and
- Develop Flood Intelligence Cards for Cooma and Bredbo

8.3.5. Investigation of Cooma Flood Warning System (RM05)

Review and assessment of the flood warning system has indicated several aspects of the current system would benefit from in-depth analysis. This analysis will consider the overall effectiveness of the current system as well as investigation into areas of improvement. Some improvements can be made in the short-term and these are listed in the following section (Option RM06). The flood warning components to be investigated in further detail include:

- Investigate the feasibility of a warning system based on depth and duration of observed rainfall, incorporating variable temporal patterns and losses, to complement BoM's existing warning system.
- Use historical and design flood modelling, and observed gauge data, to establish a relationship between the Cooma Creek gauge and a proposed new gauge at Sharp Street.
- Assess whether the gauge network successfully recorded historical rainfall events.
- Assess existing rating tables at the two gauges, using the TUFLOW hydraulic model validated to available gaugings.
- Recalibrate the Cooma Creek hydrologic model utilising the BoM Flood Warning rainfall gauge network.
- Update the Local Flood Plan description of flooding for each town based on the flood study and FRMS&P, included updated design flood levels. This has been described under the previous measure (RM04). The further work would draft each section in the Plan for update.
- Scoping study for automated road closures for road crossings that currently have gates manually operated by Council. This would be an expansion of the RM02 option, described previously.

If recommended as part of the draft Floodplain Risk Management Plan, this investigation and development of other measures can be undertaken in the short term (estimated 3 month timeframe).

Recommendation: Various components of Cooma's Flood Warning system are investigated in further detail

8.3.6. Cooma Flood Warning System Improvements (RM06)

The measure involves various changes to flood warning system for Cooma, further to updating information on flooding in the Local Flood Plan. The measure aims to improve the reliability and accuracy of the warnings issued by the Bureau of Meteorology, and to provide updated information to the SES, Council and the general public on the consequences of flooding. There is overlap with the RM05 measure, described previously, but in general, this option (RM06) pertains to improvements that can be made in the short-term, and are not dependent on further analysis. Areas that depend on option RM05 have been identified in the below list.

Recommended improvements include:

- Improve maintenance arrangements for the Cooma Back Creek gauge. Vegetation around the gauge is currently overgrown, its data collection system is not confirmed and its functionality during a flood event is not confirmed. Installation of a manual gauge at the gauge location would also be beneficial for residents' understanding of the size of different floods.
- Additional pluviograph coverage in the catchment area. **Dependant on results of the RM05 analysis.**
- Installation of a depth-marker on Cooma Creek, upstream of Sharp Street bridge. Currently the 'Koolaroo' Cooma Creek warning gauge is used to relate actual or predicted flood levels to consequences in the town, including levee overtopping. Having a depth marker in the town, in addition to the gauge, would allow residents, Council and other stakeholders to visually confirm the flood level as it occurs, and can then relate the depth to the same consequences. Beyond improving the community response during a flood event, a depth marker will also raise general awareness of flooding between flood events. Historic and design event levels could be indicated on the gauge to further raise community awareness.

  It is recommended the depth marker be installed on the west side of the creek, approximately 20 m upstream of the bridge. This location is visible from the bridge but is not as affected by afflux at the bridge itself, which can vary the flood level significantly, depending on the degree of blockage in a particular flood. The gauge would then be assigned a zero datum and a relationship to the Koolaroo gauge would be established.

Recommendation: Make improvements to the Cooma Flood Warning System including:

- maintenance of Cooma Back Creek gauge;
- Installation of a manual gauge on Cooma Back Creek near Sharp Street and
- Installation of a manual gauge on Cooma Creek near Sharp Street.

8.3.7. Bredbo Flood Warning System (RM07)

The measure involves establishment of a flood warning system for flooding caused by Bredbo River at Bredbo. The catchment is suited to a warning system as it has sufficiently large catchment response time (estimated to be 6-7 hours between the end of a rainfall burst and the peak flood level occurring) and it has significant flood risk, specifically in rarer flood events.

The components of a flood warning system for Bredbo would be:

- A network of two automatic flood level recorders in the catchment, that are sufficiently far upstream to provide advance warning of flooding, while also capturing a large-enough portion of the catchment (further discussion of location is below). The gauges would be telemetered and automatically provide live data to the BOM. Ownership and management arrangements for the gauge would be established between Council, BOM and SES and follow the *Provision of and Requirements for Flood Warning* document (SES, 2018).
- An automated flood level recorder on Bredbo River at Bredbo (likely near the highway crossing, for ease of access). There is currently a Bredbo River gauge approximately 5 km upstream of the town, however, excavation works near the gauge mean a reliable rating table cannot be established for the site, and for this reason the gauge is unlikely to form part of the warning system. An automated flood level recorder at Bredbo will provide real-time information on the degree of flooding at Bredbo.

- The three gauges (two in the upper catchment, one at Bredbo) will then form a warning gauge network. A flood warning system will be prepared, that provides an estimate of when flooding at each gauge will cause flooding at the Bredbo River gauge. This information can be provided using modelling established by the current study. It will then be updated following large flood events.
- A new section in the Local Flood Plan and Flood Intelligence Card describing the consequences of flooding at Bredbo for different levels at the new Bredbo gauge, and the recommended emergency response procedures. This will include the gauge levels at which different roads are estimated to be cut-off, as well as areas of property flooding that will require evacuation.
- Communication channels that ensure flood warnings are disseminated to Bredbo. For localised flood events that do not affect Cooma, the SES will be able to warn residents in low lying areas. For more widespread flooding, Bredbo may be isolated and a system to ensure residents are warned may be necessary. This could entail an automated SMS to flood-affected households, or similar.

The location of the two catchment gauges would be on Strike-a-light River and Bredbo River. The existing Strike-a-light River gauge (‘Strike-a-light Creek at Jerangle Road’, No. 410076) is in a suitable location but may require upgrade to an automated, telemetered recorder. A new gauge on Bredbo River approximately 14.0 km east of Bredbo would be suitable, just downstream of the Cowra Creek confluence with the river. Figure 8-2 below shows the catchment map with subcatchments and the two major watercourses. The two large subcatchments in thicker black outline would be gauged and are a combined area of 530 km^2, approximately 72% of Bredbo River’s catchment.

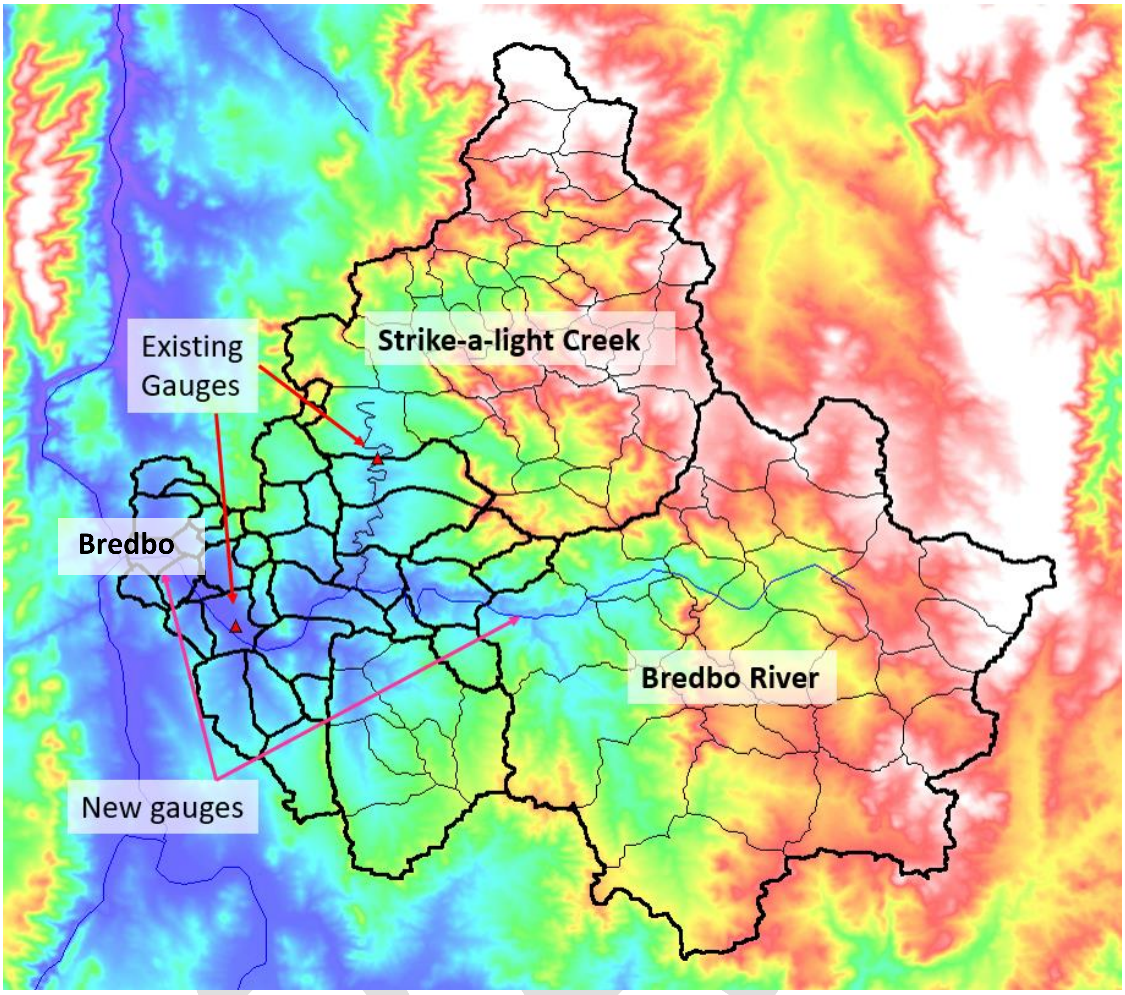


Figure 8-2: Bredbo River catchment map with warning gauge locations

Model results indicate a peak flow at the Strike-a-light gauge will take around 3 hours to reach Bredbo, while the nominated new Bredbo River gauge near Cowra Creek will take around 2 hours. More accurate estimates can be developed if the system is implemented. Based on these estimates the gauge system will provide 2-3 hours advance warning of flooding at Bredbo, and further warning will be provided by the existing BOM weather warnings. Feedback on the feasibility of a new warning system for Bredbo will be sought from Council, SES and other stakeholders during the public exhibition period.

Recommendation: A flood warning system is established for Bredbo, with input from BOM, SES and Council

8.3.8. Develop Communications Channel for Road Closures (RM08)

Liaison with NSW Ambulance indicated a relatively informal system of road closure notification. Currently, NSW Ambulance waits for Council or citizens to report road closures which could potentially affect emergency response times.

The establishment of a formal communications channel between Council, SES and NSW Ambulance regarding road closures due to flooding should be considered. Hazardous road flooding can significantly impact emergency services and prompt re-routing of vehicle access during times of flood, or even use of personnel from neighbouring areas if access is completely cut-off. The communications channel would be developed based on feedback from each entity and overseen by Council who is responsible for road closures.

Recommendation: Develop a formal communications channel between Council, SES and NSW Ambulance regarding road closures due to flooding

8.4. FLOOD MODIFICATION MEASURES

Flood modification measures were developed based on assessment of the town's flood risk (see Sections 3 to 6) as well as via community consultation and discussion with Council. Measures were developed with focus on mitigating flood risk at the flooding hotspots described in the flood risk sections. There are also general planning and response measures that apply to the study area as a whole (see previous two sections).

8.4.1. Cooma Flood Modification Measures

A staged process was used to select measures that warranted assessment using the hydraulic model and other analyses. This involved developing a longlist of measures, and then further assessing those that were most likely to be effective, with input from Council. Those that were not assessed further are not necessarily infeasible and some were not included due to the limited scope and budget of the current study. Reasons that a measure may not be feasible include prohibitively high cost for limited benefit, significant technical constraints and adverse environmental impacts. The full list of measures has been included here in order to show why not all hotspots had flood modification measures assessed. It should also be noted that a discarded option can still be assessed in detail at a future time, particularly if development in a particular area warrants associated flood mitigation works. Table 42 lists the longlist of measures and the outcome for each.

Table 42: Cooma Flood Modification Measures Longlist

Measure	Outcome
Connect stormwater outlet draining through Mulach Street levee to point further downstream	Not selected – rated as moderate feasibility. Based on the necessary extension area a new outlet may provide limited improvement to the area's drainage, especially if the creek is high.
Construct a levee on both banks of Cooma Back Creek, from Tumut Street to confluence with Sandy Creek	Not selected – rated as low feasibility. There is very limited space for a levee between the channel and various properties and would require embankment that are approximately 4 m high. May also cause higher flood risk in events larger than the design event and significant flood impacts upstream.
Implementation of a Vegetation Management Plan	Selected for assessment – Option V01 in following section. Modelling not undertaken.
Enlarge Cooma Creek channel cross section area through main levee, with steeper channel sides	Not selected – rated as moderate feasibility. Option will significant reduce the amenity of the creek area by limiting pedestrian access. It is also likely to be expensive, provide limited benefits during rare flood events and cause downstream flooding impacts.
Enlarge drainage channel at Polo Flat	Selected for assessment – Option Z02 in following section
Extend levee to properties behind Amos Street	Not selected – rated as moderate feasibility. There is limited space for a levee to be built in this area. There is likely to be significant difficulty in developing a levee design due to intersection with the low level Massie Street crossing as well as significant flows that arrive to the area down Bombala Street. Upstream flood impacts are likely.

Extend main levee up to Campbell Street	Selected for assessment – Option L02 in following section
Improve stormwater drainage through the levee	Not selected – rated as moderate feasibility. Option will benefit only localised flood events when Cooma Creek levels are low. The option is expected to have a negligible effect when Cooma Creek is in flood.
Increase main levee height to 2% or 1% AEP level of protection	Selected for assessment – Options L01A and L01B in following section
Raise Church Road to be above 1% AEP	Not selected – rated as low feasibility. Expected to be prohibitively expensive and result in local drainage and driveway access issues.
Raise low sections of the main levee to achieve overall 5% AEP protection	Selected for assessment – Option L01C in following section
Upgrade culvert under Lambie Street near Tumut Street	Not selected – rated as moderate feasibility. Culvert upgrades are likely to exacerbate conditions for existing flood liable properties downstream
Upgrade culvert under Vulcan Street to relieve road flooding	Selected for assessment – Option C03 in following section
Utilise Rotary Oval as a flood storage area for Cooma Creek flow	Selected for assessment – Option L03 in following section
Re-grade and enlarge Cooma Back Creek downstream of Sharp Street	Selected for assessment – Option Z04 in following section
Levee along Cooma Back Creek downstream of Sharp Street	Not selected – rated as low feasibility. There is very limited space for a levee between the channel and various properties and would require embankment that are approximately 4 m high. May also cause higher flood risk in events larger than the design event and significant flood impacts upstream.
Massie Street Bridge	Selected for assessment – Option M01 in following section

8.4.1.1. *Increase Main Levee Height to 1% AEP or 2% AEP Level of Protection (L01A and L01B)*

The mitigation measure consists of raising the existing main Cooma Creek levee to give protection against either the 2% AEP or 1% AEP flood event. The levee is currently overtopped in the 5% AEP event and inundates a number of properties as well as Sharp Street/Monaro Highway and other streets – see Hotspot 2 (sections 3.3.1 and 3.3.2.2) for more information. High hazard flows on Sharp and Bombala Streets pose a significant risk to life once the levee is overtopped.

This inundation and associated flood risk warrants investigation of the costs, benefits and feasibility of raising the levee. The levee is an earth embankment structure (aside from some brick/concrete wall sections), with land generally available on the 'dry' side of the levee, and so raising the crest level and footprint is generally feasible from a technical viewpoint. If the increased footprint overlaps with private property, a walled section may be necessary. The existing levee crest varies between 789.2-793.7 mAHD and would be raised around 1 m to provide 2% AEP protection and 1.5 m for 1% AEP protection (assuming freeboard of 0.5 m, exact height to be determined based on freeboard assessment). It should be noted that some sections of the levee would only require minimal raising.

The option has been assessed via model simulation of both the 2% AEP and 1% AEP event with the levee raised. Both events were assessed and while the larger event (1% AEP) is preferable for the added protection, it is often the case that adverse flood impacts or other factors make a high levee unfeasible. The alignment of the raised levee and the impact on the two events is shown in Figure 8-3 and Figure 8-4. L01A refers to the levee raised to the 1% AEP level of protection and L01B refers to the 2% AEP level of protection.

Figure 8-4 shows that protecting against overtopping in the 2% AEP has a significant effect on flood affectation, with the greatest benefit at Sharp Street and Commissioner Street properties, with a reduction of around 0.5 m on the west side of the creek and 0.3 m on the east side. The hazardous flow on Sharp Street west of the bridge, which is H3-H4 hazard in the 2% AEP existing case, is reduced to mostly H2, with some localised areas of H3 and H1. The residual flood depths are caused by overland flooding only. There is adverse impact of between 0.1 and 0.5 m along the leveed section of the creek, as flows that were previously overtopping the levee are now constrained to the channel. These impacts will be accommodated by the higher levee.

Figure 8-3 shows that protecting against overtopping in the 1% AEP has a greater reduction on flood affectation, but it also results in widespread adverse impacts upstream and downstream of the levee. The reduction is around 0.8 m on the west side of the creek and 0.5 m on the east side. The residual flood depths are caused by overland flooding only. The adverse impacts of between 0.1 and 0.2 m outside the creek occur over a large area near Albert and Campbell Streets, including impacting properties. The impact occurs because the 1% AEP creek flow is significantly constrained in entering the leveed section, which causes a backwater effect to the south.

Based on these results, only the 2% AEP level of protection (L01B) were investigated in further detail.

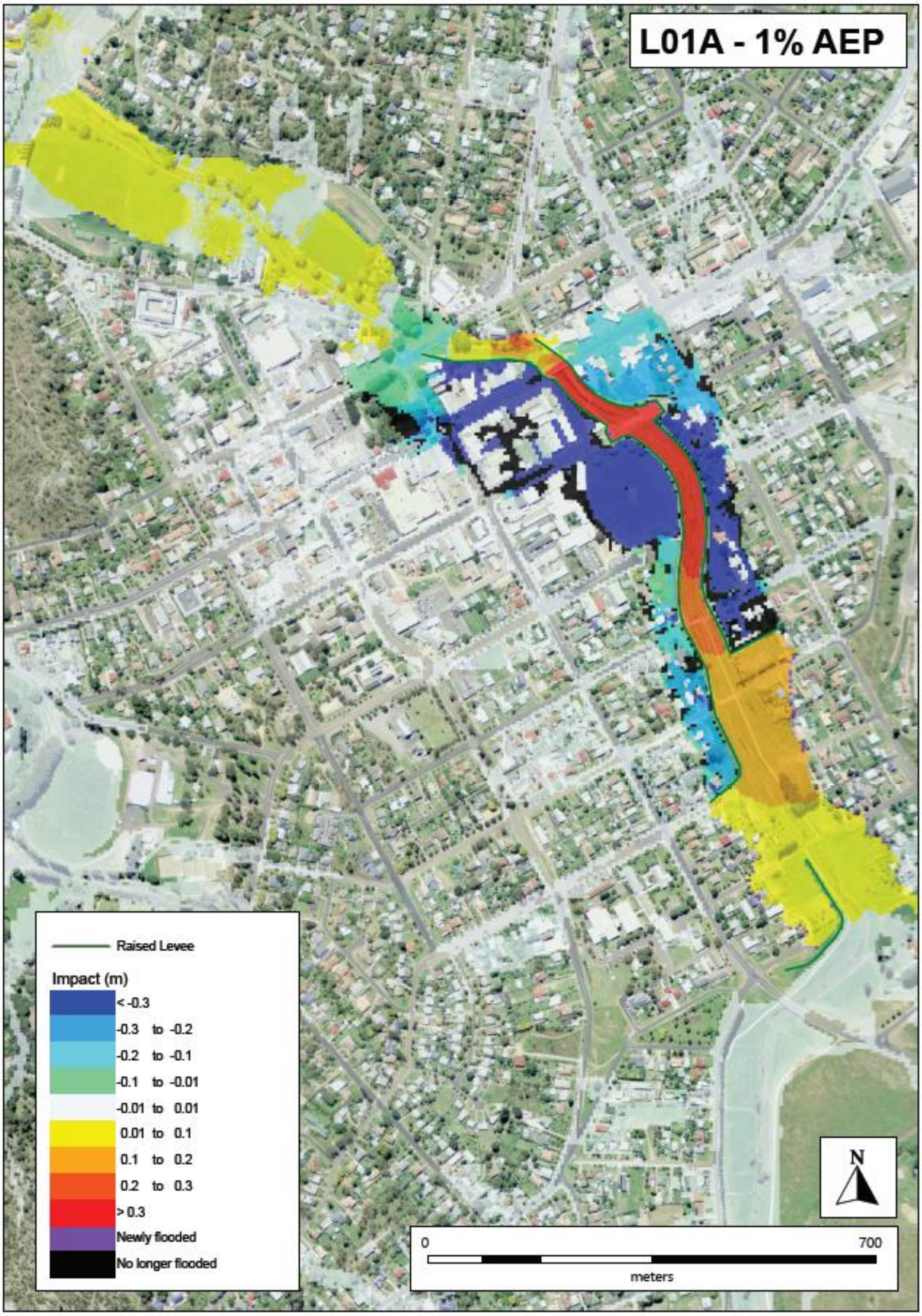


Figure 8-3: 1% AEP Impact - Option L01A (1% AEP Design level)

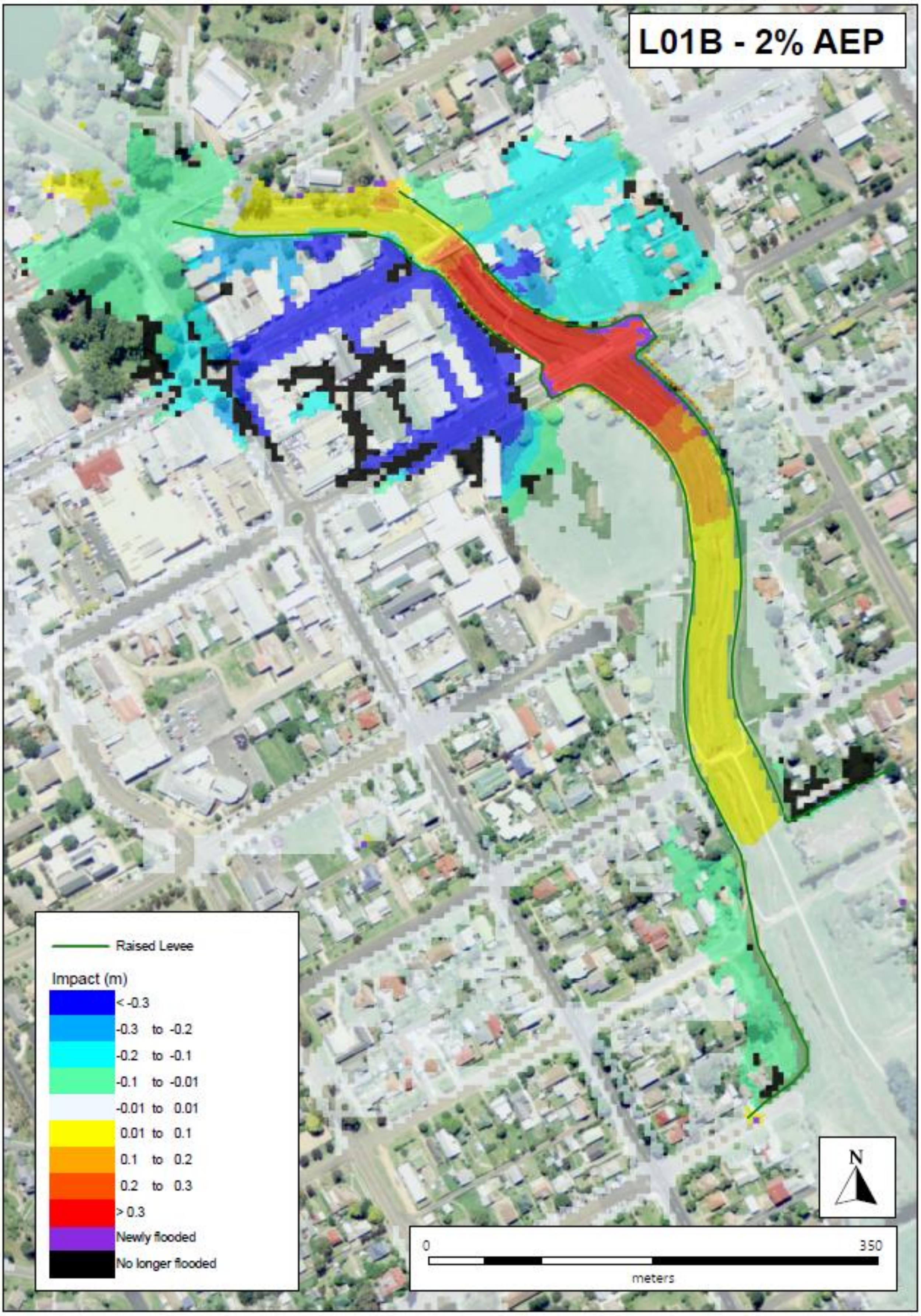


Figure 8-4: 2% AEP Impact - Option L01B (2% AEP Design level)

Further Analysis

Based on the assessment presented above, the 2% AEP levee option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 43 below. The table shows that the option has limited benefit in most flood events as the current levee is marginally overtopped in the 5% AEP, and the upgraded levee would still be overtopped in the 1% AEP (although by less than currently occurs). The greatest benefit is in the 1% and 2% AEP events, when around 10 properties are no longer flooded above floor and there is a saving of approximately $3 million in flood damages. The reduction in AAD ($90,446) is substantial.

Table 43: Option L01B 2% AEP Protection, Reduction in Damages and Above-floor Flooding

Event	Reduction in Properties Flooded Above Floor	Reduction in Event Damages
PMF	0	$ -
0.2% AEP	0	$ 277,600
0.5% AEP	1	$ 1,011,600
1% AEP	10	$ 3,337,400
2% AEP	8	$ 2,819,000
5% AEP	0	$ 107,400
10% AEP	0	$ -
20% AEP	0	$ -
	Average Annual Damage Reduction	$ 90,446

The impact on visual amenity is estimated to be significant but not a major constraint in raising the levee. As described, the levee would be raised from its existing height by approximately:

- 0.8-1.3 m between Sharp and Commissioner streets
- 0.3-0.6 m between Commissioner and Murray streets
- 0-0.3 m between Murray and Denison streets
- The Sharp bridge would also require a flood barrier to be retrofit to the upstream side of the bridge to block flow up to the levee crest level

These heights assume a freeboard of 0.5 m, while the actual freeboard would depend on detailed assessment and may be higher. The levee currently obstructs the view of the properties on various streets that back on to the creek, and this view would be further reduced with a raised levee. Feedback on the option will be sought from residents during public exhibition of this study. The option does not have significant social or environmental impacts as it involves modification to an existing structure and will have no impact on the normal functioning of the creek for non-flood event flows. A typical cross-section and a visualisation of a raised area is presented in Figure 8-6 below.

There may be significant complications associated with retrofitting a flood barrier to the upstream site of the Sharp Street bridge. The design and proposed works would need to be undertaken in conjunction with Roads and Maritime Services as they are the asset owner.

Visualisation of levee raised by approximately 1 m (yellow lines) near Commissioner Street. The average raised amount is 0.4 m but some sections will be around 1 m higher.

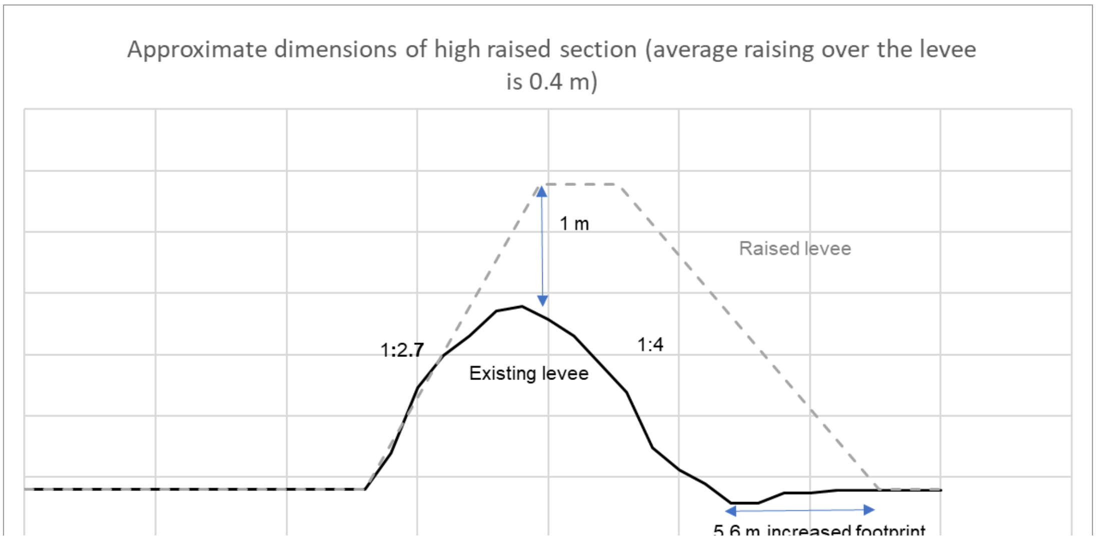


Figure 8-6: Visualisation of L01B and example cross-section

A preliminary cost estimate for the option is presented in Table 44 and the detailed costing is in Appendix F. It is noted that the per metre cost estimate is similar to levee upgrades in similar studies for Wagga Wagga and Albury. However, recent construction of a levee upgrade in Wagga Wagga cost substantially more than originally estimated (around twice as high). The cost estimate provided here is only for the purposes of economic analysis and the actual cost may be higher or lower.

Table 44: Option L01B Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$118,200
Site Preparation	$10,800
Earthworks	$883,300
Civil Construction	$288,200
Total (incl. contingency and GST)	$1,820,800
Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 1176 m of levee raised by average of 0.42 m.	

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $90,446
- NPV of reduction: $1,335,591
- Cost estimate of option: $1,820,800
- Benefit-cost ratio: 0.7

The benefit-cost ratio is 0.7, meaning its cost is slightly higher than it's expected benefit and the option cannot be justified on economic grounds alone. Overall, raising of the levee itself does not have significant technical constraints, and it provides a moderate benefit in the 1% and 2% AEP design flood events. However, modification of the Sharp Street bridge to prevent overtopping in the 2% AEP may have technical complexities and requires further investigation. Beyond the reduced property damage, the option also has a significant reduction in the risk to life from the hazardous flooding on Sharp Street during the 1% and 2% AEP events. It is therefore worth recommending for the short to medium term, pending consultation with Council, the community and other stakeholders. The overall comparison of the Cooma options is presented in Section 8.5.

Recommendation: Upgrade the Cooma levee system level of protection to 2% AEP or 5% AEP (see following section) as a short-term measure, pending Council and community feedback

8.4.1.1. *Raise low sections of the main levee to achieve overall 5% AEP protection (L01C)*

The mitigation measure consists of raising the existing Cooma Creek levee to the 5% AEP level of protection, in order to stop overtopping of low section in that event. This option is a less ambitious version of Option L01, but has been assessed in case there are significant constraints to implementing a higher level of protection (e.g. 2% AEP). The overtopping and level of protection of the current levee is described in detail in Section 3.3.1 and 3.3.2.2. As with the similar Option L01B, there is generally sufficient space to raise portions of the levee, but this would require confirmation during detailed design.

The option has been assessed via model simulation of the 5% AEP event with the levee raised. The alignment of the raised levee and the impact is shown in Figure 8-7.

Figure 8-7 shows that protecting against overtopping in the 5% AEP has minimal effect on flood affectation, with a slightly lower flood level between Sharp and Commissioner streets. The reduction is around 0.1 m and there is a corresponding increase of around 0.1 m in the channel. These impacts will be accommodated by a slightly higher levee on both sides.

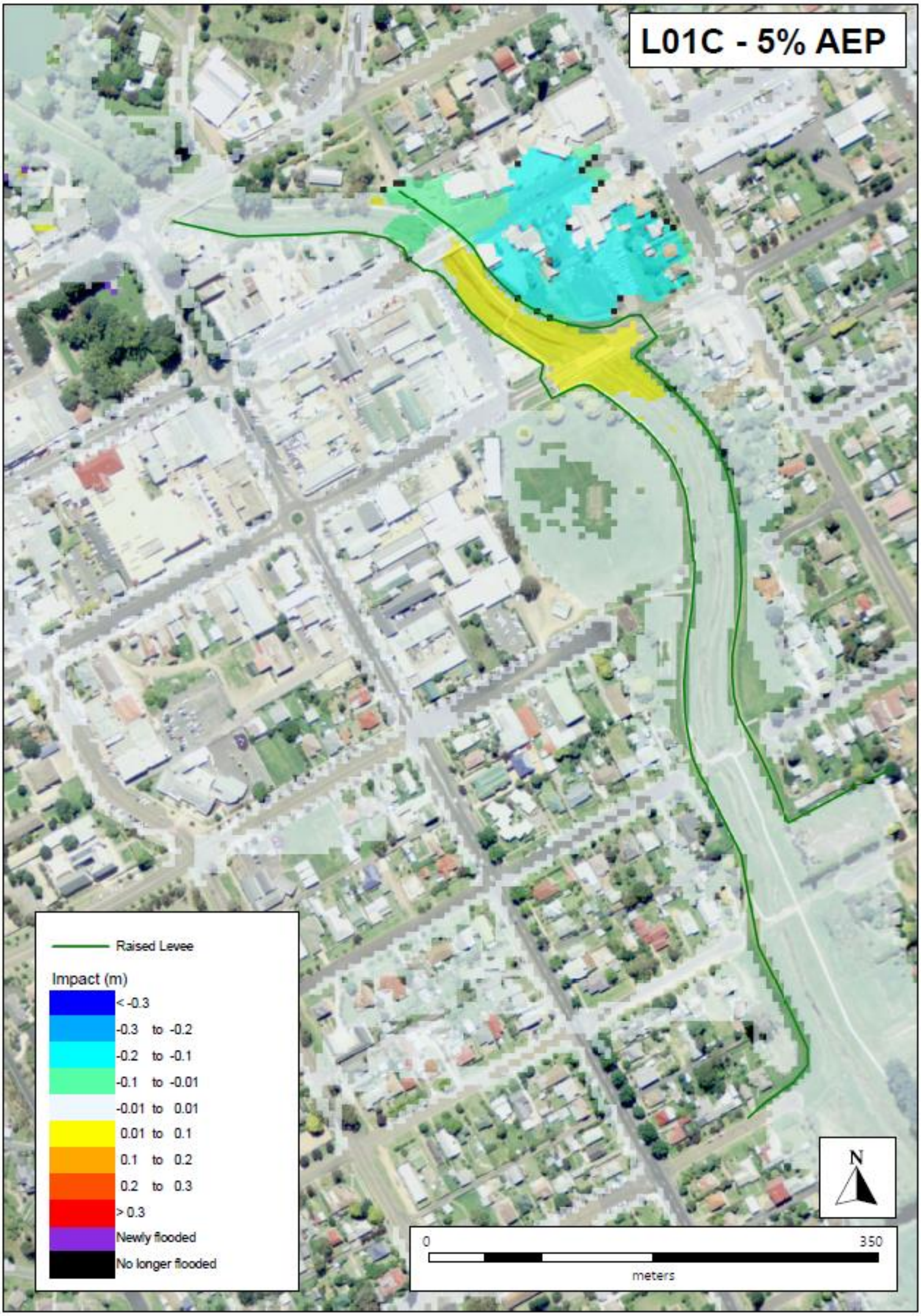


Figure 8-7: 5% AEP Impact - Option L01C (5% AEP Design level)

Further Analysis

Based on the assessment presented above, the 5% AEP levee option warranted further analysis including its benefit in a range of floods, the impacts on visual amenity and overall flood risk, and preliminary costing and cost. The option was simulated for each design flood event and the results are presented in Table 45 below. The table shows that the option has limited benefit in most flood events, which is expected as the levee would only be slightly raised from what currently exists. There is one less property flooded in the 5% AEP and one more flooded in 2% AEP. This is due to an increase in water depth northwest of the oval. There is reduced above-ground flooding in most events which results in a saving of around $100,000 in most events. The reduction in AAD is not particularly large ($10,866).

Table 45: Option L01C, Reduction in Damages and Above-floor Flooding

Event	Reduction in Properties Flooded Above Floor	Reduction in Event Damages
PMF	0	$ -
0.2% AEP	0	$ 99,400
0.5% AEP	0	$ 122,500
1% AEP	0	$ 108,000
2% AEP	-1	$ 25,300
5% AEP	1	$ 220,300
10% AEP	0	$ -
20% AEP	0	$ -
	Average Annual Damage Reduction	$ 10,866

The impact on visual amenity is estimated to be significant but not a major constraint in raising the levee. As described, the levee would be raised from its existing height by approximately:

- 0.2-0.6 m between Sharp and Commissioner streets
- 0 - 0.2 m between Commissioner and Murray streets
- 0-0.1 m between Murray and Denison streets

These heights assume a freeboard of 0.5 m, while the actual freeboard would depend on detailed assessment and may be higher. The levee currently obstructs the view of the properties on various streets that back on to the creek, and this view would be further reduced with a raised levee. Feedback on the option will be sought from residents during public exhibition of this study. The option does not have significant social or environmental impacts as it involves modification to an existing structure and will have no impact on the normal functioning of the creek. A typical cross-section and a visualisation of a raised area is presented in Figure 8-8 below.

Visualisation of levee raised by approximately 0.3 m (yellow lines) near Commissioner Street. The average raised amount is 0.2 m but some sections will be around 0.3 m higher.

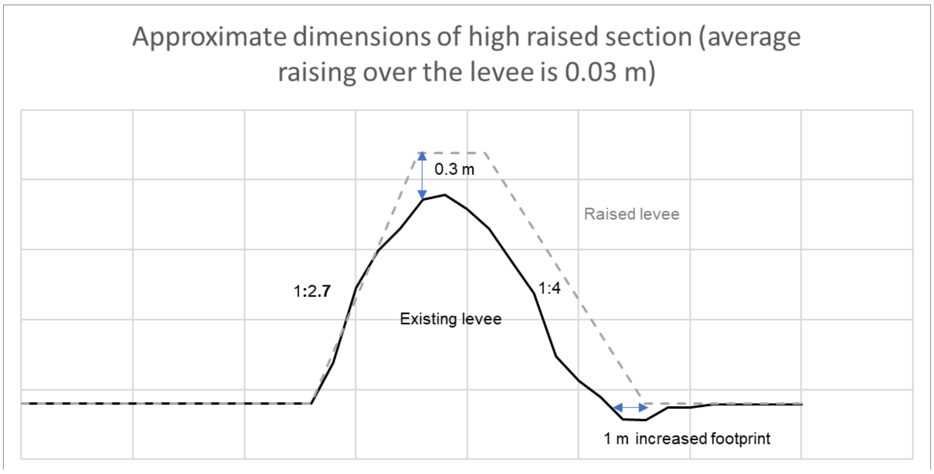


Figure 8-8: Approximate L01C Levee Height and Cross-Section

A preliminary cost estimate for the option is presented in Table 46 and the detailed costing is in Appendix F.

Table 46: Option L01C Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$34,900
Site Preparation	$5,600
Earthworks	$154,500
Civil Construction	$188,700
Total (incl. contingency and GST)	$537,000
Cost estimate is only approximate, for the purposes of economic analysis of the option. It is based on approximately 382 m of levee raised by average of 0.2 m.	

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $10,866
- NPV of reduction: $160,456
- Cost estimate of option: $537,000
- Benefit-cost ratio: 0.3

The benefit-cost ratio is 0.3, meanings its cost is around a third of the expected benefit and it is not justified on economic grounds alone. Overall, the option does not have significant technical constraints, but it provides limited additional benefit in most flood events, with most benefit in the 5% AEP event. It is recommended for implementation if a larger levee upgrade is not adopted. The option's feasibility is also dependent on feedback from Council, the community and other stakeholders. The overall comparison of the Cooma options is presented in Section 8.4.1.2.

Recommendation: Upgrade the Cooma levee system level of protection to 2% AEP or 5% AEP as a short-term measure, pending Council and community feedback

8.4.1.2. ***Extend main levee up to Campbell Street (L02)***

The mitigation measure consists of extending the existing main Cooma Creek levee to the south, to give flood protection to the area between Polo Flat Road and Victoria Street. This option was also investigated in the SMEC (1994) study. This section of the creek currently floods some properties, although it is noted that there is minimal above-floor flooding in most flood events as most houses are located outside or close to the edge of the 1% AEP flood extent. Besides the potential to reduce property flooding, the option was considered as any improvements to the existing Cooma Creek levee may prompt explanation for why the levee is not extended further.

There is land available on the sides of the creek and so construction of an earth embankment levee is generally feasible from a technical viewpoint. For 5% AEP protection, the levee would be of a similar height to what exists further north, which is around 1.5-2.5 m above natural ground levels. The option has also been assessed based on a 1% AEP level of protection, for the 1% AEP event. The exact height would be determined based on freeboard requirements.

The option has been assessed via model simulation of both the 5% AEP and the 1% AEP with the existing levee extended to near Polo Flat Road. The existing levee has also been raised for the 1% AEP option to the 1% AEP level (i.e. similar to Option L01). The reason for this approach is:

- A 5% AEP levee would generally be an extension of the existing levee and so may be paired with upgrading of the existing levee to 5% AEP (see option L01C)
- A 1% AEP levee would substantially change the 1% AEP flood behaviour and may be paired with upgrade of the existing levee above the 5% AEP (see options L01A and L01B). A new 2% AEP levee is also a possibility but the results can generally be inferred from the 5% and 1% AEP options.

The alignment of the raised levee and the impact in the two design events is shown in Figure 8-10 and Figure 8-9.

Figure 8-9 shows that extending the levee to the south, with a 5% AEP level of protection, significantly reduces flooding but also causes adverse impacts upstream. The reduction is mostly on vacant lots and the yards of properties near the creek, and is around 0.5 m. The adverse impact is 0.1-0.3 m but mostly occurs in the channel area. Overall, while the reduction in flooding is significant, there is minimal flood liability or risk in the areas benefited.

Figure 8-10 shows that the same extended levee with a higher level (1% AEP) provides significant benefit but also reduces the flow area of the creek and this causes various adverse impacts. The impacts should be examined in the context of Figure 8-3, as this option is an extended version of the L01A 1% AEP option. The reduction is around 0.4 m on the west side of the levee around Campbell and Albert streets, while on the east side there is an increase of up to 0.8 m due to the levee blocking overland flow (this could be offset with cross-drainage in the levee, but will only be effective if the creek is at a low level). There are also significant adverse impacts at the upstream end of the levee, including on properties. The overall effect is to sacrifice the wide flow width of the existing channel, to provide additional protection to some areas. While a smaller levee is possible (i.e. as described in the previous paragraph) there is limited value to 5% AEP protection because there is relatively little flood risk in that event, compared to areas downstream where properties are closer to the creek.

Based on these results the option was not investigated further and is not recommended for implementation.

Recommendation: The option is not considered feasible and is not recommended for implementation

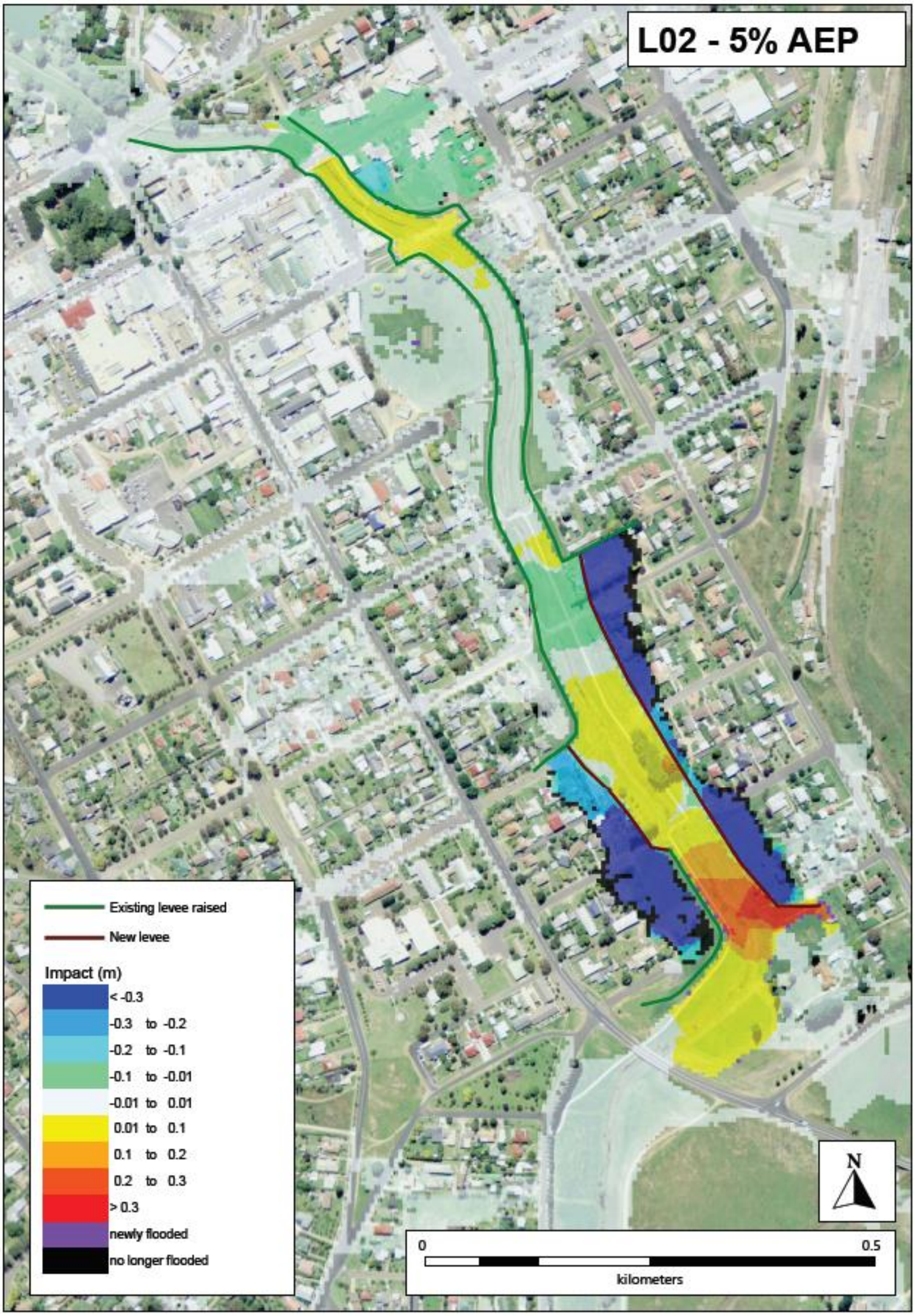


Figure 8-9: 5% AEP Impact - Option L02

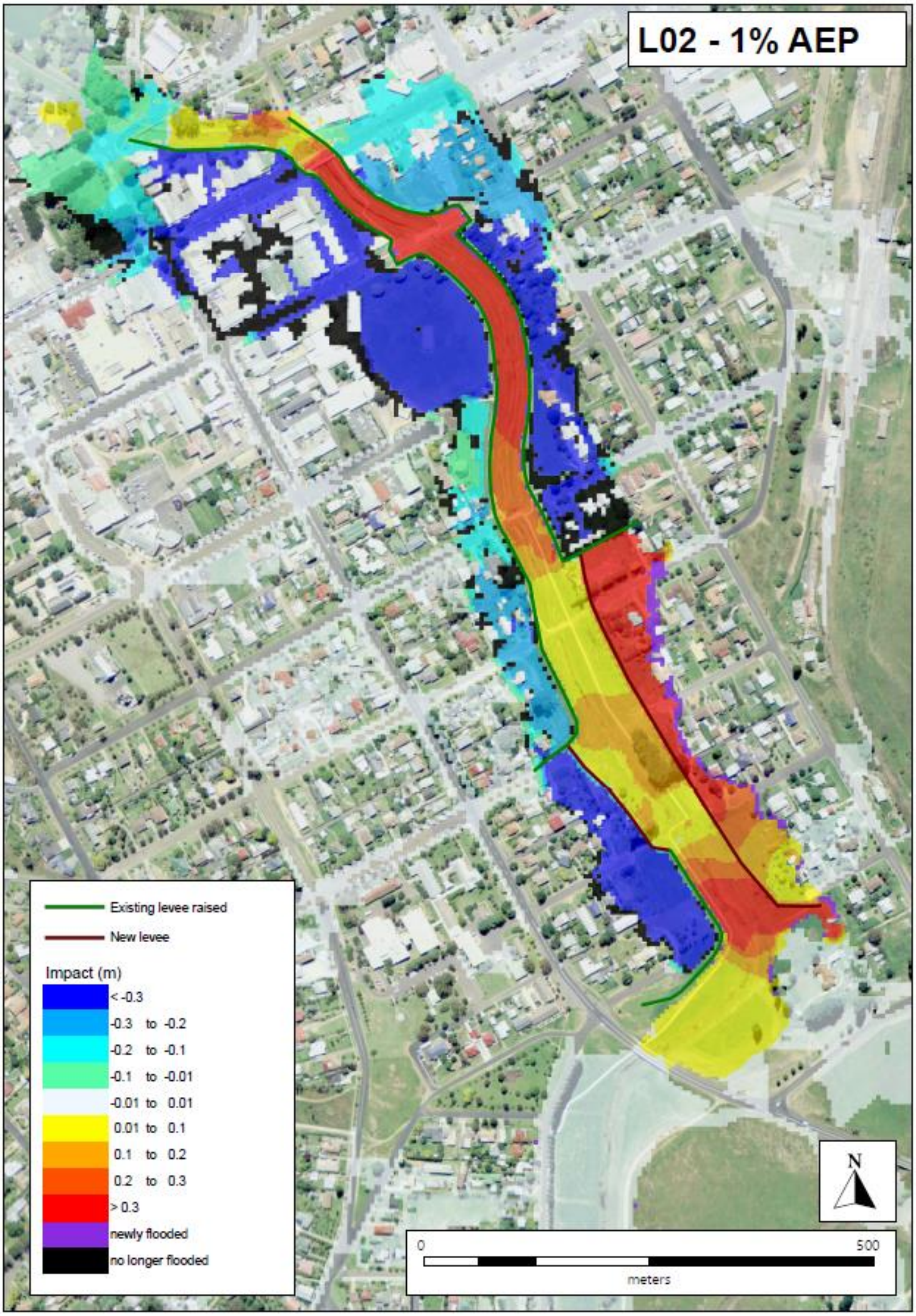


Figure 8-10: 1% AEP Impact - Option L02

8.4.1.1. *Utilise Rotary Oval as a flood storage area for Cooma Creek flow (L04)*

The mitigation measure consists of diverting a portion of Cooma Creek flow into Rotary Oval near Commissioner Street, with the objective of relieving the high flood level through this section of creek. This option aimed to complement Option L01, which involves raising the levee, as significantly more flow is confined to the creek which elevates the flood level. Rotary Oval is a large area adjacent to the creek that has potential to act as a flood storage area, so long as the increased depths are managed with levees or other works around the oval edge.

The option was developed for the 1% AEP event, where the creek levels are particularly elevated if the levee is also raised. The option uses the 1% AEP levee used in Option L01 but lowers a section of the levee adjacent to the oval by around 0.5 m. This allows flow into the oval without diverting the entire creek flow.

The option has been assessed via model simulation of the 1% AEP. The alignment of the raised levee and the overflow section into the oval, as well as the impact, is shown in Figure 8-11. The figure should be compared to Figure 8-3 which is the same except for the overflow section.

Figure 8-11 shows that utilising the oval as a flood storage area has minimal effect on peak flood levels in the 1% AEP. Relative to the impact shown in Figure 8-3, the peak flood level increase is only 0.02-0.03 m lower. This indicates that while a significant volume of flow is being diverted into the oval, as the depth is approximately 1.35 m greater, the volume is not large enough to significantly reduce the peak flow (and therefore level) on the creek.

Based on these results the option was not investigated further and is not recommended for implementation.

Recommendation: The option is not considered feasible and is not recommended for implementation

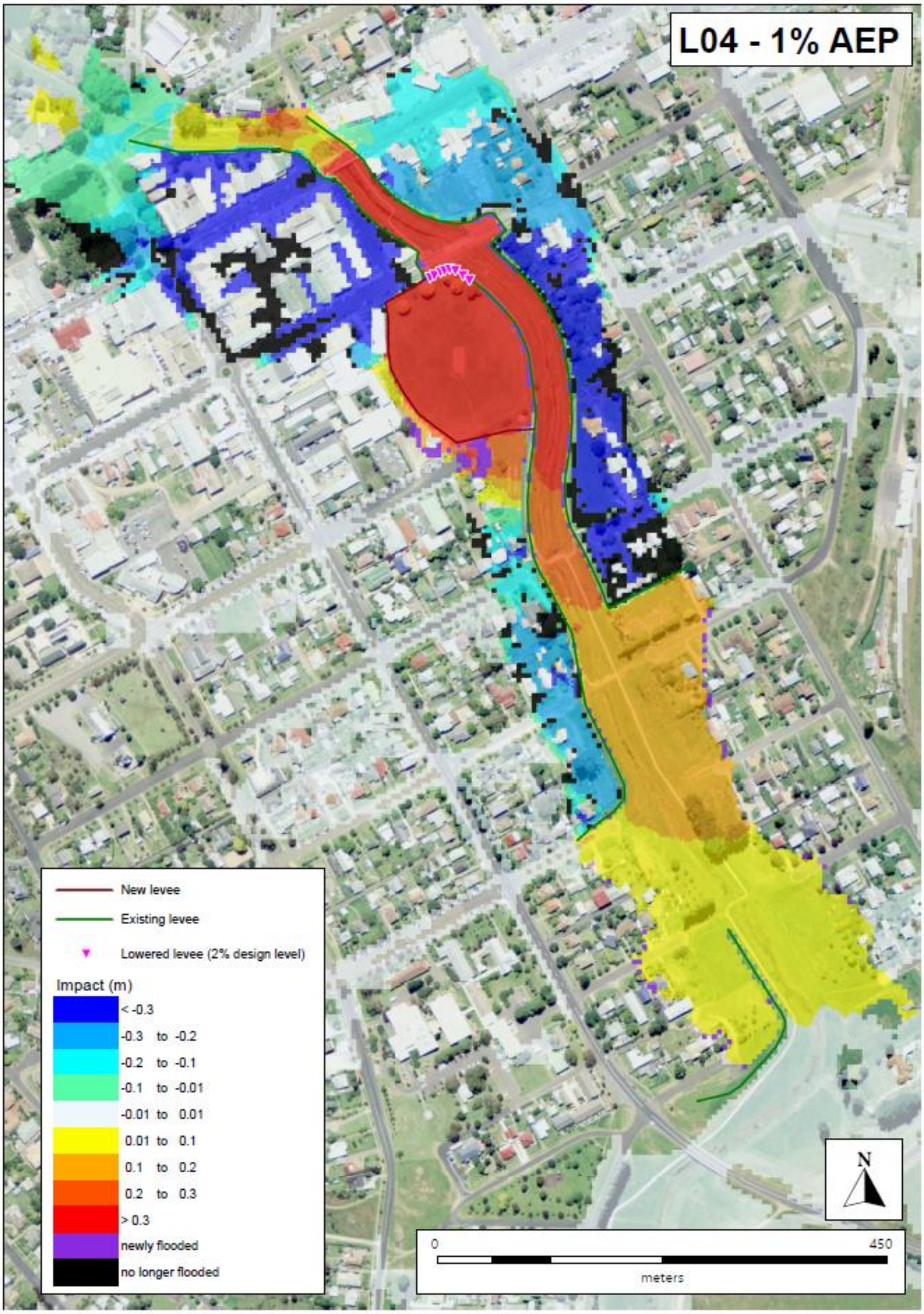


Figure 8-11: 1% AEP Impact - Option L04

8.4.1.2. *Upgrade culvert under Vulcan Street to relieve road flooding (C03)*

The mitigation measure consists of upgrading the culverts of Sandy Creek under Vulcan Street to reduce hazardous flooding on the road and provide access to the residential area to the north. This option was also investigated in the SMEC (1994) study. Currently in the 5% AEP event there is H4 hazard flow over the road, which becomes H5 in the 1% AEP. See Section 3.3.2.5 (Hotspot 5) for full description of the area's flood risk. The option consisted of raising a section of Vulcan Street, construction of a series of larger culverts, and lowering part of the creek area immediately upstream of the area.

The option has been assessed via simulation of the 1% AEP event. The dimensions of the culverts modelled are 5 culverts of 2.1 m x 1.5 m and the road is raised an average of 0.4 m, with a maximum increase of 0.9 m. The location of the culvert and the raised road, as well as the flood impact, is shown on Figure 8-12.

The figure shows that upgrading the culvert capacity (including road raising) has a significant effect on road flooding. Under the option, the road has a category H1 hazard which means the residential area to the north is accessible in most flood events. The culverts' peak flow in the 1% AEP increases from 1.0 m^3/s in the existing case to 26.0 m^3/s under the option.

Based on these results the option was given a preliminary costing estimate and compared to other options in the multi-criteria assessment (Section 8.4.1.2). The option has minimal effect on property flooding and so could not be justified on economic grounds using the standard damages assessment (which only includes direct damage to properties). An overview of preliminary costing is given in Table 47 below and full preliminary costing is provided in Appendix F.

Table 47: Option C03 Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$49,000
Site Preparation	$42,200
Earthworks	$52,200
Civil Construction	$313,600
Total (incl. contingency and GST)	$628,900
Cost estimate is only approximate, for the purposes of comparison to other options	

Recommendation: Construction of the option be considered for the short to medium term

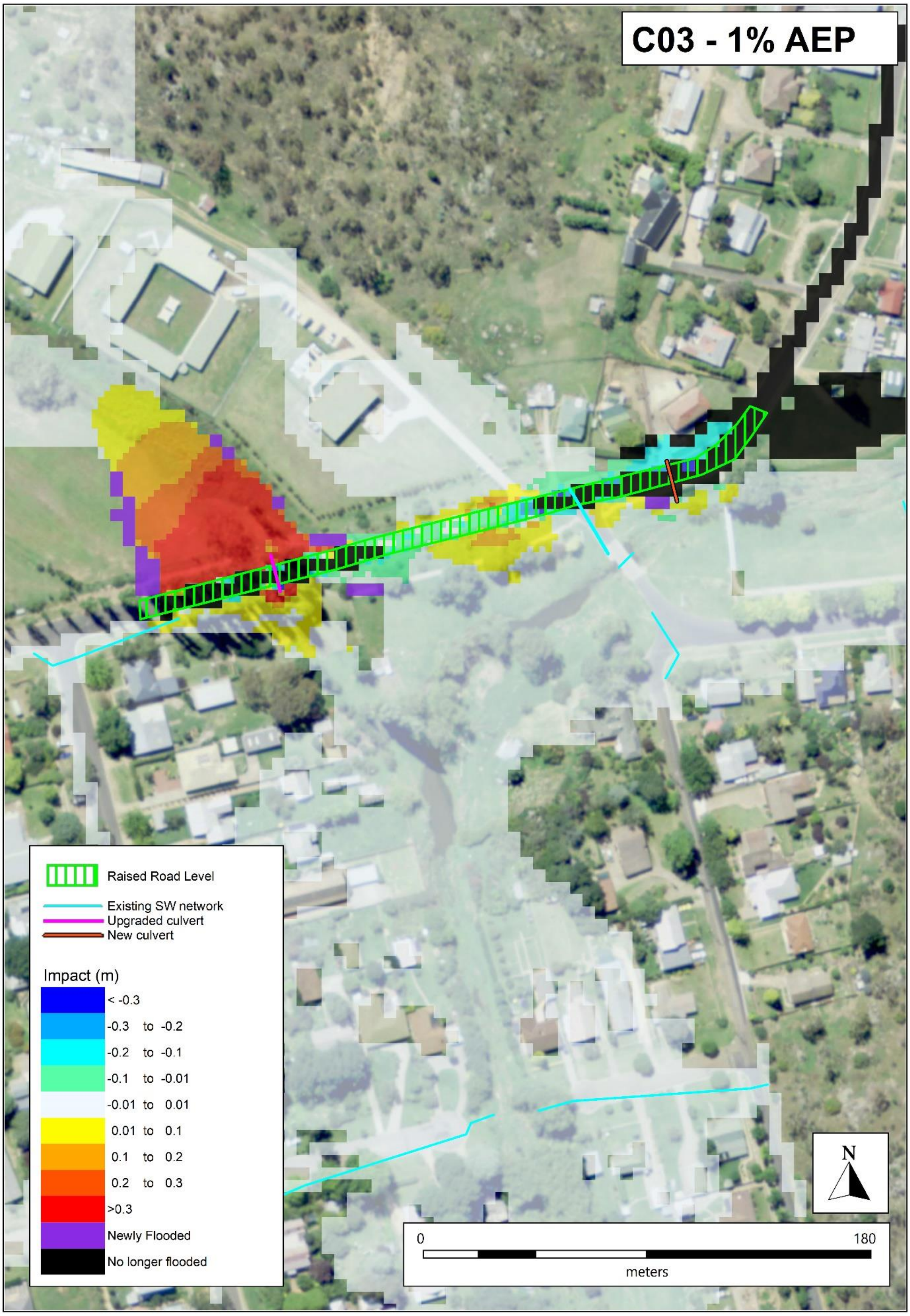


Figure 8-12: 1% AEP Impact - Option C03

8.4.1.3. *Enlarge drainage channel at Polo Flat (Z02)*

The mitigation measure consists of enlarging the drainage channel that runs through Polo Flat to drain a greater portion of the flood flows and reduce property and road flooding in the industrial area. The measure is aimed at reducing flood risk in Hotspots 7 and 8 (see Sections 3.3.2.7 and 3.3.2.8). The drain is an engineered channel that runs south to north through the area, generally adjacent to Polo Flat Road. South of Geebung Street it splits into a large culvert that passes under the Geebung Street loop road, and an open channel also through the area but adjacent to Polo Flat Road. Under the option, the drainage channel has been significantly increased in depth and width, and culverts at road crossings enlarged. The culvert section through private land has not been upgraded due to significant technical/economic constraints.

The option has been assessed via model simulation of the 1% AEP event. The alignment of the enlarged channel section and culverts is shown on Figure 8-13, along with the flood level impact. The figure also shows an example cross-section of the increased channel size.

Figure 8-13 shows that increasing the channel capacity has a significant effect on flooding in the 1% AEP, with a reduction in flood depth across a wide area. The reduction is around 0.1 to 0.2 m the southern portion of the upgrade, south of Airstrip Road, while around Geebung Street there is reduction of 0.2 m and areas that are no longer flooded. These reductions benefit around 15 buildings in the area. There is an area of adverse impact at the downstream (north) end of the upgrade, but it does not affect existing buildings.

Beyond the reduced property damage and road flooding, there is significant benefit relating to improved road access and building inundation for the SES unit on Geebung Street. This benefit, which reduces the likelihood that flooding will impede the emergency response during a flood, has a wider positive impact for the region's emergency response, as several towns are serviced by the Cooma SES unit.

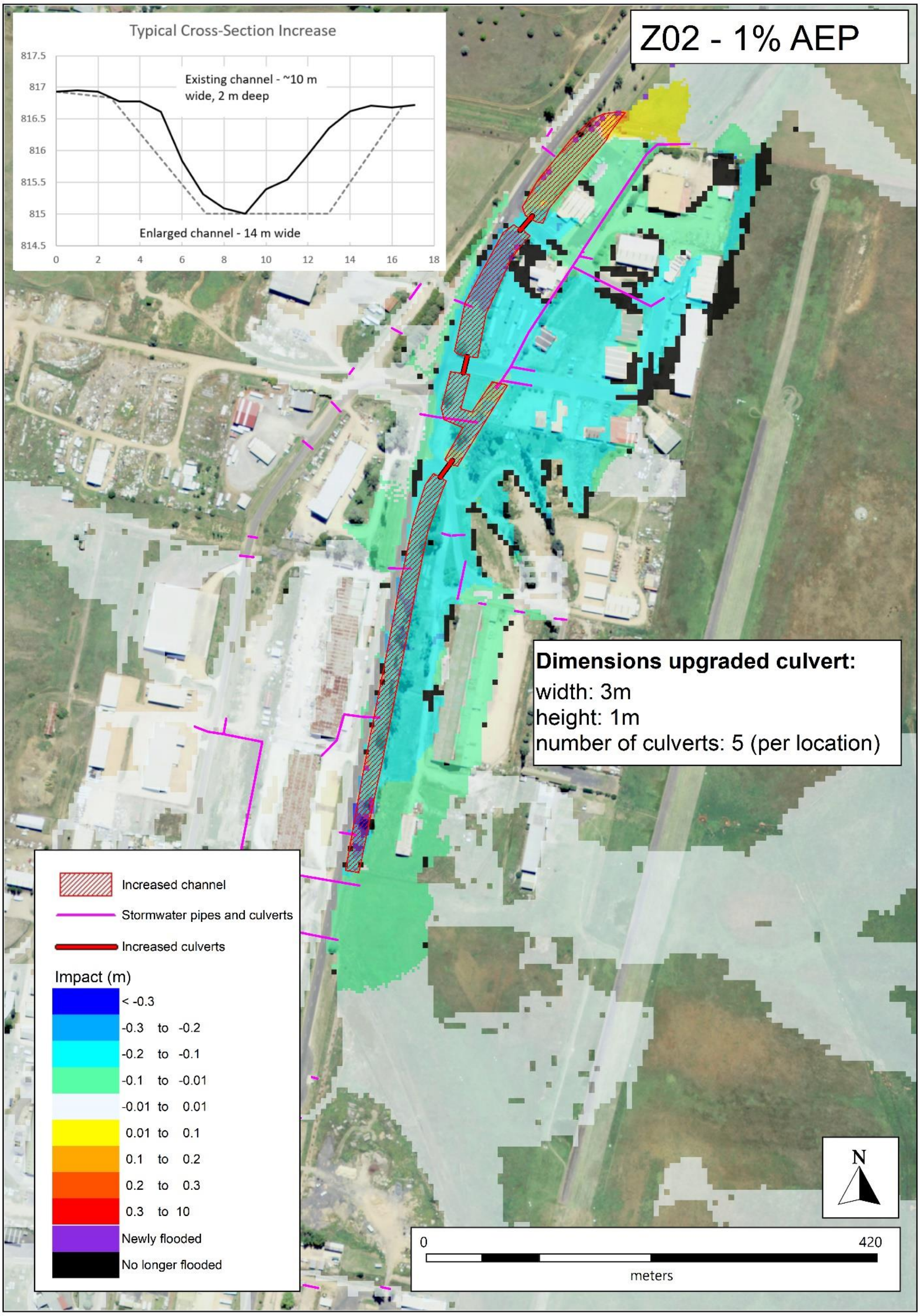


Figure 8-13: 1% AEP Impact - Option Z02 (1% AEP Design level)

Further Analysis

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods, the impacts on natural amenity and overall flood risk, and preliminary costing and economic value. The option was simulated for each design flood event and the results are presented in Table 48 below. The table shows that the option has a significant benefit in the range of design flood events, with around 5 properties no longer flooded in most flood events. There is similar reduction in the properties flooded above ground (not shown in the table). The benefit is equivalent to around $2-3m reduction in damages in each event. The reduction in AAD ($205,283) is the largest of the options assessed.

Table 48: Option Z02, Reduction in Damages and Above-floor Flooding

Event	Reduction in Properties Flooded Above Floor	Reduction in Event Damages	
PMF	0	$	2,285,900
0.2% AEP	5	$	3,925,200
0.5% AEP	5	$	4,046,000
1% AEP	2	$	2,984,200
2% AEP	4	$	2,897,600
5% AEP	6	$	1,087,500
10% AEP	3	$	319,700
20% AEP	1	$	146,100
	Average Annual Damage Reduction	$	205,283

There are some impacts on natural amenity in the area due to the option. The area is currently an industrial zone and the option would involve increasing the width and depth of the existing channel. The channel alignment is constrained by the current drainage easement, between Polo Flat Road and various private properties. There are around 35 mature trees along the channel that would be removed if the option were implemented. While additional trees could be planted nearby, the existing mature trees could not be replaced in the short term.

A preliminary cost estimate for the option is presented in Table 49 and the detailed costing is in Appendix F.

Table 49: Option Z02 Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$172,100
Site Preparation	$99,100
Earthworks	$654,500
Civil Construction	$599,700
Total (incl. contingency and GST)	$2,143,500
Cost estimate is only approximate, for the purposes of economic analysis of the option.	

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $205,283
- NPV of reduction: $2,435,436
- Cost estimate of option: 2,143,500
- Benefit-cost ratio: 1.1

The benefit-cost ratio is 1.1, which means the cost of the option is similar to its benefit and it can be justified on economic grounds. Overall, the option has significant benefit at Polo Flat with both reduced property damage for the Polo Flat area and improved access to the SES unit on Geebung Street. While the option does not have significant technical constraints, it is relatively expensive and would require removal of some trees. An alternative to full implementation would be upgrade of the section near Geebung Street, or incorporating raising Geebung Street, in order to provide benefit to that area. The overall comparison of the Cooma options is presented in Section 8.5.

Recommendation: Construction of the option be considered for the short to medium term as part of development in Polo Flat.

8.4.1.4. *Re-grade and enlarge Cooma Back Creek downstream of Sharp Street (Z04)*

The mitigation measure consists of re-grading and enlarging Cooma Back Creek between Sharp Street and Vulcan Street, including removal of areas of thick vegetation, in order to reduce property flooding along the creek. The measure is aimed at reducing flood risk to property and risk to life in Hotspot 4 (see Section 3.3.2.4). Currently the creek has a well-defined channel with steep sides and areas of thick vegetation along the section, with several houses located on the relatively flat area on either side of the creek. The option has several significant constraints, but it has been assessed given the high flood risk posed to properties and residents in the area.

The option has been assessed via model simulation of the 1% AEP and 0.2% AEP events. The location of the modified creek section is shown on Figure 8-14, along with the 1% AEP flood level impact. The figure also shows an example cross-section of the increased channel size.

Figure 8-14 shows that increasing the channel capacity has a significant effect on flooding in the 1% AEP, with reduced flood risk for flood-affected properties along the creek section. The reduction is around 0.4-0.6 upstream of Kerwan Street and 0.1-0.2 m downstream of Kerwan Street. These reductions result in reduced hazard to many of the properties. In the 0.2% AEP (not shown), there is similarly significant reduction in hazard on several affected properties, although flowpaths of H4-H5 flow still isolate some properties.

There are three significant constraints associated with the option:

1. Any works in the creek would be carried out on what is currently private property. This would require consent from the landowners and purchase of part of their land as a drainage or creek easement, by Council. All landowners would need to accept the arrangement for the works to be constructed (i.e. if part of the works are not possible, the scheme will not function). Compulsory acquisition is also possible, however is fraught for Council/community relations.
2. Modified areas of the creek would have vegetation removed. The option assumes that some vegetation is re-planted but there would be significant short-term impacts on flora and fauna, and on the natural amenity of the area.
3. Due to the limited footprint available for construction and the high velocities (3-4 m/s in the 1% AEP event) experienced in the channel, revetment walls will likely be required to stop erosion and potential undermining of nearby properties. The concept design assumes 1 : 1 grade revetment walls, which will need to be fenced to minimise risk to pedestrians near the creek during flood and dry periods alike.
4. Due to the above constraints, and combined with the fact that the creek has not experienced significant out-of-bank flooding in many years, there is likely to be high community opposition to the option. There is likely to be low awareness of the high flood risk present in rare flood events and so there is likely to be little interest in increasing the creek's capacity.

Feedback on the option will be sought from Council and from the community and other stakeholders during the public exhibition period.

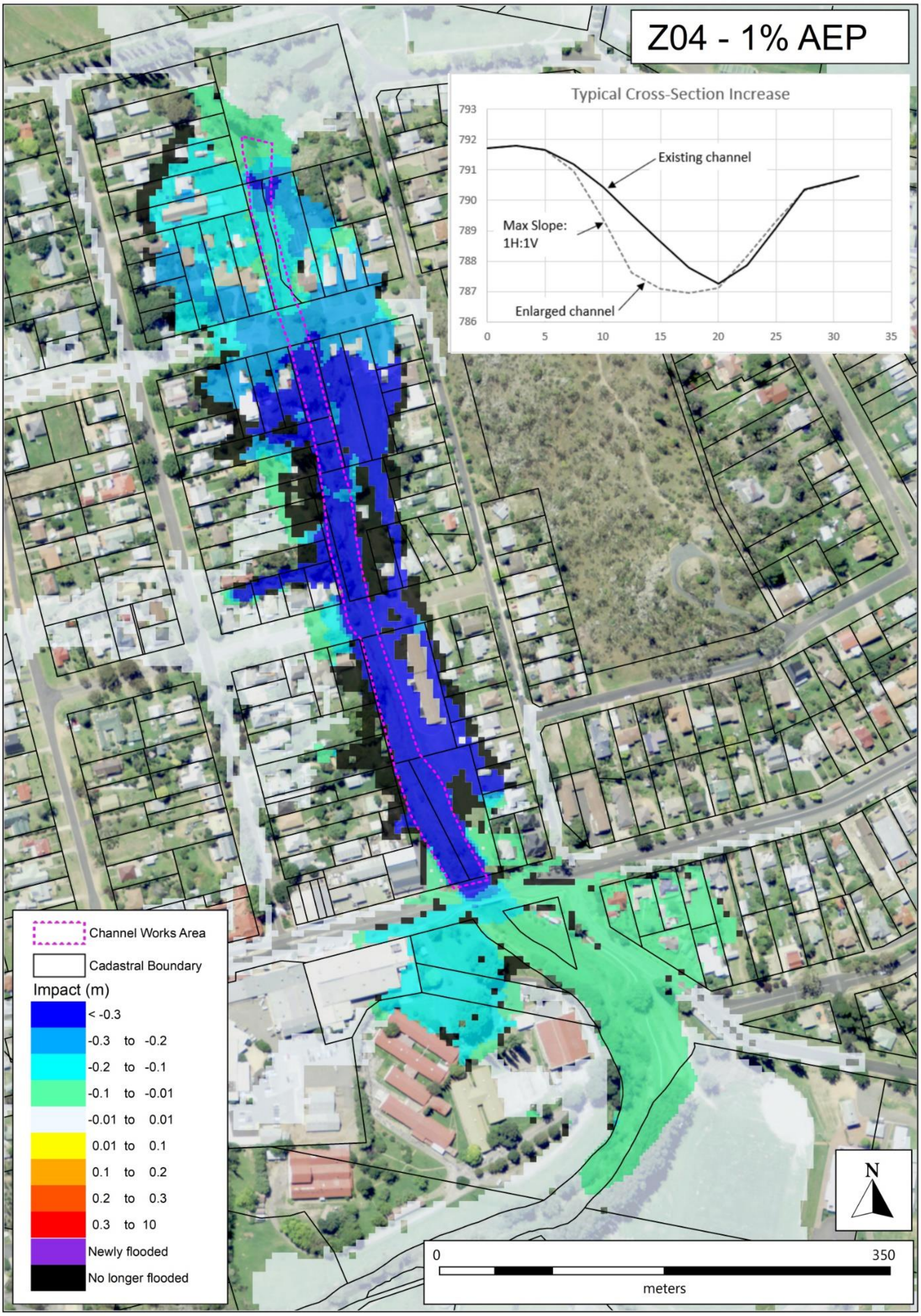


Figure 8-14: 1% AEP Impact - Option Z04

Economic Analysis

The option was simulated for each design flood event and the results are presented in Table 50 below. The table shows that the option has a significant benefit in the range of design flood events, with 10 less properties flooded above floor in the 1% AEP, and 5 less in the 2% AEP. The benefit is equivalent to around $1.7m reduction in damages in the 1% AEP event. There is a significant reduction in AAD ($58,389).

Table 50: Option Z04, Reduction in Damages and Above-floor Flooding

Event	Reduction in Properties Flooded Above Floor	Reduction in Event Damages
PMF	1	$ 335,400
0.2% AEP	15	$ 2,888,100
0.5% AEP	22	$ 2,462,100
1% AEP	10	$ 1,728,100
2% AEP	5	$ 442,700
5% AEP	2	$ 130,400
10% AEP	1	$ 42,000
20% AEP	1	$ 54,100
	Average Annual Damage Reduction	$ 58,389

A preliminary cost estimate for the option is presented in Table 51 and the detailed costing is in Appendix F.

Table 51: Option Z04 Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$429,600
Easement Purchase	$1,821,800
Site Preparation	$56,100
Earthworks	$565,800
Civil Construction	$1,423,900
Total (incl. contingency and GST)	$5,177,200
Cost estimate is only approximate, for the purposes of economic analysis of the option.	

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $58,389
- NPV of reduction: $862,214
- Cost estimate of option: $5,177,200
- Benefit-cost ratio: 0.2

The benefit-cost ratio is 0.2, which means the benefit of the option is around 20% the value of its cost and it cannot be justified on economic grounds alone. While the ratio is low, the benefit of the option largely relates to risk to life and reduced property flooding is a secondary benefit. Overall, the option has significant benefit for flood-affected properties along Cooma Back Creek but it has significant feasibility constraints. Without significant support from Council and the affected community, it is unlikely the measure could be implemented. The overall comparison of the Cooma options is presented in Section 8.5.

Recommendation: Gather feedback from community, Council and other stakeholders on the feasibility of the measure

8.4.1.5. ***Massie Street Bridge (M01)***

A bridge at Massey Street over Cooma Creek was considered by the previous FRMS in 1994 (see Section 2.3.2). The road crossing is currently a causeway and is flooded relatively often following high rainfall, with a manual gate that is closed to prevent motorists from crossing the creek. A bridge replacing the causeway is now being considered by Council as a traffic improvement for the area, as the bridge will relieve demand on Sharp Street when the Massie Street crossing is closed.

The construction of a new bridge is supported as a floodplain risk management measure as it will reduce the likelihood of vehicles entering high hazard flow on Massie Street during a flood. While gates are used to prevent this currently, there is residual risk of the gates not being closed due to insufficient warning time or unforeseen factors. Secondly, there is an opportunity for a new bridge to improve access for emergency services during a flood, who currently use Sharp Street bridge, which has flood-prone approaches from both sides. Improved access offered by the new bridge is dependant on the bridge's level and its approaches, as there is currently a high hazard flowpath on Bombala Street and parts of Amos Street.

The bridge has not been assessed using the hydraulic model, as the concept design is currently being investigated by Council. The option is recommended in principle, as it will reduce flood risk at the crossing and potentially improve vehicle access during a flood. The bridge is expected to have minimal environmental impacts that can be managed during the construction phase.

Recommendation: Construction of a new bridge at Massie Street is supported as a floodplain risk management measure. The option is being investigated by Council, separate to this study.

8.4.1.6. ***Vegetation management for all towns (V01)***

Vegetation management may provide limited localised benefits for flood affectation. Widespread removal of vegetation is not feasible and will results in significant detrimental impacts to the riparian corridor. However, selective removal of invasive species such as willows, blackberry and box elders can enhance channel conveyance and should be considered. Removal of vegetation should be undertaken in conjunction with replanting of native vegetation that is suitable for riparian regeneration. Replanting of native vegetation should aim to not increase the density of vegetation in sections of creek that are adjacent to urban areas. Selection of appropriate vegetation types will minimise the risk of channel erosion and provide various environmental benefits, whilst not significantly impacting on flood characteristics. A vegetation management program can be implemented to enhance channel conveyance characteristics and reduce erosion potential.

Recommendation: Council should consult with Waterwatch, Cooma Landcare and Local Land Services to develop a vegetation management program that aims to remove invasive plant species that impact on channel conveyance and replace with native vegetation that supports riparian health.

8.4.2. Bredbo and Michelago Flood Modification Measures

As with Cooma, a staged process was used to select measures that warranted assessment using the hydraulic model and other analyses. This involved developing a longlist of measures, and then further assessing those that were most likely to be effective, with input from Council. In Michelago there is minimal flood risk in most flood events. In Bredbo, where flood risk does exist, structural measures are unlikely feasible due to significant flood scaling and low-density development. Six measures were longlisted (see Table 52) but none were selected for further analysis by this study. Those that were not assessed further are not necessarily infeasible and some were not included due to the limited scope and budget of the current study. One (Michelago Creek crossing at Ryrie Street) is being assessed separate to this study. Overall, property modification and response modification measures will be more effective in managing flood risk in Bredbo.

Table 52: Bredbo Flood Modification Measures Longlist

Measure	Outcome
[Bredbo] Construct two sections of levee, south of Anembo Street and west of Bransby Street, to protect properties from 1% AEP Bredbo River flooding	Not selected – rated as low feasibility. New levees would be very expensive relative to the benefit they offer (around seven houses each in the 1% AEP). There would also be significant impacts on visual amenity, and minimal benefit in floods smaller than the 1% AEP.
[Bredbo] Culvert upgrade under Monaro Highway near Clifford Street	Not selected – rated as moderate feasibility. The flooding issue near the culvert is minor compared to other areas and a larger culvert may cause adverse impacts downstream.
[Bredbo] Replace the North Street causeway with a set of culverts, to provide access to the area west of the creek.	Not selected – rated as moderate feasibility. There are minimal access issues as flooding of the creek is typically only short duration, however, risk will increase if further development occurs. The option may be recommended for future consideration. As an interim measure, warning signage at the crossing will mitigate some of the risk to vehicles.
[Michelago] Upgrade culvert under Ryrie Street near Monaro Highway, or construct a swale to increase flow into the culvert	Not selected – culvert rated as moderate feasibility, swale as low feasibility. The flooding issue at the location is small and only one property would benefit from the culvert upgrade. Warning signage at the crossing will mitigate the risk to vehicles.
[Michelago] Construct a creek crossing near Ryrie Street and Micalago Road to resolve the current access issue	Council are looking at the crossing separate to the current study, including access during a flood. An assessment of a crossing as a flood risk management measure has been provided below.
[Michelago] Raise Micalago Road near railway bridge to reduce hazardous flooding on the road	Not selected – rated as moderate feasibility. The option may be investigated pending the outcome of the creek crossing (previous option). As with that option, a significant constraint will be undertaking works in the rail corridor.
[Michelago] Construct a culvert at the low point on Ryrie Street near the general store, or construct a swale to increase flow to the existing culvert	Not selected – culvert rated as high feasibility and swale as moderate. There is no significant flooding at the location and a culvert will likely impact properties on the west side of the road.

8.4.2.1. *Ryrie Street crossing (R01)*

Community consultation during the flood study and discussion with Council has emphasised the strong community support for a crossing of Michelago Creek near Ryrie Street and Micalago Road. There is significant interest in improving the travel time to Michelago as currently residents living south of the creek, along Micalago Road, have to drive onto the Monaro Highway to access the town. Community members have also raised the value of improved access during a flood, as currently the Micalago Road area is cut-off from the town during flooding of Michelago Creek, which inundates Micalago Road near the railway bridge.

For the purposes of understanding the available options, three possibilities have been considered:

1. a new road causeway constructed between Micalago Road, approximately 40 m west of the railway bridge, and Ryrie Street to the north
2. a new bridge crossing of the creek, set approximately at the level of Micalago Road west of the railway bridge
3. a new bridge crossing of the creek, set above the 1% AEP flood level on Michelago Creek, which would have a bridge deck level of approximately 2.8 m above the current Micalago Road level.

Micalago Road from the bridge and to the east of the railway raised to the 1% AEP level to allow flood free access.

The first two options would improve road access to the town but the road would continue to be cut-off during a 20% AEP event. Given the high occurrence of vehicles crossing roads with hazardous floodwaters, a new road crossing that is flood-affected would likely increase flood risk in the area. Possible mitigation measures would be to include dynamic warning signage at the location, or an automatic boom gate to prevent vehicles entering floodwaters. Overall, the first two options would not reduce flood risk in the area and are not recommended as part of this study.

The third option involves a bridge and road raising that would provide access to the Micalago Road area for floods up to the 1% AEP event. This would allow residents to access the town during a flood, and provide access for emergency services to the area. The constraints of the option are related to the much larger structure required for a higher bridge and the significant length of road raising, including through a section under the existing rail bridge. It would require raising of three sections of road – Micalago Road to the west, to the east through the railway bridge, and Ryrie Street to the north, by 2-3 m above what currently exists. While technically feasible, the project would be very expensive relative to the expected benefit, with regards to flooding.

While this assessment does not oppose the construction of a creek crossing, it finds that a crossing is not feasible as a flood risk management measure. Option 3 has been included in the multi-criteria assessment for completeness and so it can be compared to other measures.

8.4.3. Berridale Flood Modification Measures

Similar to the other towns, a staged process was used to select measures that warranted assessment using the hydraulic model and other analyses. The full list of measures has been included here in Table 53 in order to show why not all hotspots had flood modification measures assessed. Options that improve road access to the area east of Myack Creek have incorporated previous studies' discussion of development in the area (see studies in Section 2.3)

Table 53: Berridale Flood Modification Measures Longlist

Measure	Outcome
Upgrade culvert under Dalgety Road at Myack Creek to improve road access	Not selected – rated as moderate feasibility. The measure may be considered during any future upgrades of Dalgety Road. In the interim, implementation of warning signage may reduce the risk to vehicles.
Upgrade culvert under Kosciuszko Road at Wullwye Creek secondary channel to improve road access	Not selected – rated as moderate feasibility. Would likely require very large culverts or a bridge and therefore prohibitive cost (and little benefit in small floods). Warning signage can better mitigate the flood risk.
Raise road and install culvert at Short Street causeway to improve road access	Selected for assessment – Option C01B in following section
Upgrade culverts at William Street and Myack Creek to improve road access	Selected for assessment – Option C02 in following section
Implement Vegetation Management Plan on Myack Creek near William Street	See Section 8.4.1.5 – rated as moderate feasibility. Wide-scale clearing will have significant environmental impacts. There is limited potential for beneficial clearing that also does not impact the existing ecosystem. Existing or planned programs involving removal of invasive species may have some benefit on flood risk.

Channel works from William Street to confluence with Coolamatong Creek	Not selected – rated as low feasibility. The option may have downstream impacts and also there is likely environmental impacts from channel works.
Improve Coolamatong Creek conveyance near Myack Street including culvert upgrade	Option already tested and designed separate to the FRMS. The proposed design has been included here for completeness (Option Z01 in following section)
Construct a bund to divert flow around Snowy River Hostel	Selected for assessment – Option B01B in following section

8.4.3.1. ***Raise road and install culvert at Short Street (C01B)***

The mitigation measure consists of raising the road and install at Short Street causeway to reduce hazardous flooding on the road and provide access to the residential area to the east. Currently in the 5% AEP event there is H5 hazard flow over the road, which is also present in larger floods. It is likely that the Short Street causeway is frequently flooded by H2 hazard flow or higher, posing a significant risk to vehicles. See Section 5.3.1.3 (Hotspot 14) for full description of the area's flood risk. The option consisted of raising a section of Short Street and construction of a series of larger culverts.

The option has been assessed via simulation of the 5% AEP event. The dimensions of the culverts modelled are 7 culverts of 3 m x 1.5 m and the road is raised an average of 0.7 m. The location of the culvert and the raised road, as well as the flood impact, is shown on Figure 8-15.

The figure shows that installing culverts (including road raising) has a significant effect on road flooding. Under the option, the road is no longer flooded for most parts which makes the residences to the east accessible in most flood events. The culverts' peak flow in the 5% AEP is 26.7m^3/s.

The drawbacks of the option are that it requires very large culverts which are expensive relative to the benefit it offers. Flooding of the road is unlikely to last more than several hours during a flood, and the risk of crossing the hazardous flow may be better managed via warning signage and other response modification measures.

Based on these results the option was given a preliminary costing estimate and compared to other options in the multi-criteria assessment (Section 8.4.1.2). The option has minimal effect on property flooding and so could not be justified on economic grounds using the standard damages assessment (which only includes direct damage to properties). An overview of preliminary costing is given in Table 54 below and full preliminary costing is provided in Appendix F.

Table 54: Option C01B Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$30,200
Site Preparation	$5,500
Earthworks	$18,900
Civil Construction	$280,300
Total (incl. contingency and GST)	$464,500
Cost estimate is only approximate, for the purposes of comparison to other options.	

Recommendation: The option is not recommended at the current time but should be considered as part of any future development near Short Street

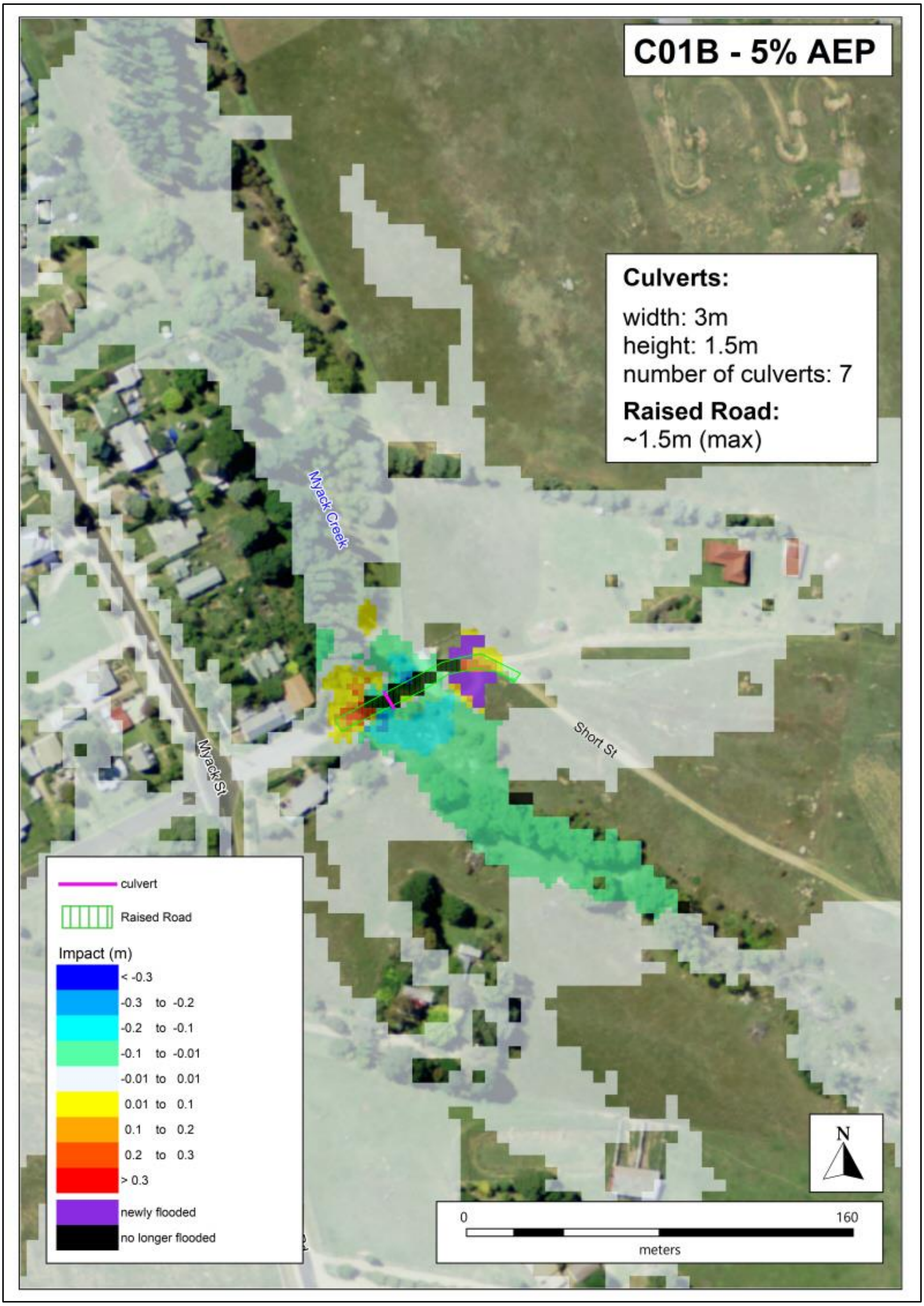


Figure 8-15: 1% AEP Impact - Option C01B

8.4.3.2. *Upgrade culverts at William Street on Myack Creek (C02)*

The mitigation measure consists of upgrading the culverts of Myack Creek under William Street to reduce hazardous on the road and provide access to the residential area to the east. Currently in the 5% AEP event all flow is conveyed through the existing culverts and there is no road flooding, while in the 1% AEP flow over the road is up to H4 hazard. The measure is aimed at reducing road flooding at Hotspot 15 (see Section 5.3.1.4 for further information). The option consisted of replacing the existing large culverts with a larger set, raising the road, and lowering part of the creek area immediately upstream of the area.

The option has been assessed via simulation of the 1% AEP event. The dimensions of the culverts modelled are 6 culverts of 3.6 m x 1.8 m and the road is raised an average of 0.65 m. The location of the culvert and the raised road, as well as the flood impact, is shown on Figure 8-16.

The figure shows that upgrading the culvert capacity (including road raising) has a significant effect on road flooding. Under the option, the road is no longer flooded which means the residential area to the east is accessible in most flood events. The culverts' peak flow in the 1% AEP increases from 23.1 m^3/s in the existing case to 50.7 m^3/s under the option.

The drawbacks of the option are that it requires very large culverts which are expensive relative to the benefit it offers. Relative to other crossings of Myack Creek, William Street is not severely flood-affected, due to the large culverts that currently exist. Also, flooding of the road is unlikely to last more than several hours during a flood, and the risk of crossing the hazardous flow may be better managed via warning signage.

Based on these results the option was given a preliminary costing estimate and compared to other options in the multi-criteria assessment (Section 8.5). The option has minimal effect on property flooding and so could not be justified on economic grounds using the standard damages assessment (which only includes direct damage to properties). An overview of preliminary costing is given in Table 47 below and full preliminary costing is provided in Appendix F.

Table 55: Option C02 Cost Estimate

Item	Cost Estimate
Pre-construction Costs	$40,000
Site Preparation	$3,000
Earthworks	$24,500
Civil Construction	$372,700
Total (incl. contingency and GST)	$616,300
Cost estimate is only approximate, for the purposes of comparison to other options	

Recommendation: The option is not recommended at the current time but should be considered as part of any future development near O'Brien Avenue

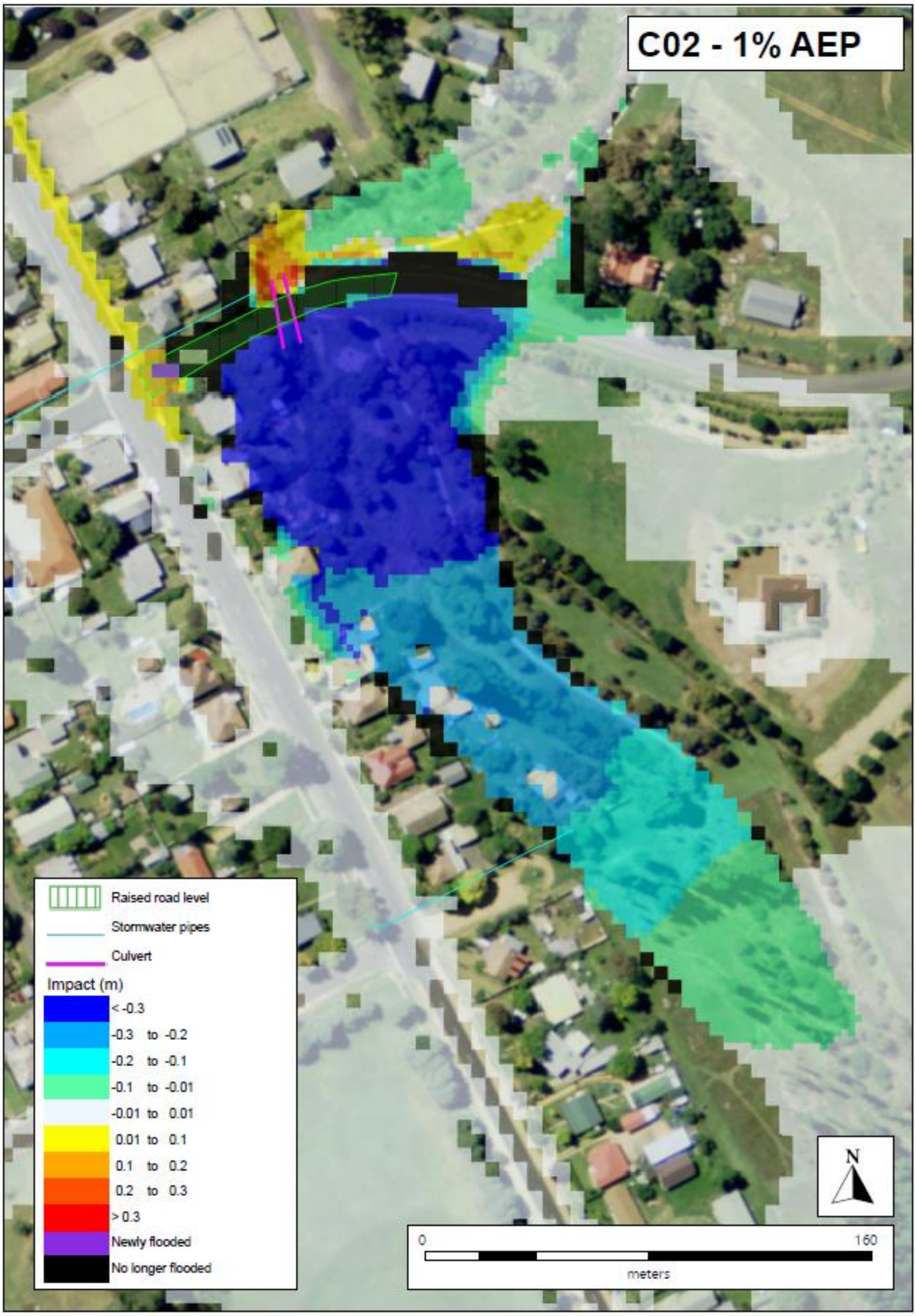


Figure 8-16: 1% AEP Impact - Option C02

8.4.3.3. *Improve Coolamatong Creek conveyance near Myack Street including culvert upgrade (Z01)*

The mitigation measure has been developed prior to the current study, drawing from the mitigation measures proposed by Berridale Township Flood Study in 2015 (see Section 2.3.7). It is aimed at reducing flood risk at Hotspot 16 (see section 5.3.1.5). Although the measure was not developed by the current study, it has been included here for completeness.

The mitigation measure consists of increasing the capacity of Coolamatong Creek including increasing the culvert size at Myack Street, to reduce property and road flooding in the area. Flooding of the area affects several properties and roads and is described in detail Section 5.3.1.5. The creek is currently a grassed park area with Myack Street close to the creek invert level, leading to overtopping in flood events. Design drawings for the proposed changes to the park area show removal of seven trees.

The option has been assessed via model simulation of the 5% AEP and 1% AEP events. The alignment of the enlarged creek and the upgraded culvert is shown on Figure 8-17, along with the flood level impact for the 5% AEP. Figure 8-18 shows the 1% AEP impact.

Figure 8-17 shows that increasing the channel capacity results in a reduction in flood depth of around 0.1 m in the 5% AEP event. There is an increased flood level on the road due to the road having been raised, while the hazard over the road decreases. The impact is similar in the 1% AEP, with a slightly larger decrease in flood level upstream (south) of the road.

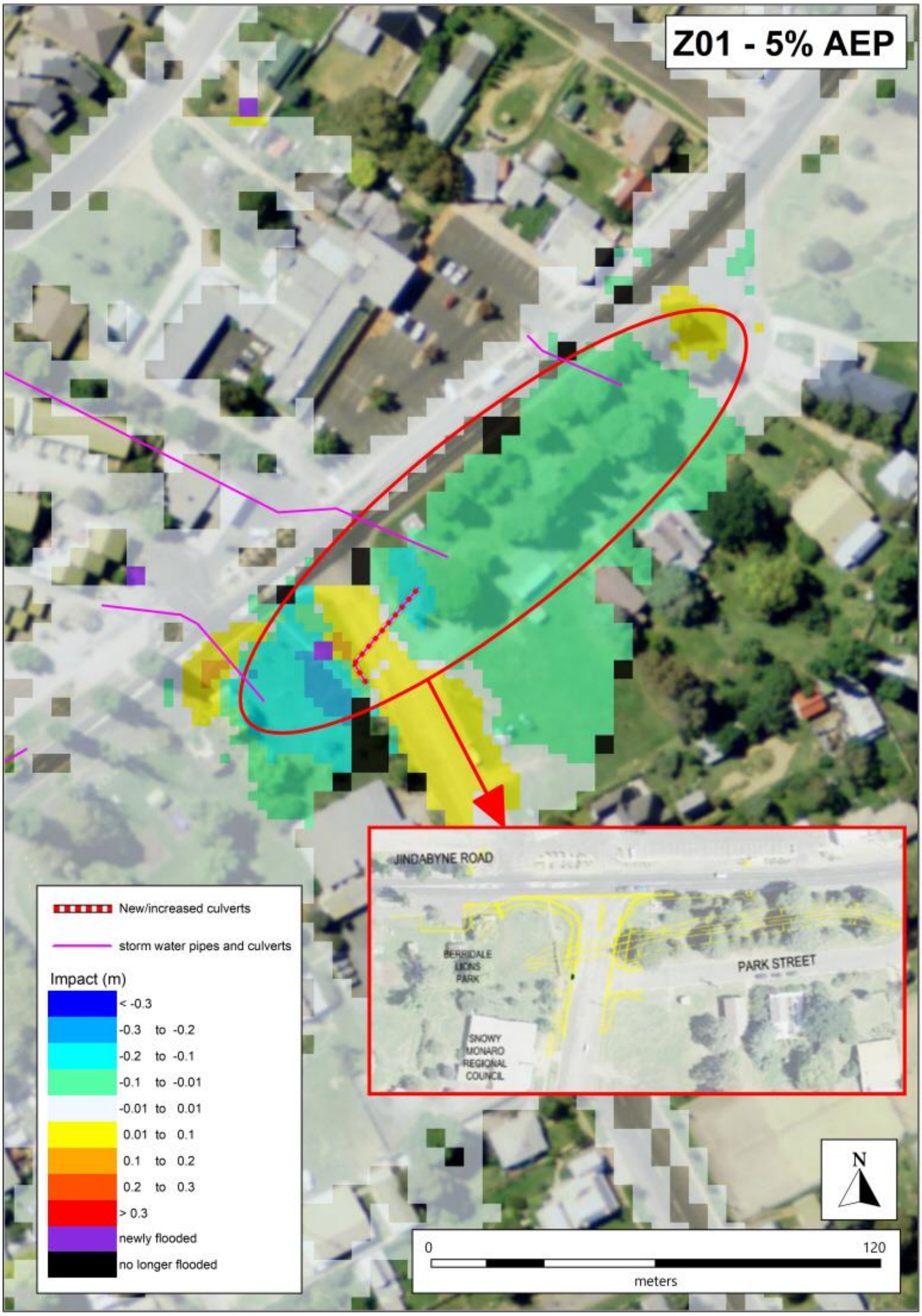


Figure 8-17: 5% AEP Impact - Option Z01

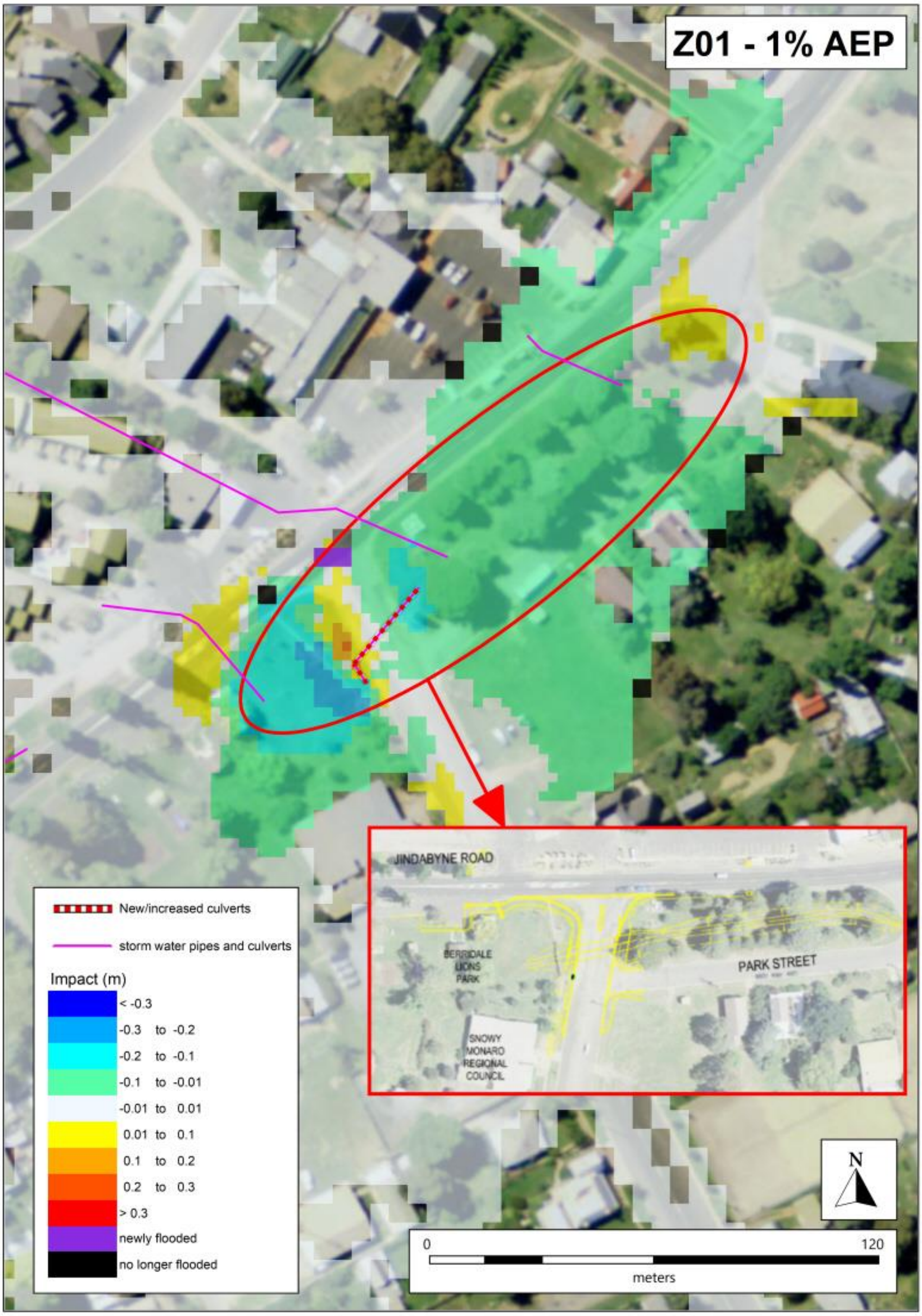


Figure 8-18: 1% AEP Impact - Option Z01

Based on the assessment presented above, the option warranted further analysis including its benefit in a range of floods. It is understood the social and environmental impacts have already been assessed for the option.

The option was simulated for each design flood event and the results are presented in Table 56 below. The table shows that the option has a minimal benefit in certain sized floods, with 2 properties no longer flooded above floor level in the 5% AEP event and 1 in the 10% AEP. In larger events the changes do not have as great an effect on flood behaviour, and in smaller events (10% and 20% AEP) there is less flooding in the existing case. The benefit is equivalent to around $45,000 reduction in damages in the 1%, 2% and 5% AEP events, but minimal in other events. The reduction in AAD is $3,681.

Table 56: Option Z01, Reduction in Damages and Above-floor Flooding

Event	Reduction in Properties Flooded Above Floor	Reduction in Event Damages
PMF	0	$ -
0.2% AEP	0	$ 14,900
0.5% AEP	0	$ 5,500
1% AEP	0	$ 36,400
2% AEP	1	$ 45,400
5% AEP	2	$ 61,000
10% AEP	0	$ -
20% AEP	0	$ -
	Average Annual Damage Reduction	$ 3,681

The reduction in AAD does not include the improved road access, which is significant. In the existing case, there is hazardous flow over Myack Street at the creek crossing, with H3 hazard in the 20% AEP and H4 hazard in the 10% AEP. With the upgraded culverts and re-graded channel, there is less flow over the road and the hazard is reduced to H1 (20% AEP) and H2 (10% AEP). There is still hazardous flow over the road in larger flood events.

A cost estimate of $500,000 for the option has been supplied by Council.

The option's reduction in Average Annual Damages, the Net Present Value (NPV) of this reduction (assuming 50 year design life and 7% discount rate) and the benefit-cost ratio are as follows:

- Average Annual Damage reduction: $3,680
- NPV of reduction: $54,344
- Cost estimate of option: $500,000
- Benefit-cost ratio: 0.1

The benefit-cost ratio is 0.1, meaning its cost is significantly higher than its expected benefit and it is not justified on economic grounds alone. Overall, the option improves road access in small floods and provides marginal improvements to property flooding in the 5% AEP event, but has limited benefit in larger flood events. It has not been included in the Floodplain Risk Management Plan or the multi-criteria assessment as the works are being undertaken by Council separate to this study's recommendations. The option is due to be constructed in 2020.

8.4.3.4. ***Bund to divert flow around Snowy River Hostel (B01B)***

The mitigation measure consists of diverting the shallow overland flow that currently impacts the Snowy River Hostel. Currently sheet flow accumulates at the hostel causing depths of 0.3 m in the 5% AEP and 0.4 m in the 1% AEP, due to sheet flow from the adjacent paddock. See Section 5.3.1.6 (Hotspot 17) for full description of the area's flood risk. The option consists of constructing a bund of around 0.4 m height along the north-east and north-west sides of the lot. This bund was found to cause adverse impacts and so it was paired with a swale, around 0.4 m deep and 8 metres wide, to divert the flow to the south.

The option has been assessed via simulation of the 1% AEP event. The location of the bund and the swale, as well as the flood impact, is shown on Figure 8-19.

The figure shows that diverting the flow is generally possible but there are small areas of adverse impact, and the overall works are very large relative to the benefit achieved. Construction of a bund and swale means that large areas around the hostel are no longer flooded, and flow is diverted to the natural drainage path between Highdale Street and Robertson Street. However, the slight redistribution of flow means there are small areas of adverse impact on Jindalee Street and Robertson Street properties. Therefore the works would likely require further development before a satisfactory impact is achieved.

Given the large scale of the works, with bund and swale over a length of ~200 m, as well as the constraints of building on private property, the option is not considered feasible. It is recommended the hostel look at improving the drainage within their site to divert the majority of flow away from entrances. Such a measure would be undertaken by the property owner and is not part of the Floodplain Risk Management Plan.

Recommendation: The option is not recommended but drainage improvements within the property may alleviate the issue

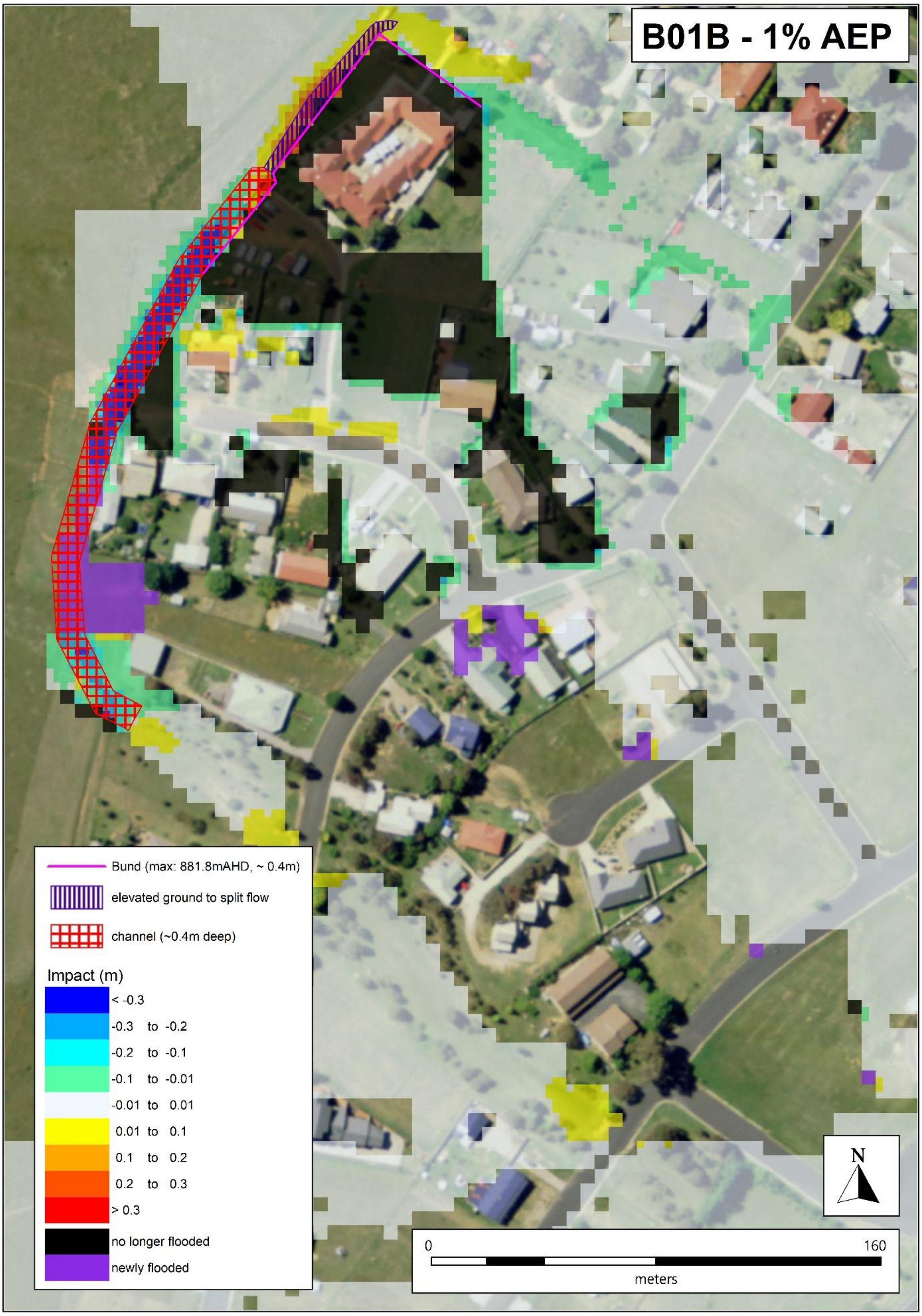


Figure 8-19: 1% AEP Impact - Option B01B

8.5. Multi-criteria Assessment of Measures

The assessment of various flood modification, property modification and response modification measures has been presented in the preceding sections, and measures that are both feasible and reduce flood risk have been recommended. In this section, these criteria and others are scored across the recommended options, in order to compare their relative advantages and disadvantages. This enables options to be prioritised and is a useful tool for decision-makers and other stakeholders. It should be noted that scoring and ranking is only used for an indicative comparison and is not intended to act as a final verdict on the options. Also note that the scoring and ranking may be updated following the public exhibition period, especially in regard to community acceptance.

The results of the analysis are presented in Table 57. Each criteria corresponds to a column and has been scored between -3 (lowest score) and 3 (highest score).

Table 57: Multi-criteria Assessment

Reference	Mitigation Measure	Impact on road flooding	Impact on property flooding	Impact on risk to life	Technical Feasibility	Community Acceptance	Economic Value	Cost and available funding	Environmental Impact	Impact on SES	Political Feasibility	Total Score	Rank
PM01	Adopt updated Flood Planning Area for each town	0	3	1	3	2	3	0	0	2	2	16	3
PM02	Local Environment Plan Amendments	0	2	1	3	2	3	0	0	2	2	15	4
PM03	Advice on Land-use Zoning Considering Flooding	0	2	2	2	2	2	0	0	1	1	12	9
PM04	Updated Flood Planning Controls in the DCP(s)	0	2	2	2	1	2	0	0	1	2	12	9
PM05	Voluntary Purchase in Cooma	0	2	3	0	-3	-2	0	0	2	-2	0	18
RM01	Warning Signage at Hazardous Road Crossings	0	0	3	2	2	1	1	0	3	2	14	6
RM02	Install automatic boom gates at high hazard/high traffic crossings	0	0	3	2	2	2	0	0	3	2	14	6
RM03	Community Flood Education	2	2	2	3	2	3	2	0	2	2	20	1
RM04	Updated Local Flood Plan and Intelligence Cards	1	1	2	3	3	3	2	0	2	3	20	1
RM06	Cooma Flood Warning System Improvements	1	1	2	2	2	2	1	0	2	2	15	4
RM07	Bredbo Flood Warning System	1	1	3	2	1	1	1	0	3	1	14	6
RM08	Develop communications channels for road closures	0	0	2	1	2	2	0	0	3	2	12	9
L01B	Increase Main Cooma Levee to 2% AEP Level of Protection	2	2	2	1	1	0	1	0	2	1	12	9
L01C	Increase Main Cooma Levee to 5% AEP Level of Protection	1	1	1	2	2	0	2	0	1	2	12	9
C03	Upgrade Culvert under Vulcan Street, Cooma	2	0	2	1	1	1	1	-1	2	1	10	14

Z02	Enlarge Drainage Channel at Polo Flat	2	2	1	1	1	1	1	-1	1	1	10	14
Z04	Re-grade and enlarge Cooma Back Creek downstream of Sharp Street	1	3	2	0	-3	-2	1	-3	1	-1	-1	21
V01	Vegetation management plan for all towns	0	1	0	2	2	-1	1	3	0	1	9	16
M01	Massie Street Bridge	0	0	2	1	2	-1	-1	0	2	2	7	17
C01B	Raise Road and Install Culvert at Short Street, Berridale	1	0	1	1	0	-3	-2	-1	1	-1	-3	22
C02	Upgrade Culverts at William Street, Myack Creek	2	1	1	1	0	-3	-2	-1	2	-1	0	18
R01	Ryrie Street crossing	1	0	1	0	3	-3	-3	0	1	0	0	18

The table shows the highest ranked measures are updating the Local Flood Plan and Flood Intelligence Cards and carrying out community flood education. Other highly ranked measures are adopting a Flood Planning Area for each town, amending parts of the LEPs, and improvements to Cooma's flood warning system. These measures all have widespread benefit, particularly to property flooding and risk to life, while having no significant drawbacks. High scoring structural measures include upgrading the Cooma levee system to either 5% or 2% AEP level of protection, upgrading Vulcan Street at Sandy Creek and enlarging the Polo Flat drainage channel. Other structural measures are ranked low as they are expensive and only provide localised reduction in flood risk.

The results of the assessment were used to inform the draft Plan in the executive summary of this document, including the priority of each recommended measure.

APPENDIX A   FLOOD RISK MAPPING - COOMA

APPENDIX B FLOOD RISK MAPPING - BREDBO

APPENDIX C FLOOD RISK MAPPING - BERRIDALE

APPENDIX D FLOOD RISK MAPPING - MICHELAGO

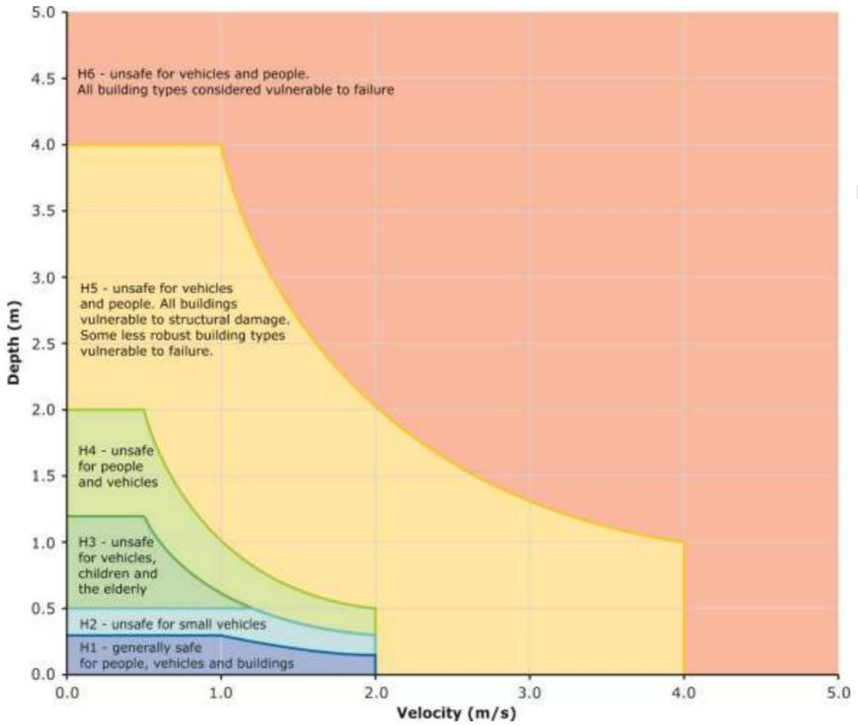
APPENDIX E TECHNICAL ANALYSIS BACKGROUND

E. INTRODUCTION

This appendix contains various background information to the technical analysis presented in the main body of the report, specifically the flood risk section for each town. The information is useful in understanding the analysis applied but was omitted from the main body to shorten the report and improve its functionality.

E.1.Hazard

Flood hazard is defined as the threat that a particular type of flooding will pose to human activity. It is initially calculated based on the flood's depth and velocity in each model grid cell, as part of the flood study stage. It is finalised during the floodplain risk management stage by considering other factors not covered by the depth-velocity calculation. The calculation is based on the Australian Emergency Management Handbook 7 guideline (reference in Table 3), which considers the threat to types of people (children, adult) and activity (pedestrian, vehicle and within a building). The calculation is presented in the below chart.



The chart divides a particular flood event into six categories of hazard, specifically:

- H1 – Generally safe for people, vehicles and buildings
- H2 – Unsafe for small vehicles
- H3 – Unsafe for vehicles, children and the elderly
- H4 – Unsafe for people and vehicles
- H5 – Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure.
- H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

Assessment of the hydraulic flood hazard did not identify any requirements for finalising the flood hazard definition. Areas of hazard not captured by the depth-velocity calculation are described qualitatively in the flood risk section for each town. These include levee failure and evacuation constraints.

E.2.Flood Function

Flood function is a processed model output that classify floodwaters into flow conveyance (previously floodway), flood storage or flood fringe. These categories describe the function of flow in a particular area of the floodplain and are commonly used by town planners to understand flood behaviour in an area of potential development. According to the Australian Emergency Management Handbook 7 (AIDR, 2017), these three categories can be defined as:

Flow Conveyance – the areas where a significant proportion of the floodwaters flow and typically align with defined channels. If these areas are blocked or developed, there will be significant redistribution of flow and increased flood levels across the floodplain. Generally, the flow conveyance is areas of deep and/or fast-moving floodwaters.

Flood Storage – areas where, during a flood, a significant proportion of floodwaters extend into, water is stored and then recedes after a flood. Filling or development in these areas may increase flood levels nearby.

Flood Fringe – areas that make up the remainder of the flood extent. Development in these areas are unlikely to alter flood behaviour in the surrounding area.

There is no prescribed methodology for deriving each category and as such categorisation is typically determined based on experience and knowledge of the study area. As per the study brief, the hydraulic categories for mainstream flooding have been derived using three methods. The general approach uses the following steps for mainstream flow:

1. For the 1% AEP design event, derive an estimate of the hydraulic categories in accordance with Howells et al, 2003[3], which uses thresholds for the velocity-depth product, velocity and depth to define each category.
2. For isolated areas of flood storage or flood fringe that are surrounded by flow conveyance, convert them to flow conveyance if they are less than 0.3 ha in area. Similarly, if a particular channel or flowpath of flow conveyance is discontinuous at a point due to a localised man-made change, convert the area to flow conveyance if necessary to achieve correct impact in the next step.
3. Model the effect of fully developing the non-flow conveyance area by blocking out all non-flow conveyance areas of the model so they are impermeable to flow. Measure the change in peak flood levels that results from the reduced flow area. If the increase is around 0.1 m, the categories are considered reasonable, if a larger increase is recorded, increase the flow conveyance area by changing the thresholds in step 1, or decrease the area if the impact is too low.
4. Consider splitting the floodplain into sections with different depth-velocity thresholds, as recommended by Murtagh et al, 2017[4].
5. Once a reasonable estimate of the hydraulic categories is found, confirm their delineation by measuring the percentage of flow in areas of flow conveyance compared to total flow. The flow conveyance is expected to have approximately 80-90% of total flow.
6. Once the thresholds of velocity-depth product, velocity and depth are determined for the 1% AEP event, apply the same criteria for deriving the 5% AEP and PMF hydraulic categories.

[3] Howells, L., McLuckie, D., Collings, G. and Lawson, N. - *Defining the Floodway – Can One Size Fit All?* Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes February 2003
[4] Murtagh, J., Albert, N., Babister, M., McLuckie, D., Robinson, K., *Hydraulic Categorisation*, 2017 Floodplain Management Australia National Conference

The dispersed and shallow nature of overland flooding means that the same process cannot be used to delineate hydraulic categories for overland flow. For overland flow, a velocity and velocity-depth product threshold is chosen and then iteratively adjusted until the predominant overland flowpaths in each town have a continuous floodway.

The adopted thresholds for each town are presented below.

Cooma

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Cooma are:

- Upstream of the confluence of Cooma Back Creek and Cooma Creek, flow conveyance where v*d > 0.40 m^2/s and v > 0.40 m
- Downstream of the confluence of Cooma Back Creek and Cooma Creek, flow conveyance where v*d > 0.70 m^2/s and v > 0.70 m
- For all areas outside the flow conveyance, flood storage where d > 0.5 m, otherwise flood fringe.

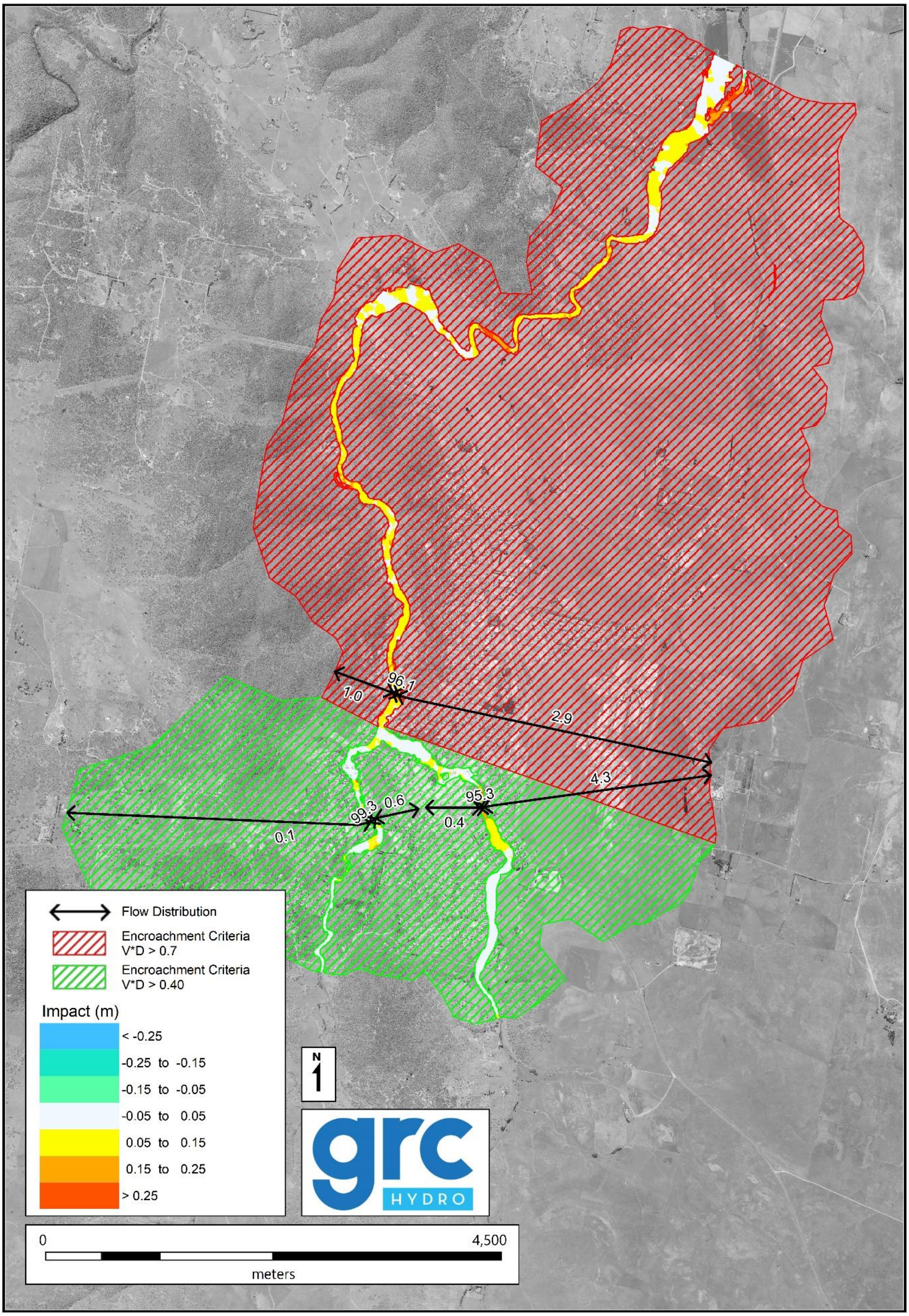
The results of the assessment are shown in Figure 8-20, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the flow conveyance and non-flow conveyance area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for most areas (see yellow areas of impact) and the flow conveyance flow is between 95 and 99%, which is indicative of the majority of the flow being contained in the channel, as occurs in Cooma.

The figure shows the target afflux was not achieved in all sections of the channel. The thresholds were adopted after running a number of velocity and velocity-depth thresholds, including 0.25, 0.3, 0.35, 0.4, (with and without additional manual changes) and 0.7. Multiple thresholds were adopted for upstream and downstream of the confluence, but further splitting of areas was concluded to have limited returns for the added complexity.

The adopted thresholds, which also use the approach proposed by Howells et. al., for overland flow are:

- Flow conveyance – peak value of velocity multiplied by depth (V × D) > 0.10 m^2/s and peak velocity > 0.10 m/s, or peak velocity > 1.0m/s and peak depth > 0.15m;
- Flood storage – catchment area outside flow conveyance where peak depth > 0.5m; and
- Flood fringe – catchment area outside flow conveyance where peak depth < 0.5m.

Figure 8-20: Encroachment Criteria Cooma



Bredbo

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Bredbo are:

- flow conveyance where v*d > 0.70 m^2/s and v > 0.70 m
- For all areas outside the flow conveyance, flood storage where d > 0.5 m, otherwise flood fringe.

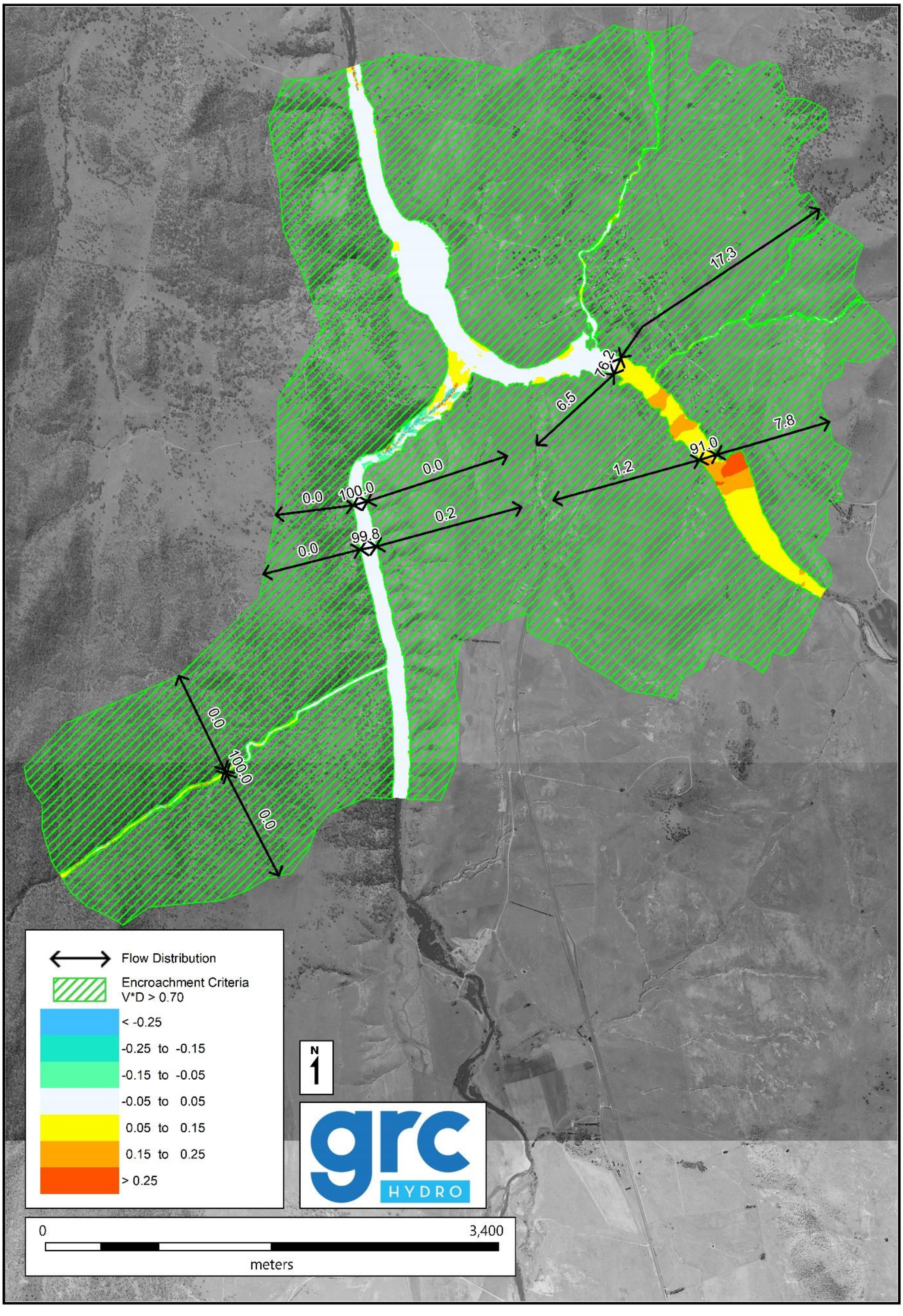
The results of the assessment are shown in Figure 8-21, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the flow conveyance and non-flow conveyance area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for most areas close to the town centre (see yellow areas of impact) and the flow conveyance is between 76% and 91% on Bredbo River.

The figure shows the target afflux was achieved in the vicinity of the town, however most sections of the Murrumbidgee River channel did not achieve the targets due to the gorge type topography which makes the majority of the floodplain behave as Flow Conveyance. The thresholds were adopted after running a number of velocity and velocity-depth thresholds, including 0.25, 0.3, 0.35, 0.4, 0.7 (with and without additional manual changes) and 1.0. Across these seven runs, the adopted values returned the best result.

The adopted thresholds for overland flow are:

- Flow conveyance – peak value of velocity multiplied by depth (V × D) > 0.25 m^2/s and peak velocity > 0.25 m/s, or peak velocity > 1.0m/s and peak depth > 0.15m;
- Flood storage – catchment area outside flow conveyance where peak depth > 0.5m; and
- Flood fringe – catchment area outside flow conveyance where peak depth < 0.5m.

Figure 8-21: Encroachment Criteria Bredbo



Berridale

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Bredbo are:

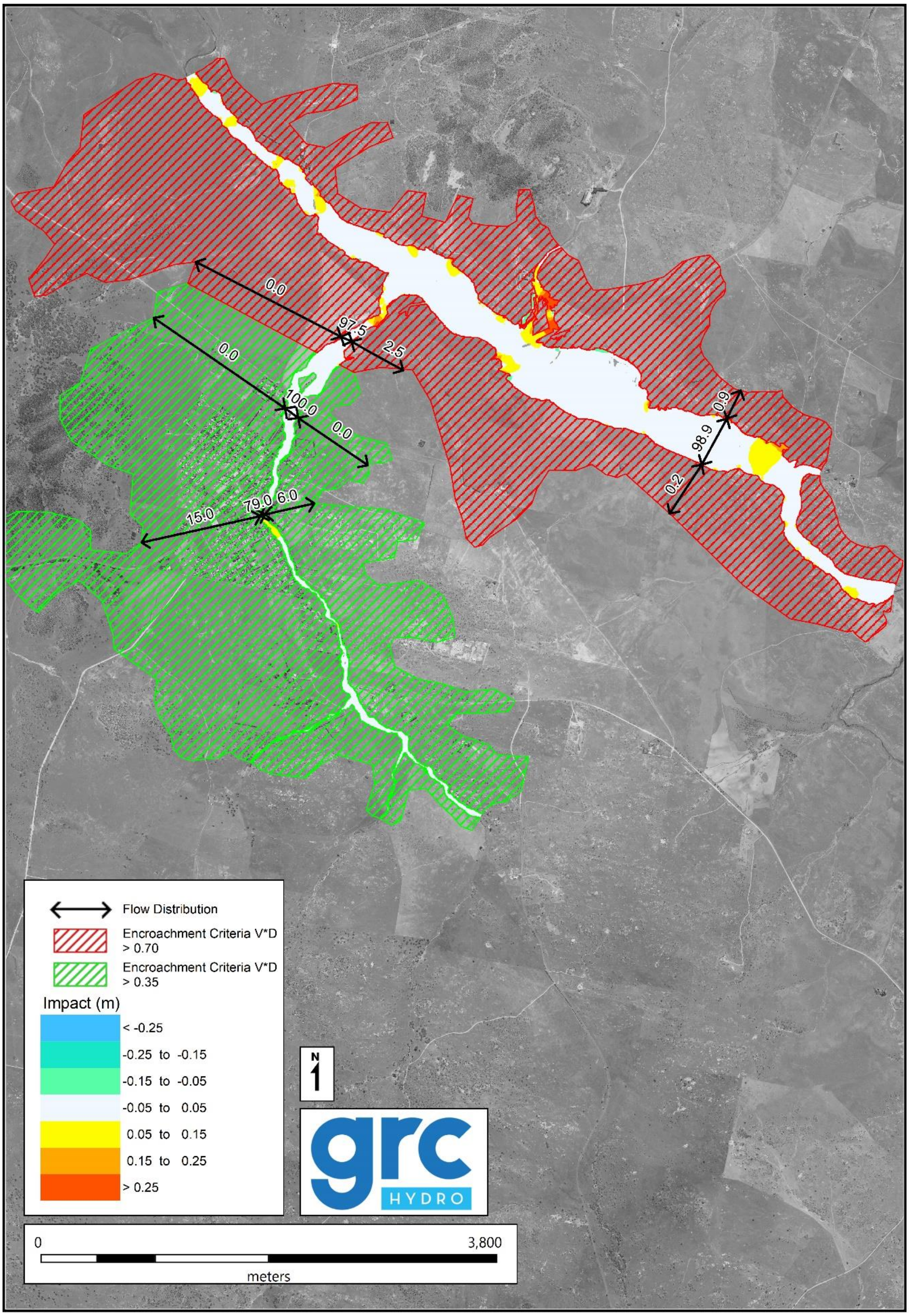
- For areas around Myack Creek, flow conveyance where v*d > 0.35 m^2/s and v > 0.35 m
- For areas around Wullwye Creek, flow conveyance where v*d > 0.70 m^2/s and v > 0.70 m
- For all areas outside the flow conveyance, flood storage where d > 0.5 m, otherwise flood fringe.

The results of the assessment are shown in Figure 8-22, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the flow conveyance and non-flow conveyance area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for some areas (see yellow areas of impact) and the flow conveyance flow is between 79% and 100%. The 0.1 m afflux is not achieved everywhere, because 'islands' of flood storage were changed to flow conveyance, which made a significantly larger flow conveyance in Wullwye Creek. As with other towns, the adopted thresholds are the result of an iterative process. For Berridale, six thresholds were tested: 0.25, 0.3, 0.35, 0.4 and 0.7 (with and without manual changes).

The adopted thresholds for overland flow are:

- Flow conveyance – peak value of velocity multiplied by depth (V × D) > 0.25 m^2/s and peak velocity > 0.25 m/s, or peak velocity > 1.0m/s and peak depth > 0.15m;
- Flood storage – catchment area outside flow conveyance where peak depth > 0.5m; and
- Flood fringe – catchment area outside flow conveyance where peak depth < 0.5m.

Figure 8-22: Encroachment Criteria Berridale



Michelago

The velocity (v), depth (d) and velocity*depth (v*d) thresholds determined for mainstream flooding in Bredbo are:

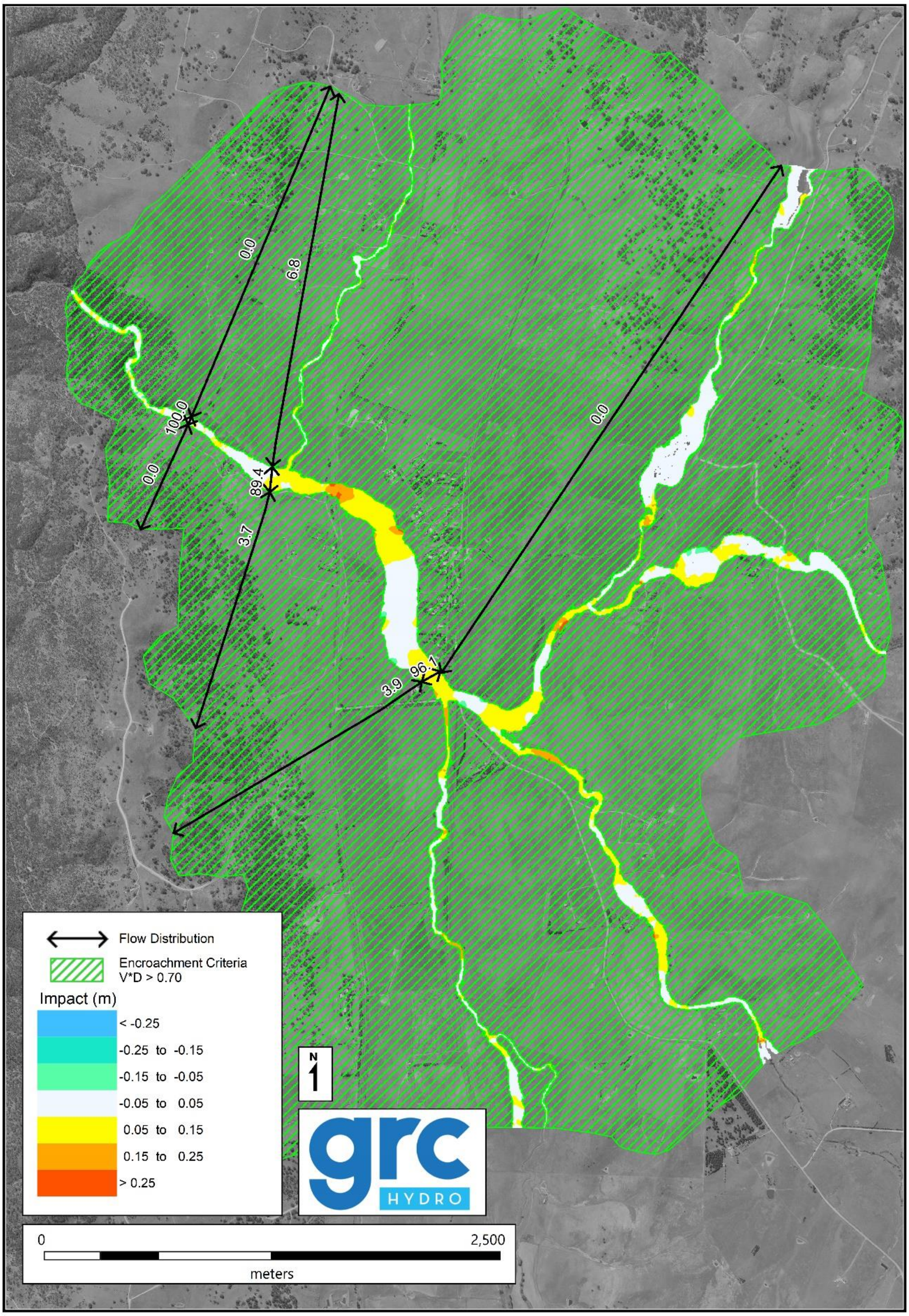
- Flow conveyance where v*d > 0.70 m^2/s and v > 0.70 m
- For all areas outside the flow conveyance, flood storage where d > 0.5 m, otherwise flood fringe.

The results of the assessment are shown in Figure 8-23, which shows the afflux from blocking the adopted mainstream flood storage area, as well as a breakdown of the flow percentage for the mainstream flow, comparing the flow conveyance and non-flow conveyance area. The figure shows that the adopted thresholds achieve the 0.1 m afflux for most areas (see yellow areas of impact) and the flow conveyance is between 89% and 100%. Similarly to Bredbo, most sections of the Murrumbidgee River channel did not achieve the targets due to the gorge type topography which makes the majority of the floodplain behave as Flow Conveyance. As with other towns, the adopted thresholds are the result of selecting from a number of tested values, with 0.25, 0.3, 0.35, 0.4, 0.7 (with and without manual changes) all run.

The adopted thresholds for overland flow are:

- Flow conveyance – peak value of velocity multiplied by depth (V × D) > 0.10 m^2/s and peak velocity > 0.10 m/s, or peak velocity > 1.0m/s and peak depth > 0.15m;
- Flood storage – catchment area outside flow conveyance where peak depth > 0.5m; and
- Flood fringe – catchment area outside flow conveyance where peak depth < 0.5m.

Figure 8-23: Encroachment Criteria Michelago



E.3.Flood Damages

A flood damages assessment is used to quantify the economic impact of flooding on the community. Generally, a flood damages assessment aggregates the following:

- Direct costs to individual properties such as structural damages or damage to contents;
- Indirect costs to individual properties such as clean-up, disposal or loss of income; and
- Cost of damage to infrastructure.

The flood damages assessment for the current study has been completed in accordance with guidance for estimating residential flood damages from the NSW Department of Environment and Climate Change (now DPIE). This guideline uses the depth of flooding above ground and floor level to estimate the variation of damage to structures and yards. The absolute flood damages flood value are used solely for the purpose of calculating benefit-cost ratios for proposed management measures and by the state government in prioritising resources.

The flood damages assessment entails comparison of design flood levels to the floor level and ground level at each property. Based on this comparison, a site-specific level of flood affectation is derived. This informs the residential flood damages calculation, whereby a monetary value is applied to each property based on the level of property damage over a range of design flood events. The flood damages for a town or suburb is typically summarised using the Average Annual Damages (AAD), which is an estimate of the average financial cost of flooding due to property damage in any year. The AAD is calculated by scaling down the cost of a flood event based on the likelihood it will happen in a given year.

For Cooma, the DPIE damages methodology was expanded to include non-residential properties, of which there are a significant number. Literature review indicates that estimates of tangible non-residential flood damages on a large scale can be highly varied. Non-residential flood damages are dependent on factors such as:

- The nature of business undertaken at the property. For example, a business which has a quick turnaround of produce (or limited stock), such as a florist, is likely to suffer a smaller economic loss due to flooding than a business with highly valuable stock and a slower turnaround time, such as an electronics store.
- The floor space of a non-residential property can be related to the amount of stock stored on site and therefore the amount of stock vulnerable to flooding.
- The duration of inundation of a non-residential property and extent of damages can directly affect the length of time that the business may be closed.
- The level of flood awareness/preparedness such as the amount of flood warning and ability to move vulnerable stock can affect the level of flood damage experienced.

To further complicate the calculation of non-residential flood damages, a change of occupancy of a non-residential property can greatly change the economic flood damage experienced due to the potential change in the nature of business at the property.

There is no prescribed methodology for calculating non-residential flood damages provided by DPIE.

The Flood and Coastal Erosion Risk Management – A Manual for Economic Appraisal produced by the Flood Hazard Research Centre at Middlesex University in the United Kingdom developed non-residential flood damages curves based on observed flood damages from the early 2000's. The current study has adopted a typical non-residential flood damage relationship between depth of inundation and damage per square metre of floor space from this Manual and applied it for non-residential properties in Cooma (the other three towns were not used as they have only a small number of non-residential properties). This flood damages curve was adjusted to account for the exchange rate from pounds sterling to Australian dollars and inflation from 2013 to present. The floor space of each non-residential property in Cooma was individually calculated and the flood damages curve was adjusted accordingly.

While the methodology described above will provide only an indicative non-residential Annual Average Damages estimate, this estimate is considered fit for purpose in the comparative assessment of flood mitigation measures and the relative cost benefit presented in Section 8.3.7.

E.4.Cumulative Impact Assessment

Section 7.1 describes the assessment of the cumulative impact on flood behaviour of a ‘fully developed’ scenario in each of the four towns. This was assessed via modelling of higher impervious in the hydrologic model, for areas of development. 30% imperviousness was used for suburban development and 80% imperviousness was used for Cooma’s industrial areas. No existing areas of development had their imperviousness decreased. The ‘fully developed’ areas were based on the current LEP zonings and were confirmed with Council. These areas are shown in Figure 8-24 to Figure 8-27. While they may expand further or have higher intensities of development over longer term planning horizons, the modelling assumptions are valid for the current study and capture the most likely ‘fully developed’ state of each town.

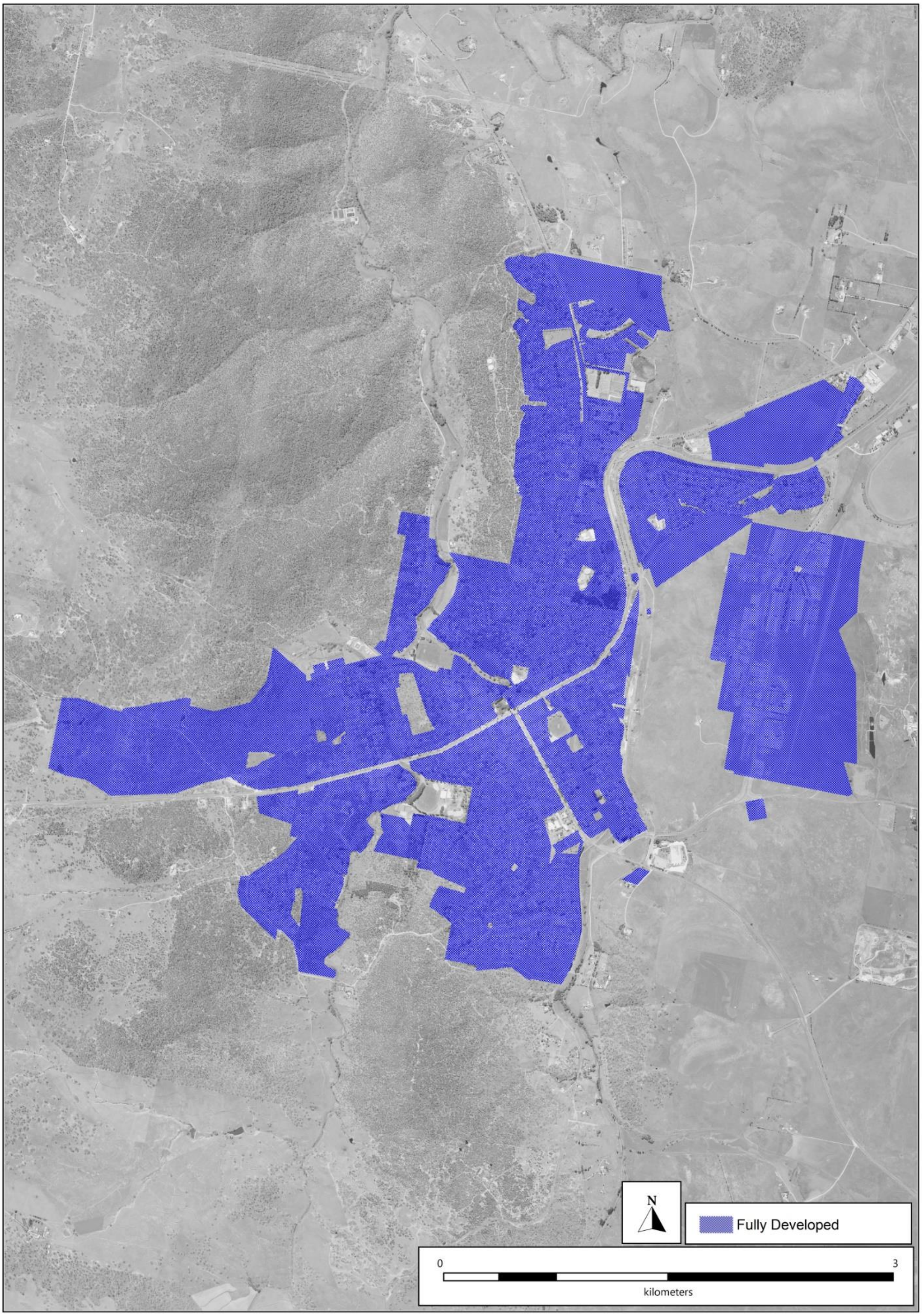


Figure 8-24 Cooma 'Fully Developed' Area

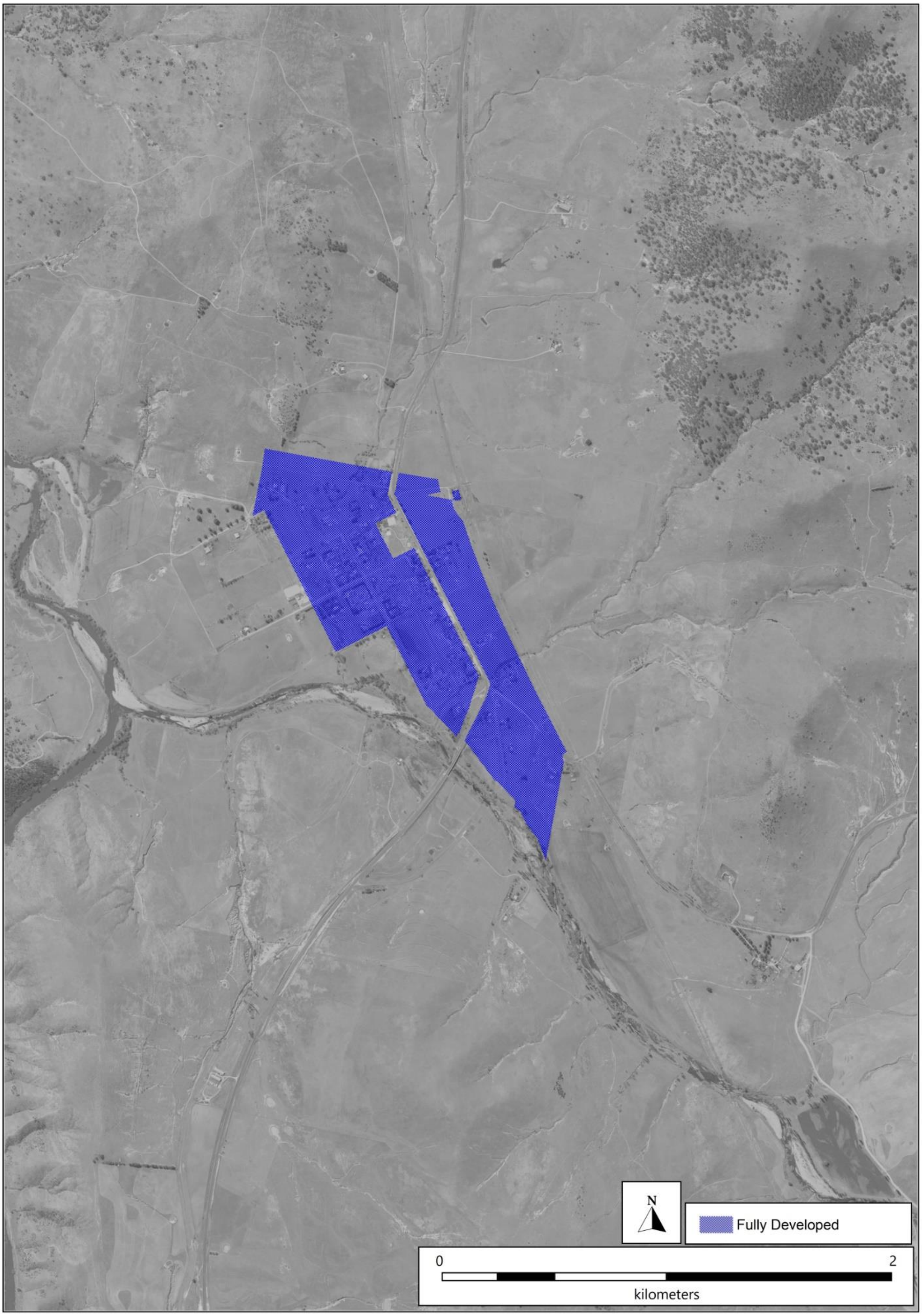


Figure 8-25: Bredbo 'Fully Developed' Area

Figure 8-26: Berridale 'Fully Developed' Area

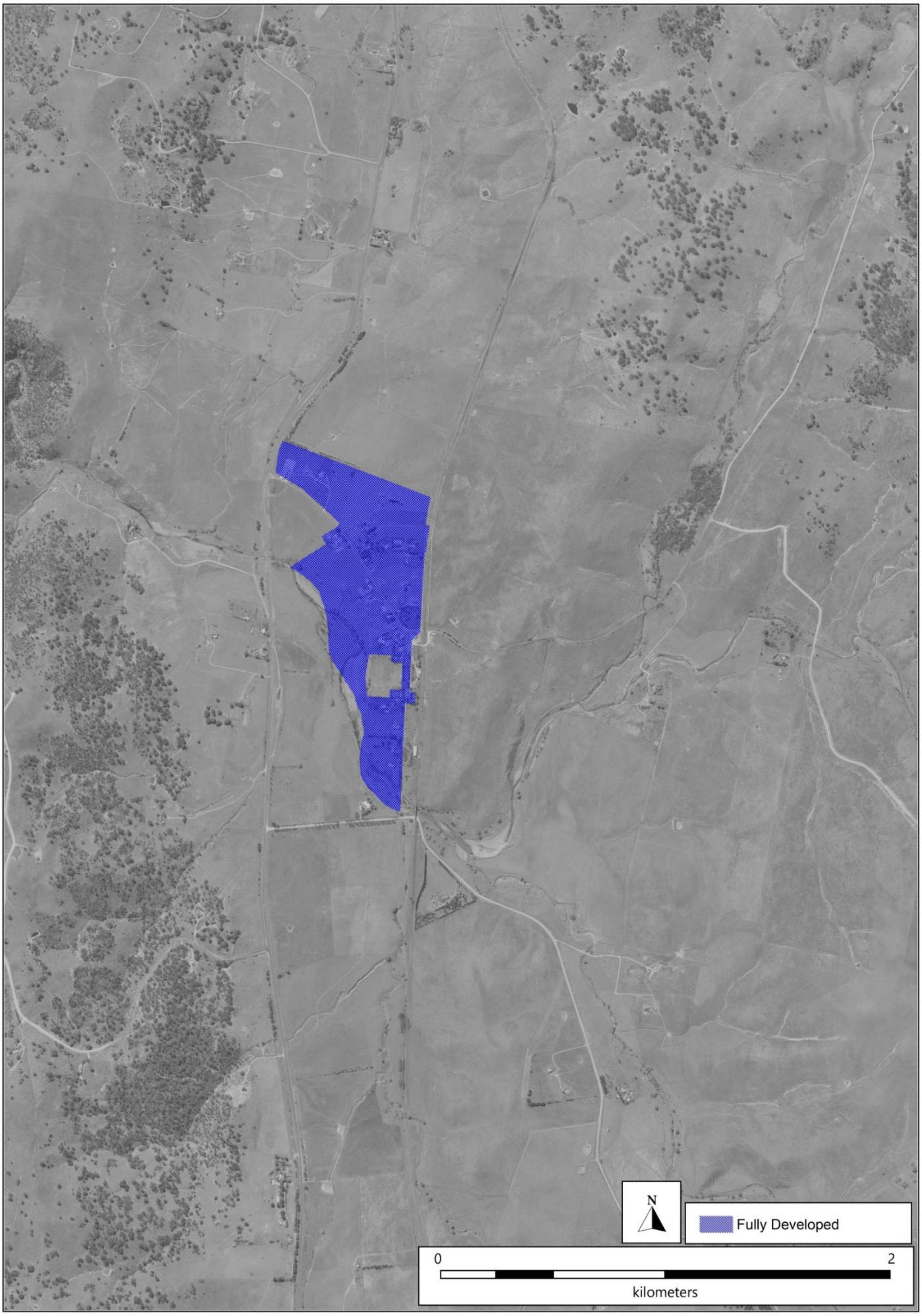


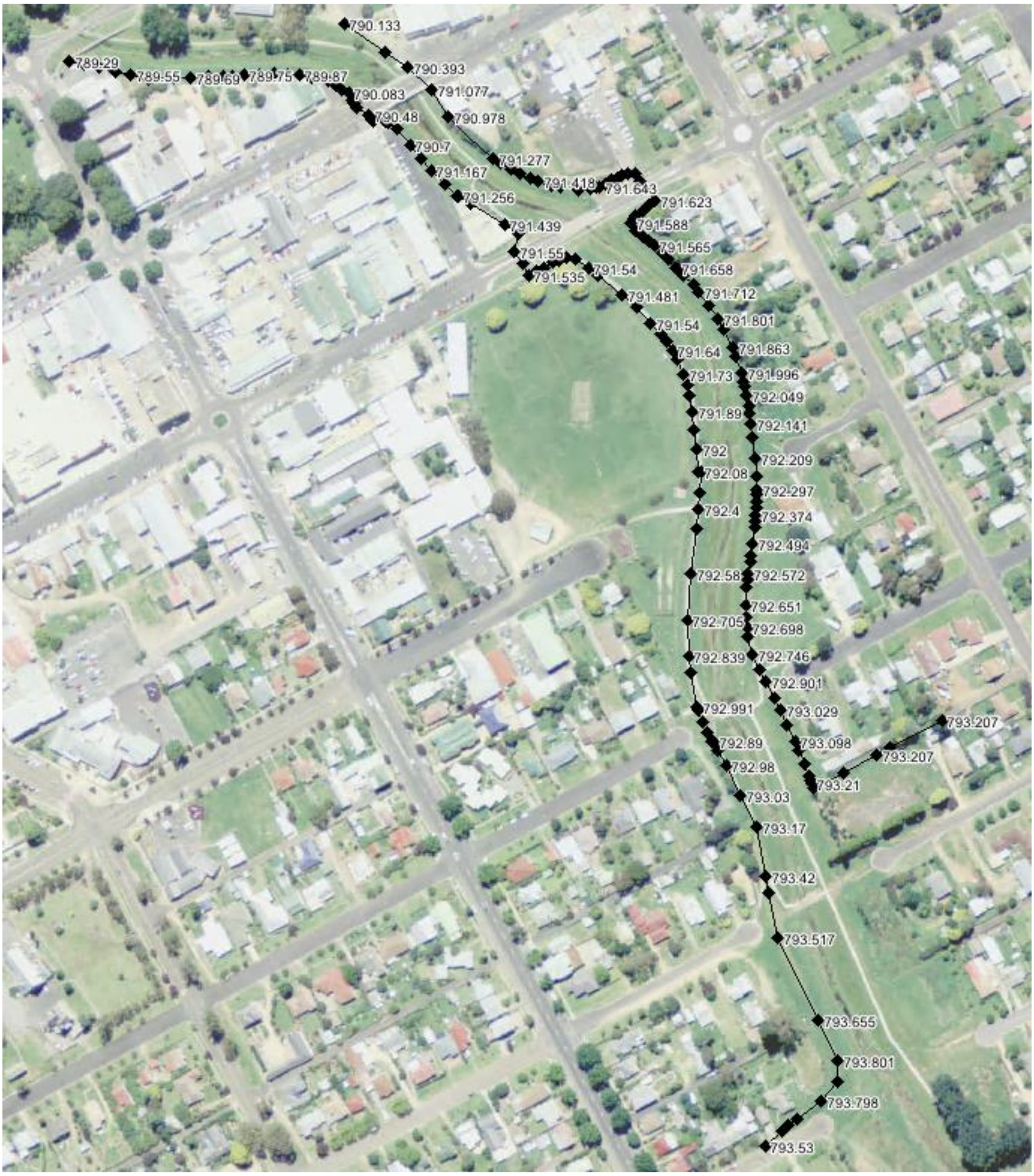
Figure 8-27 Michelago 'Fully Developed' Area

APPENDIX F PRELIMINARY COSTINGS

The following section provides cost estimates for the structural measures assessed for each town. The costings were developed based on Rawlinsons 2019 Construction Cost Guide and past experience. The costings are only estimates used for the purpose of economic assessment and comparison of each measure. For this reason they are only indicative and should not be used for any purpose beyond the current study.

Costing Estimate – Raise Cooma levee to 2% AEP level (L01B)					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 118,230.75
1.4	Detailed Design (assumed 10% of construction cost)				$ 118,230.75
2	**Site Preparation**				
2.1	Clear site of light vegetation and cart away	$0.38	14633.6	m2	$ 5,560.76
2.2	Demolition of footpath (~400m) near Rotary Oval	$3.50	600.0	m3	$ 2,100.00
2.3	Demolition of Commissioner Street approaches (~150m)	$3.50	900.0	m3	$ 3,150.00
3	**Earthworks**				
3.1	Excavation of fillling	$22.00	14633.6	m3	$ 321,938.51
3.2	Haulage of fill (assumed <10 km)	$13.80	14633.6	m3	$ 201,943.25
3.3	Placement, compaction and shaping	$6.50	20629.3	m2	$ 134,090.25
3.4	Top soil placement	$10.60	20629.3	m2	$ 218,670.25
3.5	Hydro mulch, sprayed grass seed compound	$3,250.00	2.1	ha	$ 6,704.51
4	**Civil Construction**				
4.1	Reinstate footpath (~400m) near Rotary Oval	$48.90	600.0	m2	$ 29,340.00
4.2	Modification to Sharp Street Bridge to obstruct flow	$100,000.00	1.0	$	$ 100,000.00
4.3	Replace retaining wall upstream of Sharp Street	$591.00	150.0	m	$ 88,650.00
4.4	Reinstate Commissioner Street road surface	$41.65	900.0	m2	$ 37,485.00
4.5	Kerbs and markings (~150m)	$42.25	300.0	m	$ 12,675.00
4.6	Traffic control for Commissioner Street	$4,000.00	5.0	days	$ 20,000.00
5	**Contingency**				
	Assume 20% of construction cost				$ 236,461.51
				Subtotal	$ 1,655,230.54
				GST	$ 165,523.05
				Total	$ 1,820,753.59

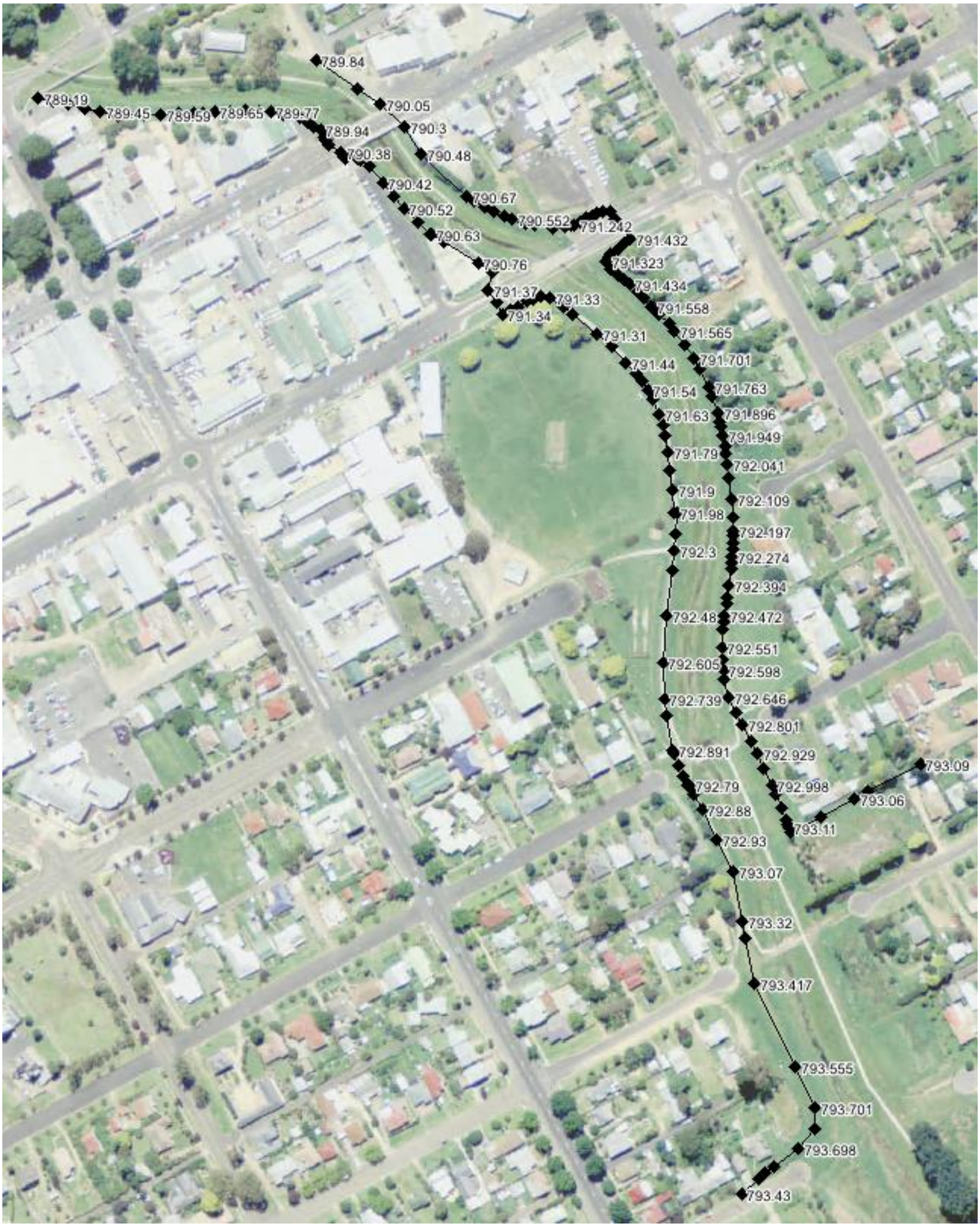
Map below indicates the modelled levee height (2% AEP). Height does not include freeboard.



Costing Estimate – Raise Cooma levee to 5% AEP level (L01C)

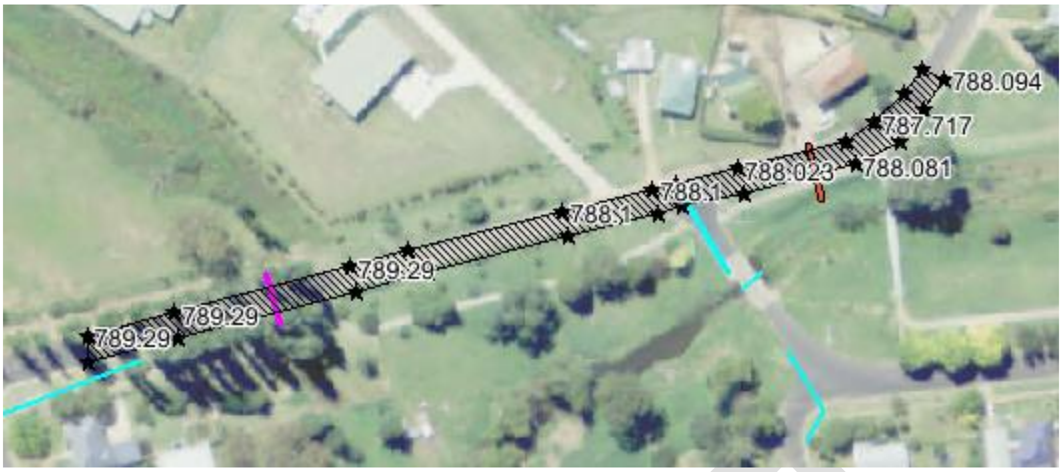
No.	Item	Unit rate ($)	Amount	Units	Cost
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 34,868.94
1.4	Detailed Design (assumed 10% of construction cost)				$ 34,868.94
2	**Site Preparation**				
2.1	Clear site of light vegetation and cart away	$0.38	14633.6	m2	$ 5,560.76
3	**Earthworks**				
3.1	Excavation of fill	$22.00	2070.8	m3	$ 45,558.41
3.2	Haulage of fill (assumed <10 km)	$13.80	2070.8	m3	$ 28,577.55
3.3	Placement, compaction and shaping	$6.50	4610.8	m2	$ 29,970.02
3.4	Top soil placement	$10.60	4610.8	m2	$ 48,874.18
3.5	Hydro mulch, sprayed grass seed compound	$3,250.00	0.5	ha	$ 1,498.50
4	**Civil Construction**				
4.1	Modification to Sharp Street Bridge to obstruct flow	$100,000.00	1.0	$	$ 100,000.00
4.2	Replace retaining wall upstream of Sharp Street	$591.00	150.0	m	$ 88,650.00
5	**Contingency**				
	Assume 20% of construction cost				$ 69,737.88
				Subtotal	$ 488,165.19
				GST	$ 48,816.52
				Total	$ 536,981.71

Map below indicates the modelled levee height (5% AEP or the existing levee, whichever is higher). Height does not include freeboard.



Costing Estimate - Raise Vulcan Street and upgrade culverts (C03)					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 41,530.54
1.4	Detailed Design (assumed 10% of construction cost)				$ 41,530.54
2	**Site Preparation**				
2.1	Break up and remove bitumen paving with basecourse	$3.50	2385.0	m2	$ 8,347.50
2.2	Removal of large trees (~20)	$944.00	20.0	per	$ 18,880.00
2.3	Demolition of culverts and disposal	$15,000.00	1.0	per	$ 15,000.00
3	**Earthworks**				
3.1	Excavation of fill	$22.00	1034.2	m3	$ 22,752.17
3.2	Haulage of fill (assumed <10 km)	$13.80	1034.2	m3	$ 14,271.82
3.3	Placement, compaction and shaping	$6.50	2385.0	m2	$ 15,502.50
4	**Civil Construction**				
4.1	Install culverts (2100x1500mm)	$2,441.98	50.0	m	$ 122,099.14
4.2	Culvert head walls (large culverts)	$448.00	20.0	$	$ 8,960.00
4.3	Install culverts (diameter 450mm)	$246.00	17.0	m	$ 4,182.00
4.4	Culvert head walls (small culverts)	$1,375.00	2.0	per	$ 2,750.00
4.5	Traffic safety barriers	$390.00	100.0	m	$ 39,000.00
4.6	Reinstate Vulcan Street road surface	$41.65	2385.0	m2	$ 99,335.25
4.7	Kerbs and markings (~100m)	$42.25	100.0	m	$ 4,225.00
4.8	Traffic control for Vulcan Street	$4,000.00	10.0	days	$ 40,000.00
5	**Contingency**				
	Assume 20% of construction cost				$ 83,061.07
				Subtotal	$ 581,427.52
				GST	$ 58,142.75
				Total	$ 639,570.27

Map below indicates height of raised road section.



Costing Estimate - increase channel and upgrade culverts at Polo Flat (Z02)					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 162,389.43
1.4	Detailed Design (assumed 10% of construction cost)				$ 162,389.43
2	**Site Preparation**				
2.1	Clear site of light vegetation and cart away	$0.38	13675.0	m2	$ 5,196.50
2.2	Removal of large trees (~20)	$944.00	20.0	per	$ 18,880.00
2.3	Demolition of Airstrip Road and Geebung Street (x2) crossing and disposal	$25,000.00	3.0	per	$ 75,000.00
3	**Earthworks**				
3.1	Excavate trenches 1.00/2.00 deep in light soil	$58.00	6177.5	m3	$ 358,295.00
3.2	Fill disposal (assumed <10 km)	$13.80	6177.5	m3	$ 85,249.50
3.3	Compaction and shaping	$4.50	13675.0	m2	$ 61,537.50
3.4	Top soil placement	$10.60	13675.0	m2	$ 144,955.00
3.5	Hydro mulch, sprayed grass seed compound	$3,250.00	1.4	ha	$ 4,444.38
4	**Civil Construction**				
4.1	Reinstate Airstrip Road and Geebung Street (x2) culverts	$2,441.98	150.0	m	$ 366,297.41
4.2	Culvert head walls	$448.00	30.0	m2	$ 13,440.00
4.3	Traffic safety barriers	$390.00	150.0	m	$ 58,500.00
4.4	Replace retaining wall upstream of Sharp Street	$591.00	150.0	m	$ 88,650.00
4.5	Reinstate Airstrip Road and Geebung Street	$41.65	3.0	m2	$ 124.95
4.6	Kerbs and markings (~150m)	$42.25	300.0	m	$ 12,675.00
4.7	Traffic control for Commissioner Street	$4,000.00	15.0	days	$ 60,000.00
5	**Contingency**				
	Assume 20% of construction cost				$ 270,649.05
				Subtotal	$ 1,948,673.14
				GST	$ 194,867.31
				Total	$ 2,143,540.46

Costing Estimate - Raise road and install culverts at Short Street, Berridale (C01B)					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 30,165.39
1.4	Detailed Design (assumed 10% of construction cost)				$ 30,165.39
2	**Site Preparation**				
2.1	Break up and remove bitumen paving with basecourse	$3.50	492.0	m2	$ 1,722.00
2.2	Removal of large trees (~20)	$944.00	4.0	per	$ 3,776.00
3	**Earthworks**				
3.1	Excavation of fill	$22.00	353.5	m3	$ 7,777.81
3.2	Haulage of fill (assumed <10 km)	$13.80	353.5	m3	$ 4,878.81
3.3	Placement, compaction and shaping	$6.50	492.0	m2	$ 3,198.00
4	**Civil Construction**				
4.1	Install culverts	$3,158.02	70.0	m2	$ 221,061.52
4.2	Culvert head walls	$448.00	20.0	m2	$ 8,960.00
4.3	Traffic safety barriers	$390.00	60.0	m	$ 23,400.00
4.4	Reinstate Short Street road surface	$41.65	82.0	m2	$ 3,415.30
4.5	Kerbs and markings (~100m)	$42.25	82.0	m	$ 3,464.50
4.6	Traffic control for Vulcan Street	$4,000.00	5.0	days	$ 20,000.00
5	**Contingency**				
	Assume 20% of construction cost				$ 60,330.79
				Subtotal	$ 422,315.52
				GST	$ 42,231.55
				Total	$ 464,547.07

Costing Estimate - Raise road and upgrade culverts at William Street on Myack Creek (C02)					
No.	**Item**	**Unit rate ($)**	**Amount**	**Units**	**Cost**
1	**Pre-construction Costs**				
1.1	Detailed Survey		1		
1.2	Contractor setup including WHS		1		
1.3	Project Management		1		
	Assume 10% of construction cost				$ 40,017.08
1.4	Detailed Design (assumed 10% of construction cost)				$ 40,017.08
2	**Site Preparation**				
2.1	Break up and remove bitumen paving with basecourse	$3.50	864.0	m2	$ 3,024.00
3	**Earthworks**				
3.1	Excavation of fill	$22.00	526.2	m3	$ 11,575.50
3.2	Haulage of fill (assumed <10 km)	$13.80	526.2	m3	$ 7,261.00
3.3	Placement, compaction and shaping	$6.50	864.0	m2	$ 5,616.00
4	**Civil Construction**				
4.1	Install culverts	$4,208.21	60.0	m	$ 252,492.74
4.2	Culvert head walls	$448.00	20.0	m2	$ 8,960.00
4.3	Traffic safety barriers	$390.00	80.0	m	$ 31,200.00
4.4	Reinstate William Street road surface	$41.65	864.0	m2	$ 35,985.60
4.5	Kerbs and markings (~100m)	$42.25	96.0	m	$ 4,056.00
4.6	Traffic control for William Street	$4,000.00	10.0	days	$ 40,000.00
5	**Contingency**				
	Assume 20% of construction cost				$ 80,034.17
				Subtotal	$ 560,239.18
				GST	$ 56,023.92
				Total	$ 616,263.10