Captains Flat Floodplain Risk Management Study & Plan

Floodplain Risk Management Study

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Prepared for
Queanbeyan-Palerang Regional Council

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Cardno
Shaping the Future

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Contact Information

Cardno (NSW/ACT) Pty Ltd
Trading as Cardno
ABN 95 001 145 035

Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia

Telephone: 02 9496 7700
Facsimile: 02 9439 5170
International: +61 2 9496 7700

Sydney@cardno.com.au
www.cardno.com.au

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Foreword

The Captains Flat Floodplain Risk Management Study and Plan was commissioned in September 2014 by the then Palerang Council with financial and technical assistance from the NSW Government delivered through the Office of Environment and Heritage. The study was undertaken based on the policies, documents and local government area of Palerang Council at that time.

In June 2016, Palerang Council was merged with Queanbeyan Council to create the Queanbeyan-Palerang Regional Council. At which time, the Captains Flat Floodplain Risk Management Study and Plan was largely complete having undergone the public exhibition period of the final study reports.

The majority of the Study and Plan will not be affected by the merger as the topics discussed are focused on the Captains Flat Township. The environment and heritage chapters examined data from within the Palerang LGA region. However, as the purpose was to identify environmental and heritage constraints in the region of the township, the merger is not expected to alter the contents of these chapters.

The only chapter that may be affected by the merger is the chapter discussing Council's polies and planning controls. This chapter was written based on the Palerang Council's controls at the time of writing.

It is suggested that this chapter be read in this light, and any recommendations arising from this chapter be first compared against the controls adopted for the merged Queanbeyan-Palerang Regional Council to determine if they are still applicable.

Executive Summary

Cardno were commissioned by Palerang Council to undertake the Floodplain Risk Management Study and Plan for the Captains Flat Township.

Flooding in Captains Flat can pose a hazard to some residents and properties near creeks and overland flowpaths. The purpose of this study is to identify and examine options for the management of flooding within the study area.

The Molonglo River catchment covers an area of approximately 2,000 square kilometres, extending from the Murrumbidgee River to the headwaters of the Molonglo and Queanbeyan Rivers. The land use of the catchment varies considerably, ranging from highly developed areas within Canberra and Queanbeyan, to wetlands, pine forests and rural land.

The study area of Captains Flat is located in the upper reaches of the Molonglo River catchment, near to the rivers headwaters in the Tallaganda State Forest.

Three tributaries join the Molonglo River in the vicinity of Captains Flat, namely Kerrs Creek, Keatings Collapse, and a local, unnamed creek referred to as Town Creek. The combined catchment area of the Molonglo River and these tributaries upstream of Captains Flat is 45 square kilometres.

The Molonglo River has been dammed immediately upstream of the confluence of Kerrs Creek and Keatings Collapse to form Captains Flat Dam, an 820ML dam which supplies water to Captains Flat.

The catchment around and upstream of Captains Flat is predominately rural properties and national park areas. The township itself comprises a relatively small part of the catchment, and is made up of medium to low density residential areas with some commercial and industrial properties.

The township has experienced significant historical flooding, with the most severe occurring in December 2010. In this event, over a dozen properties experienced overfloor flooding, some with depths in excess of 1m. Flooding was exacerbated by the blocking of parts of the drainage system. Downstream of the township, the Molonglo River passes through relatively undeveloped areas comprised of grazing land or open floodplains. Significant development is not encountered along the river until the locality of Carwoola, to the east of Queanbeyan, approximately 30km downstream from Captains Flat.

An assessment was undertaken on the number of properties to be affected under different frequency storm events, as well as an estimate of the appropriate economic damage for that event. The following table summarises these results.

Options to reduce or manage the effects of flooding in the catchment were investigated, and recommendations of a mix of strategies to manage the risks of flooding were developed.

Under the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and stakeholders, a number of potential options for the management of flooding and/or the associated risks to life and property were identified.

Table i Flood affected properties and damages under existing conditions

Flood Event	Properties with Over-floor flooding	Properties with Over-ground flooding	Flood Damage
20% AEP	0	0	$0
10% AEP	19	47	$1,503,827
5% AEP	22	61	$2,184,615
2% AEP	32	72	$3,813,480
1% AEP	37	76	$4,505,429
0.5% AEP	43	84	$5,333,093
PMF	102	110	$12,071,225
Average Annual Damage			**$367,075**

These options included:

- Flood modification measures
- Property modification measures
- Emergency response measures

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The assessment found, of the all the options investigated (including flood, property and emergency measures), the top three identified by the multi-criteria analysis were:

1. F 4 Vegetation Management
2. P 2 Building and Development Control Plans
3. P 3 Flood Proofing Guidelines

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1. FM 4 Vegetation Management
2. FM 2 Structure Upgrade
3. FM 1 Drainage Upgrade

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring is not “absolute” and the proposed scoring and weighting should be reviewed in light of any additional future information.

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* Denotes figure included in body of report. Remaining figures are included at the end of the report

Glossary

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded given year. A 90% AEP flood has a high probability of occurring or being exceeded would occur quite often and would be relatively small. A 1%AEP flood has a low pro occurrence or being exceeded each year; it would be fairly rare but it would be relati
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.

Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding

	generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government Floodplain Development Manual, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
DCP	Development Control Plan
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second
NSW	New South Wales
OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
NSW SES	State Emergency Service

1 Introduction

Cardno were commissioned by Palerang Council to undertake the Floodplain Risk Management Study and Plan for the Captains Flat Township.

The study has been undertaken to define the existing flooding behaviour and associated hazards of the study area, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed.

1.1 Study Context

The NSW Floodplain Management process progresses through 6 steps in an iterative process:

1. Formation of a Floodplain Management Committee
2. Data Collection
3. Flood Study
4. Floodplain Risk Management Study
5. Floodplain Risk Management Plan
6. Implementation of the Overland Flow / Floodplain Risk Management Plan

The study currently being undertaken addresses points four and five above.

1.2 Study Objectives

The overall objective of this study is to develop a Floodplain Risk Management Study where management issues are assessed, management options are investigated, and recommendations are made, and a Floodplain Flood Risk Management Plan detailing how flood prone land within the study area is to be managed.

The specific objectives of the Floodplain Risk Management Study are:

- Review the current Captains Flat Flood Study (Cardno, August 2013) and update the model to reflect current catchment conditions;
- Review Council's existing environmental planning policies and instruments including Council's long term planning strategies for the study area, particularly in the light of the potential impact of climate change & in terms of consistency with the principles of the Floodplain Development Manual (2005).
- Identify residential flood planning levels and flood planning area
- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events and taking into account the potential impacts of climate change.

- To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future and taking into account the potential impacts of climate change;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;
- In terms of the Department of Planning Circular PS 07-003 and "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual", determine if and where exceptional circumstance are appropriate for flood related development controls on residential development on land outside the residential flood planning area.
- In consultation with the NSW SES, review the local flood plan, identify deficiencies in information and address the issues identified in the DECCW Guideline "NSW SES Requirements from the FRM Process."
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Examine ways in which the river and floodplain environment may be enhanced without having a detrimental effect on flooding; and,
- Identification of modifications required to current policies in the light of investigations.

2 Catchment Description

The Molonglo River catchment covers an area of approximately 2,000 square kilometres, extending from the Murrumbidgee River to the headwaters of the Molonglo and Queanbeyan Rivers. The land use of the catchment varies considerably, ranging from highly developed areas within Canberra and Queanbeyan, to wetlands, pine forests and rural land.

The study area of Captains Flat is located in the upper reaches of the Molonglo River catchment, near to the river's headwaters in the Tallaganda State Forest.

The study area and upstream catchment are shown in **Figure 2-1**.

Three tributaries join the Molonglo River in the vicinity of Captains Flat, namely Kerrs Creek, Keatings Collapse, and a local, unnamed creek referred to as Town Creek. The combined catchment area of the Molonglo River and these tributaries upstream of Captains Flat is 45 square kilometres.

The Molonglo River has been dammed immediately upstream of the confluence of Kerrs Creek and Keatings Collapse to form Captains Flat Dam, an 820ML dam which supplies water to Captains Flat.

The key features of the study area are shown in **Figure 2-2**.

The catchment around and upstream of Captains Flat is predominately rural properties and national park areas. The township itself comprises a relatively small part of the catchment, and is made up of medium to low density residential areas with some commercial and industrial properties.

The township has experienced significant historical flooding, with the most severe occurring in December 2010. In this event, over a dozen properties experienced overfloor flooding, some with depths in excess of 1m. Flooding was exacerbated by the blocking of parts of the drainage system.

Downstream of the township, the Molonglo River passes through relatively undeveloped areas comprised of grazing land or open floodplains. Significant development is not encountered along the river until the locality of Carwoola, to the east of Queanbeyan, approximately 30km downstream from Captains Flat.

3 Review of Available Data

3.1 Previous Reports and Studies

A number of previous studies have been conducted concerning the Captains Flat region and the wider Molonglo River catchment. These studies have been reviewed as part of this assessment and relevant information incorporated.

These previous studies are summarised in **Table 3-1**.

Table 3-1 Summary of Previous Studies and Reports

Study / Report	Description
Captains Flat Dam: Probable Maximum Flood Review Study (NSW Public Works: Hydrology group, 2003)	The study was undertaken to update the 1991 PMF study in light of additional data received, and to incorporate changes in the PMP estimation methodology. As part of the investigation, a RORB model was developed which was calibrated to flood events in 1978, 1998 and 1991. The study found minimal changes compared to the 1991 PMF estimation.
Captains Flat Dam: Further Studies, covering Dambreak Study, Stability Under Earthquake and Stability of Tailings Dumps (NSW Public Works: Dams and Civil, 2004)	The report contains a number of investigations undertaken to inform the development of a Dam Safety Emergency Plan for Captains Flat Dam (see below). The investigations undertaken included a dam break study, earthquake stability assessment, and a review of the failure risks of the adjacent tailings dumps. The dam break study developed a MIKE-11 model downstream of the dam to assess the impacts of failure. The dam was classified as having a "High C" consequence category due to the population at risk and the minimal warning times available. The earthquake investigation undertaken concluded that the dam met the stability requirements for the selected maximum design earthquake, and would remain stable following an earthquake. The adjacent tailings dumps were assessed to determine the flooding impacts of their failure, as a result of material entering the dam, and displacing water over the spillway. Flooding risks were found to be minimal, as a result of the low volume of material expected to be displaced during failure, and the low risks of failure due to shallow batters and large benches.
Molonglo River: Rescue Action Plan 2010 (Molonglo Catchment Group, 2010)	Prepared through collaboration with a number of stakeholders including the ACT government, WaterWatch Molonglo Catchment, Murrumbidgee Catchment Management Authority and CIC Australia. The Action Plan was prepared to guide natural resource management within the Molonglo River catchment. The plan does not comment on flooding behaviour, but does note the role of floods in affecting geomorphology and weed dispersion.

Study / Report	Description
Dam Safety Emergency Plan for Captains Flat Dam (NSW Public Works: Dams and Civil, 2011)	The plan details the roles, responsibilities and trigger points for the emergency management of Captains Flat Dam. The plan also details available surveillance, communication, monitoring and warning systems in place at the dam.
Captains Flat Flood Study (Cardno, 2012)	The Captains Flat Flood Study was completed in 2012 and forms the basis for the assessments undertaken as part of the Floodplain Risk Management Study and Plan. The Flood Study developed a RORB hydrological model and a SOBEK hydraulic model to define the existing flood behaviour within the Captains Flat township. The models were calibrated to three historical events (July 1988, June1991 and July 1991) and validated against post flood survey marks from the December 2010 event. The calibrated and validated models were used to assess existing flood behaviour for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events and the PMF event.

3.2 Survey Information

Council provided existing survey data for aspects of the study area. Additional survey was commissioned for the aspects and areas not covered by the existing survey.

3.2.1 Existing Survey

Survey was provided by Council from a number of sources. The following summarises the information received:

- Stormwater survey (Individual A4 forms for each drainage line; prepared November 1981)
- Sewer survey (Drawing Numbers 792142-1A, 1B, 1C, 1D and 79166-2; issued June 1981)
- Foxlow St Drain (Drawing Numbers 06021-2, and 06021-5 to 06021-12; issued December 2008)
- Additional survey collected as part of the Flood Study, namely road crest levels throughout the township, detailed cross sections of the Molonglo River and its tributaries, structure survey and terrain survey (11795a12_email_07.11.12.dwg, received December 2012)

3.2.2 Additional Survey

Additional survey was undertaken to collect property floor and ground levels for the flood damages assessment. The survey was undertaken by Council surveyors for all properties within the PMF extent.

3.3 GIS Data

The following Geographic Information System (GIS) data was provided by Council as part of the study:

- Cadastre;
- Aerial image of the study area;
- 5m contours of the catchment area;
- Land-use and Council zoning regions; and,
- Captains Flat catchment extent polygon.

3.4 Historic Flood Information

The study area has experienced a number of flood events, with a significant event occurring in 2010, which was in the order of a 5% AEP event along the Molonglo River and a 2% AEP event along Kerrs Creek. Other events occurred in 2012, 1991, 1988 and 1978.

A post flood survey was conducted following the 2010 flood event. A survey was made of flood marks on buildings, debris extents and creek top of bank levels, as well as providing photographs of what debris and flood marks remained at the time of survey.

3.5 Historic Rainfall Data

Two pluviograph stations are located within the Captains Flat catchment area, as well as a stream flow gauge on the Molonglo River at Copper Creek. In addition, a number of daily rainfall stations are located in the regions surrounding the catchment. The pluviograph and stream flow stations and gauges are shown in **Figure 3-1**. Details on the gauges are shown in **Table 3-2** and daily rainfall totals for the rainfall stations are shown in **Table 3-3**. All data was sourced from ALS Group, on behalf of ACT Environmental.

Table 3-2 Captains Flat Rainfall and Stream Flow Gauge Information

Station Number	Station Name	Type
570982	Molonglo River at Copper Creek	Pluviograph
570960	Parkers Gap	Pluviograph
570923	Rossi (Sawmill)	Daily
570965	Queanbeyan River at Tinderry (NSW)	Daily
570968	Tinderry Mounts at Simon Creek	Daily
410757	Molonglo River at Copper Creek	Stream flow
41000208	Molonglo River at Kobada	Stream Flow

Table 3-3 Peak Daily Rainfall

Station Number	Total Daily Rainfall (mm to 9am)			
	Dec 2010	June 1991	July 1988	March 1978
570982	-	2.8	0	4.2
570960	0.8	0.21	5.3	13.3
570923	0.6	0.2	2.3	-
570965	0.6	5.07	1.6	14.5
570968	0.8	0.2	1.0	4.6

3.6 Previous Modelling

The flood study undertaken in 2012 (Cardno, 2013) developed hydrological and hydraulic models to assess the flood behaviour of the study area. Hydrological modelling was undertaken using the RORB software package, and the hydraulics using the SOBEK software package.

3.6.1 Hydrology

A previous RORB model for the study area was constructed in 1993 to assess the behaviour of Captains Flat dam in the PMF flood event. This model was calibrated to four historical events.

Although the RORB model was not available, the accompanying report which detailed the catchment layout and model parameters, as well as the details of the models calibration, contained sufficient information to allow the new RORB to be built in line with the previous model.

The new model was calibrated against three historical events.

3.6.2 Hydraulics

The Flood Study developed a 1D/2D SOBEK model. The model extends from immediately downstream of Captains Flat Dam to the Captains Flat Road Bridge over the Molonglo River. The model was calibrated to the December 2010 flood event for which post flood survey was available, and used to define the flood behaviour for the PMF event and the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

4 Community Consultation

Community consultation is proposed to be undertaken in three key phases over the course of the project:

- Resident Survey
- Community Forums
- Public Exhibition of Draft Floodplain Risk Management Study and Plan

4.1 Community Information Brochure / Questionnaire

Community consultation was undertaken in December 2014. An information cover letter and a questionnaire were distributed to those properties owners within the Captains Flat Township. The cover letter and questionnaire are attached in **Appendix A**. The cover letter provided an outline of the floodplain risk management process and the objectives of the study. The questionnaire sought information about historical flooding events and flood awareness within the community.

The cover letter and questionnaire were delivered to approximately 320 property owners within the catchment area. Surveys were also hand-delivered to properties to ensure that renters were given an opportunity to respond. The cover letter also provided a link to a study website that provided additional information and the option to complete the survey online.

From the distribution, 25 responses were received, representing a return of approximately 8%. This rate of return was similar to that of the previous Flood Study, and is typical for these types of surveys. A summary of the findings of the resident survey are presented below.

4.1.1 Method of Return

Respondents had the choice of either completing the hardcopy survey mailed out, or the online survey. The majority of the respondents elected to complete the hard copy (22), while only three completed the survey online. The method of response is likely due to the fact that the surveys were posted out to residents, and completing the supplied hardcopy may have been easier for respondents.

4.1.2 Years at Address

One of the questions in the survey related to the length of time that residents had resided at their current address.

Of the 25 respondents, 62% have been at their address for over 10 years, 38% have lived at their address for over 20 years. Of the respondents, 86% were living in Captains Flat at the time of the December 2010 flood event.

Figure 4-1 provides an overview of the periods of residency.

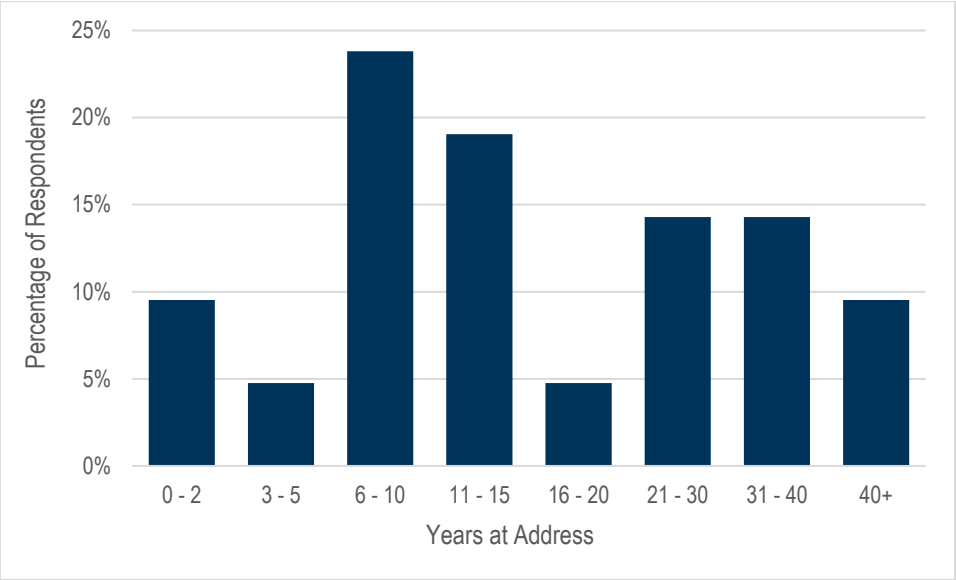

Figure 4-1: Years respondents have spent at current address

4.1.3 Age of Respondents

Respondents were asked to record the age of the permanent residents at the property. Young children and elderly persons are at an increased risk during flood events, so it is important to know how large a demographic these populations are the study area.

The results from the survey, shown in **Figure 4-2**, suggest that there are few young children in the study area; none of the respondents indicated any persons aged less than 25 years living in their properties. The majority of the respondents, 67%, were aged between 25 and 64 years, with 33% aged 65 years or above.

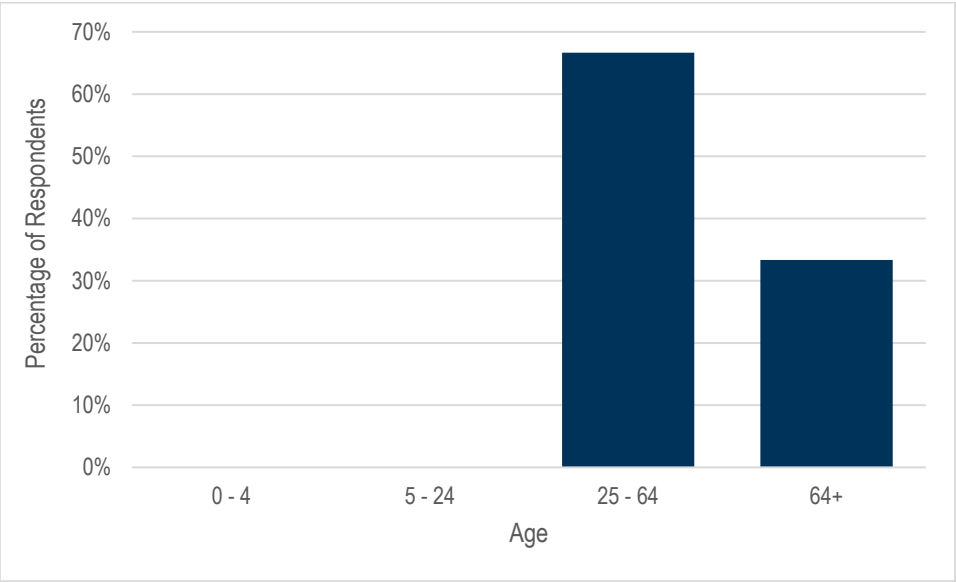

Figure 4-2: Age of Respondents

4.1.4 Community Preferred Communication Avenue

Ongoing communication with the community is an important part of the study. Part of the questionnaire asked residents the best method for passing on flood study related information. The results are shown below in **Figure 4-3**.

The most popular method of communication by a large margin was mail outs. Information days and newspaper articles were also highly ranked. It is noted that these responses may contain some bias, as the data was gathered from a mail out survey.

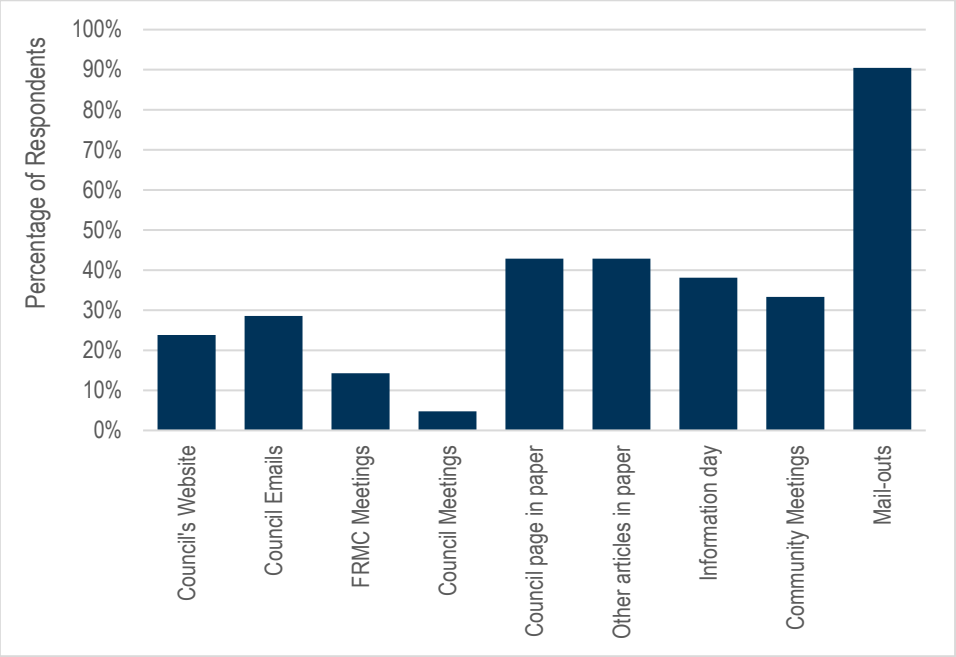

Figure 4-3: Preferred Communication Method

4.1.5 Community Preferred Flood Mitigation Options

The questionnaire asked respondents to give a ranking of 1 – 5 to a variety of potential flood mitigation and management options, with one being the more preferred and five not being preferred. By taking an average of the marks given to each option, the options were ranked based on resident preference. The ranking is shown in **Figure 4-4**.

The majority of options were generally supported, with average scores of 2 – 3. Two options were highly supported with average scores less than 2; environmental channel improvements and improved flowpaths.

There was little support for voluntary purchase, with an average score of greater than 4. Voluntary raising and channel diversions were also ranked relatively poorly.

Overall, the community showed a preference for non-structural mitigation options.

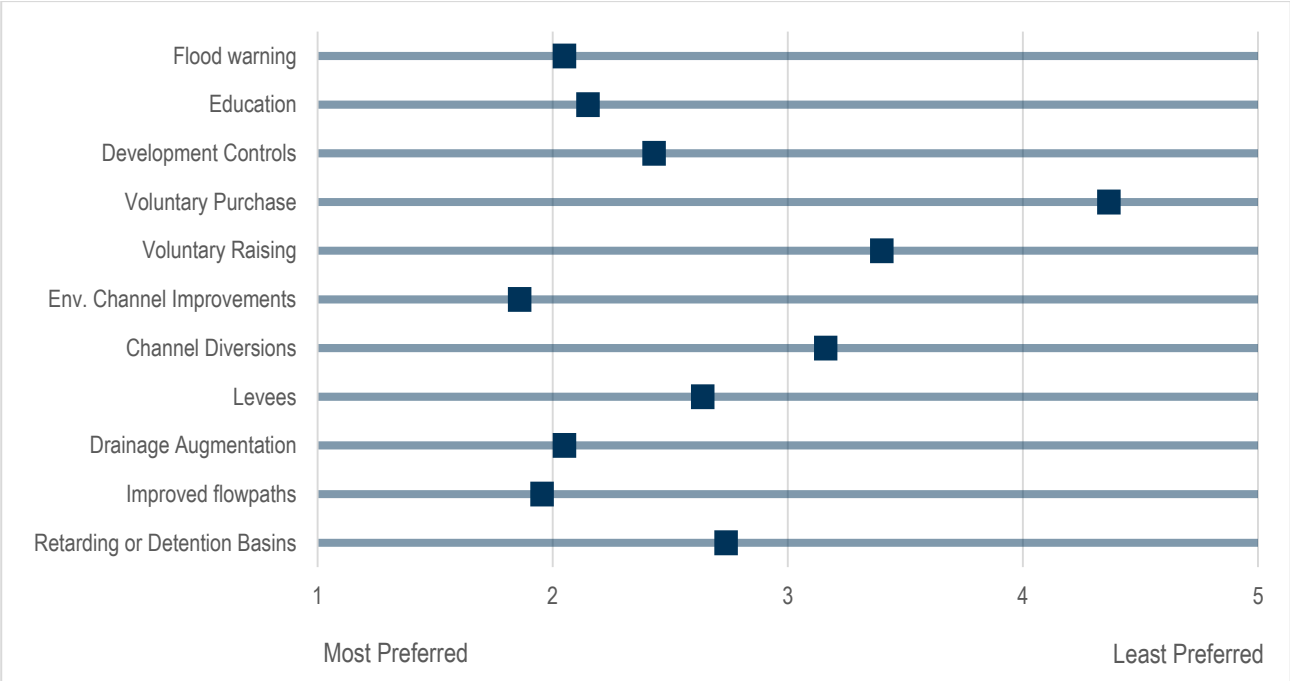

Figure 4-4: Community Preferred Flood Mitigation Options

4.1.6 Community Comments

Respondents were also provided an opportunity to provide further comment on the questions asked in the survey. Of the 25 returned surveys, 9 elected to provide further information (36%). Each of these respondents commented on either the amount of debris / blockage observed in creeks, channels and drains, or listed clearing and vegetation management as recommended options, suggesting that this issue has a high level of importance for the community.

4.2 Community Workshops

A community workshop was help at the Captains Flat Community Hall on Wednesday 8th April 2015. The workshop was undertaken to discuss the study to the community, and in particular to consult with the community on potential mitigation options. A preliminary assessment of selected options was presented to the community, and comment and feedback was sought on the suitability of these options, and whether the community had additional options to be assessed.

Key comments and feedback from the community workshops included:

- Revetment/armouring of any reworked creek is required
- The environmental and aesthetic appeal of the creeks must be considered in the works
- Vegetation and debris management was strongly supported
- Strong agreement to examine culvert blockage and capacity in the project
- Sheet flow off surrounding hills should be considered
- There is a build-up of silt at the inlet to Kerrs Creek culverts
- Concerns about easement along back of properties along Foxlow St near Town Creek

- Vegetation removal must include removal of poisoned willows
- Residents should be encouraged to take care of their own properties to protect the wider town
- Loss of land is occurred from erosion in Kerrs Creek

4.3 Public Exhibition

A public exhibition workshop was held at the Captains Flat Community Hall on Wednesday 2nd March 2016. The workshop was undertaken to present the draft outcomes and recommendations from the study to the community and to invite a final round of community input prior to finalising the Floodplain Risk Management Study and Plan.

The majority of residents expressed general support for the draft Plans. Key comments from the discussion are outlined below:

- Voluntary purchase may sterilise the southern portion of the town. It was explained that this was the intent of that measure as it is a high risk area within the town
- Voluntary purchase would only apply to residential properties, leaving the commercial areas isolated, particularly so for the pre-school
- An early warning system needs to be a priority to increase the time for residents to evacuate
- Maintenance of stormwater infrastructure needs to be improved and be undertaken more frequently. It was explained that stormwater infrastructure is generally sufficient only for minor events and that no maintenance schedule will prevent flooding in this area

Two submissions were made during the public exhibition period. The first submission was made by the Queanbeyan & District Preschool Association. There points made in their submission were:

- If voluntary purchase proceeds, the preschool would be left in an isolated area leading to an increase in overall risk, not just flood risk.
- If the other blocks in the area, were to be bought by council and reclassified we would have concerns as to who would be responsible for the upkeep of the area around the Preschool.
- If the preschool was further isolated, it may prove less of an attraction for parents to bring their children to our service and we would suffer in regards to our operational viability (as it stands we currently only operate two days per week).
- Evacuation times need to be made as long as possible to allow safe evacuation of the centre. They have suggested an evacuation alert time of one to two hours would be appropriate.
- As Foxlow Bridge goes under in many flood events, the only evacuation route is Miners Road. This road has safety issues and should be improved to provide an enhanced evacuation route
- Vegetation management should be undertaken to reduce debris obstructions along the Molonglo River.
- Consideration of raising and repairing Foxlow Bridge should be considered.

With regard to the raising of Foxlow Street bridge, this option was not found to be suitable as it would also require raising of significant lengths of Jerangle Road and Foxlow Street to tie into the raised road that is not feasible due to existing access requirements.

The second submission made was by Captains Flat Public School. The points made in their submission were:

- The Captains Flat Public School has been identified in the draft Plan as a potential flood refuge location
- The current principal is supportive of this arrangement provided suitable arrangements for issues related to Workplace Health and Safety, site access, site management and required equipment and supplies can be satisfactorily agreed with Council and the SES.

5 Existing Flood Behaviour

5.1 Properties with Overfloor Flooding

A detailed assessment of the flood damages and overfloor flooding is provided in **Section 6** of this report. The results are summarised below in **Table 5.1**. Single storey dwellings have been highlighted, as these properties have limited opportunity for vertical evacuation. It is noted that almost all flood affected residential properties are single storey.

The results in **Table 5.1** indicate that overfloor flooding commences in the 10% AEP. There is little difference between the overfloor flooding observed in the 10% AEP and the 5% AEP events, however the number of affected properties rises sharply in the 2% AEP event.

The table also shows that all the properties affected by overfloor flooding in the 1% AEP event are single storey buildings, as are the majority of those affected by overfloor flooding in the PMF.

Table 5-1 Properties with Overfloor Flooding

Flood Event (AEP)	Residential Properties		Commercial Properties	Industrial Properties
	Single Storey	Total Residential		
PMF	88	92	10	0
0.5%	33	34	9	0
1%	28	28	9	0
2%	23	23	9	0
5%	14	14	8	
10%	13	13	6	0
20%	0	0	0	0

5.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters (refer Captains Flat Flood Study (Cardno, 2014)), does not consider a range of other factors that influence the “true” flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include the:

- Size of the flood;
- Effective warning time;
- Rate of rise of floodwaters;
- Duration of flooding;
- Ease of evacuation;
- Effective flood access; and,
- Flood readiness.

True flood hazard maps are provided for the 1% AEP event and the PMF event in **Figure 5-1** and **Figure 5-2**.

5.2.1 Size of Flood

A comparison of peak flood levels for the design events is shown in **Figure 5-3**. The section is taken across the Molonglo River, 50m upstream of the Foxlow Street Bridge. The figure shows that there is a steady increase in flood levels between the 20% AEP and the 0.5% AEP, with flood levels rising from 844.9mAHD to 845.4mAHD.

Between the 0.5% AEP and the PMF event however is a significant jump of 2.5m in flood height. This demonstrates that the study area has a significant residual flood risk that will be present even if buildings are constructed above the FPL (refer **Section 10** for further details).

In order to demonstrate this on the true hazard mapping, an additional hazard classification, *Residual Risk*, has been added to the 1% AEP true hazard map. This hazard area shows regions that are flood free in the 1% AEP, but are prone to high hazard flooding in the PMF event.

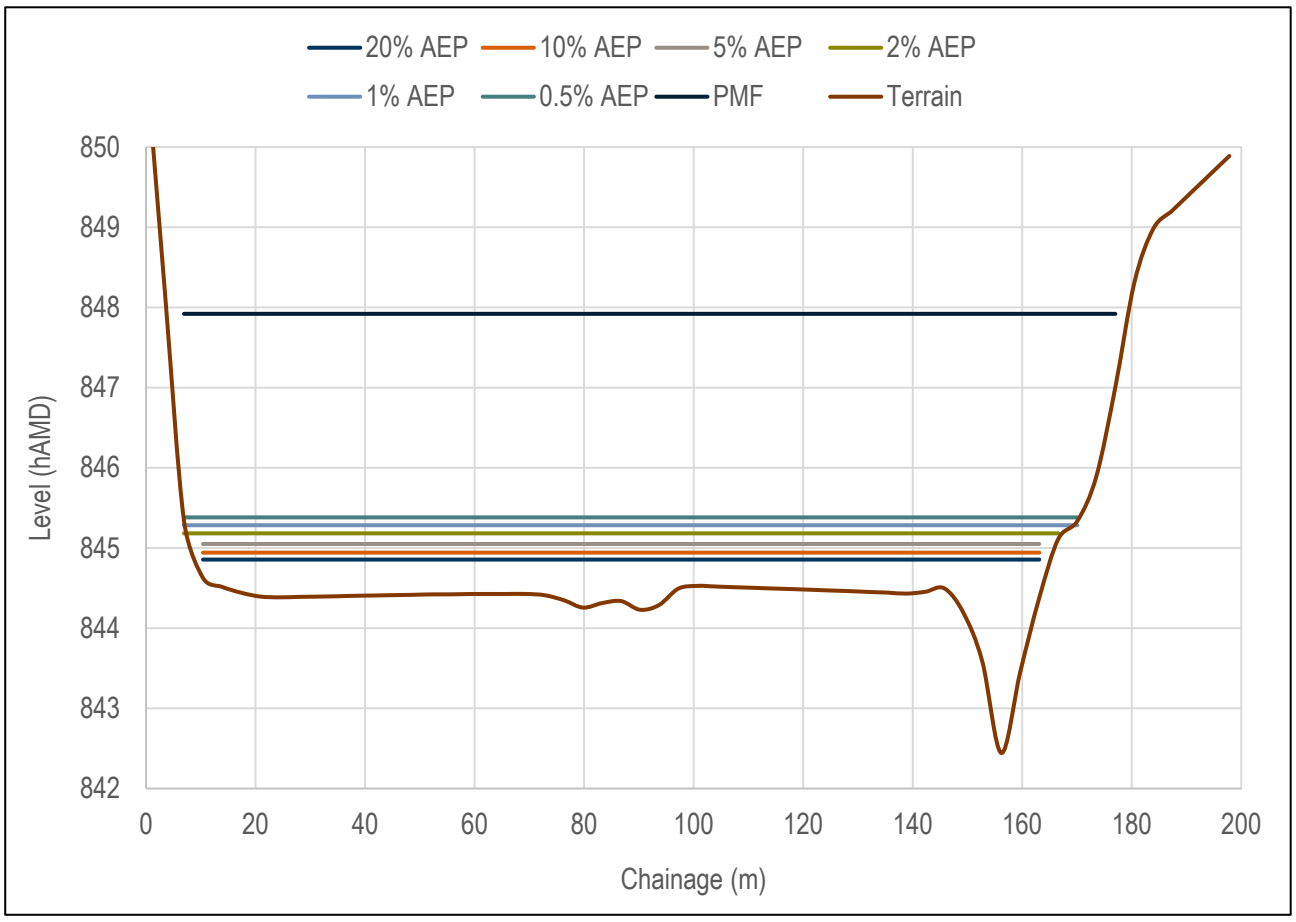

Figure 5-3 Comparison of Peak Flood Heights

5.2.2 Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuation). The effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The critical duration storm for the study area ranges from 9 hours for the Molonglo River to 6 hours for Kerrs Creek for the 1% AEP event and the PMF. The smaller creek systems have shorter critical durations, but these do not have as much impact on properties as the longer duration systems, such as the Molonglo River. However, as discussed in **Section 11**, the shorter duration, non-critical storms in the Molonglo River still result in significant flooding. As such, the adoption of the 6 hour event to assess warning times was adopted across the whole catchment.

As such, the peak of the flow generally occurs at various locations within the catchment within 2 to 3 hours from the start of the flood event. However, as there is no warning system in place, and that flooding in the township may arise from upstream rainfall that does not fall within the study area, this does not translate to 2 to 3 hours warning for the community. For most residents, the first warning they presently have of a flood occurring is inundation of their property or loss of access along roadways.

Therefore, there is little to no warning time throughout the study area. In the true hazard mapping, any flooding that results in overfloor flooding of properties has been classified as high hazard, given the lack of warning time available to residents.

5.2.3 Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 0.5 m was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 0.5 m flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (NSW Government, 2005).

In the study area, there are no properties with flow behaviour within these constraints for the 1% AEP or PMF events which are not already selected by the provisional high hazard criteria (**Section 5.2.5**).

5.2.4 Depth and Velocity of Flood Waters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping for the PMF and 1% AEP events were undertaken as part of the Flood Study (Cardno, 2014). This provisional hazard mapping has been used as the basis for determination of true flood hazard.

5.2.5 Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple

of hours, even in the longer duration events. Those properties affected by longer periods of inundation are already selected by the provisional high hazard criteria.

5.2.6 Ease of evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

- The number of people requiring assistance;
- Mobility of those being evacuated;
- Time of day;
- Warning time;
- Availability of suitable evacuation equipment;
- Distance from other population centres;
- Presence of suitable evacuation routes; and
- Availability of emergency response agencies to assist evacuation.

Although the duration of flooding in the catchment is relatively short, as noted previously, Captains Flat is affected by several of the factors listed above. These include an extremely short warning time (Section 5.2.2), high water velocity and depth (Captains Flat Flood Study, Cardno, 2014), a lack of suitable evacuation routes (as the Foxlow Bridge is cut in relatively frequent events) and very limited availability of emergency response agencies to assist in evacuations given the distance from other response units such as the SES, RFS, NSW Police and NSW Fire and Rescue (excluding those based within Captains Flat) located throughout the region.

In addition to these factors, as a small town with little employment within the town itself, the majority of able bodied adults leave the town to travel to their place of work. This results a significant change in the population demographics of the town during these periods, exacerbating evacuation difficulties.

Therefore, ease of evacuation for the majority of the catchment is considered to be an issue, particularly for properties that experience overfloor flooding in the 1% AEP and PMF events that do not have a second floor. This allows for limited opportunities for residents to escape the inundation within their properties. There are a total of 28 of these residential properties in the 1% AEP event and 88 in the PMF event.

These locations are all classified as high hazard in the true hazard mapping.

5.2.7 Effective Flood Access

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potentially reduce damages. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

In the true hazard mapping, properties that are isolated as a result of flooding of access roads have been classified as high hazard.

5.2.8 Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond efficiently to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The last significant flood event in the study area occurred in 2010. Based on the responses from the resident survey (refer **Section 4**) approximately 86% of respondents were living in Captains Flat at the time of the 2010 flood event.

Although a large proportion of residents were living in Captains Flat at the time of the 2010 flood event, the community consultation has drawn out a substantial lack of flood readiness. While residents have a sense that the town is affected by flooding, it was apparent that the community in general had little understanding of how serious the risk of flooding in the town is and how vulnerable certain portions of the town are to extreme flood events.

This lack of awareness of the actual flood risk increases the hazard faced by the community, as it heightens the chance that residents will undertake unsafe actions during flood events.

True hazard mapping revisions undertaken to reflect flood warning, ease of evacuation and effective access have resulted classifying as high hazard any properties that overfloor flooding, or who would require egress through flood waters to be classified as high hazard. The lack of flood awareness in the community further supports this classification.

5.3 Flood Emergency Response Planning Classification of Communities

Flood emergency response classification provides an indication of the relative vulnerability of the community and provides the NSW SES with valuable information in managing emergency responses to flood events.

The classifications are shown in **Figure 5-3**.

The classification has been undertaken in accordance with the floodplain risk management guideline 'Flood Emergency Response Planning Classification of Communities' (DECC 2007).

The Flood Emergency Response Planning Classifications are:

- High Flood Island – region not inundated by the PMF, but which is surrounded by floodwaters
- Low Flood Island – region is first surrounded, and then impacted by flooding in the PMF
- High Trapped Perimeter – region is not inundated by the PMF but access may be restricted
- Low Trapped Perimeter – region is first isolated, and then impacted by flooding in the PMF
- Overland Escape Route – region and access impacted by PMF. People can escape rising flood waters by moving overland to higher ground
- Rising Road Access – regions where access roads rise steadily to flood free ground and allow egress as flood waters rise
- Indirectly Affected Areas – regions that are outside the flood limit that retain access throughout the event

As a result of the limited warning time identified in the true hazard assessment (refer **Section 5.2**), properties along the Molonglo River and Kerrs Creek have been classed as low flood islands since the first warning these properties may have

of flooding occurring is inundation of their dwelling, by which time high hazard flooding will be occurring on their lot, they have been classed as low flood islands.

Furthermore, as demonstrated in the December 2010 event, the timings of the various watercourses, can result in access being lost before the primary flowpath is activated. In the 2010 event, flows from Keatings Collapse resulted in access along Foxlow Street being lost some time before flooding commenced from the Molonglo River.

6 Current Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as various types; these types are summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

Type	Description
Direct	Building contents (internal)
	Structural damage (building repair)
	External items (vehicles, contents of sheds, etc.)
Indirect	Clean-up (immediate, removal of debris)
	Financial (loss of revenue, extra expenditure)
	Opportunity (non-provision of public service)
Intangible	Social (increased levels of insecurity, depression, stress)
	Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spread-sheets. For the purposes of this project, generic spread-sheets have been used based on a combination of OEH residential damage curves and FLDamage.

6.2 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments, and available research in the area, is used as a substitute.

OEH has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

The following sections set out the methodology for the determination of damages within the Captains Flat catchment.

6.2.1 Residential Damage Curves

The draft DNR (now OEH) Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (NSW Government, 2005) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings, namely:

- Single story, slab on ground,
- Two story, slab on ground,
- Single story, high set.

Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for a damage of $10,988 (March 2015 dollars) to be incurred when the water level reaches the base of the house. We have assumed that this remains constant until overfloor flooding occurs. A nominal $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped by more than 0.3m of depth but only up to 0.3m below the floor of the house. This may occur on steeper properties and larger properties where the garden and fences may be impacted, but the flood waters do not reach the house.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- A value of 150m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain. With a floor area of 150m^2, the default contents value is $61,500 (March 2015 dollars),
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents and hence reducing the potential damages of household contents,
- The Township is a small part of the regional area, and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in regional areas where re-construction resources are limited and large floods can cause a strain on these resources.

6.2.1.1 Average Weekly Earnings

The OEH curves are derived for late 2001 and were updated to represent March 2015 dollars. General recommendations by OEH are to adjust the values in residential damage curves by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data from the Australian Bureau of Statistics at the time of this study was for March 2015. Therefore, all ordinates in the residential

flood damage curves were updated to March 2015 dollars. In addition, all damage curves include GST as per OEH recommendations.

The OEH guidelines were derived in November 2001, which allows us to use the November 2001 AWE statistics (issued quarterly) for comparison purposes. March 2015 AWE values were taken from the Australian Bureau of Statistics website. Consequently, damages have been increased by 64%, which includes the increase due to GST, have been included compared to 2001 values.

Table 6-2 Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$673.60
March	2015	$1,104.70

6.2.2 Commercial Damage Curves

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

- Low value commercial,
- Medium value commercial,
- High value commercial.

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual commercial properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2015 dollars, using data from the Australian Bureau of Statistics (ABS, 2011). It was assumed that the FLDamage data was in June 1990 dollars. Consequently, commercial damages have been increased by 81.8% and GST has been included compared to 1990 values.

Table 6-3 CPI Statistics for Commercial Damage Curves

Month	Year	CPI
June	1990	$102.50
March	2015	$204.93

6.3 Industrial Damage Curves

There were no industrial properties within the study area, and consequently these curves were not used.

6.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6-1**. For purposes of illustration, the commercial damage curves are shown for a property with a floor area of 150m^2, although the size will be individually determined for each commercial property when calculating catchment damages.

6.5 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event.

Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

The AAD value attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event. For example, the 1% AEP design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve. Further information of the calculation of AAD can be found in Appendix M of the Floodplain Development Manual (NSW Government, 2005).

6.6 Results

The results from the damage analysis are shown in **Table 6-4**. Based on the analysis described above, the average annual damage for the Captains Flat floodplain under existing conditions is $367,075.

Table 6-4 Captains Flat Existing Damage Analysis Results

	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damages ($)
PMF					
Residential	92	1.46	3.41	109	$ 8,611,724
Commercial	10	3.05	3.54	1	$ 3,459,501
PMF Total	102			110	$ 12,071,225
0.5% AEP					
Residential	34	0.65	0.95	74	$ 2,882,728
Commercial	9	0.96	1.03	10	$ 2,450,365
0.5% AEP Total	43			84	$ 5,333,093
1% AEP					
Residential	28	0.33	0.86	66	$ 2,241,891
Commercial	9	0.53	0.94	10	$ 2,263,538
1% AEP Total	37			76	$ 4,505,429
2% AEP					
Residential	23	0.31	0.78	62	$ 1,840,950
Commercial	9	0.44	0.85	10	$ 1,972,530
2% AEP Total	32			72	$ 3,813,480
5% AEP					
Residential	14	0.25	0.68	51	$ 1,347,984
Commercial	8	0.36	0.72	10	$ 836,631
5% AEP	22			61	$ 2,184,615
10% AEP					
Residential	13	0.28	0.59	38	$ 886,301
Commercial	6	0.28	0.60	9	$ 617,525
10% AEP Total	19			47	$ 1,503,827
20% AEP					
Residential	0	-	-	0	$ -
Commercial	0	-	-	0	$ -
20% AEP Total	0			0	$ -

7 Social Issues

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, in the consideration of emergency response or evacuation procedures, information may need to be presented in a range of languages and/or additional arrangements may need to be made for less mobile members of the community.

Demographic data for Captains Flat, sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census, was reviewed to gain an appreciation of the social characteristics of the area. The Captains Flat catchment comprises an area along the Molongolo River, and includes parts of the suburbs of Captains Flat and Jingera. Analysis has been based on data for the Captains Flat State Suburb (referred to henceforth as 'Captains Flat') which is a defined area for Census data amalgamation and comprises the suburbs of Anembo, Captains Flat, Jingera and Tinderry.

Census data showed that the population of Captains Flat in 2011 was 743, with a median age of 39 years, slightly higher than the median for NSW (38). A summary of the age distribution is provided in **Table 7-1**. Over half the people living in the LGA are aged between 15-54 years. Children aged 0-14 years made up 20.1% of the population and people aged 65 years and over made up 8.2% of the population. While the majority of residents are likely to be generally able-bodied, the lack of employment within Captains Flat means that many of these residents will be outside of the township during work hours, and would be unavailable to assist if a flood event occurred at this time. Furthermore, access through the Township is lost at a number of locations during flood events, which will limit the ability of people to assist at-risk residents such as children and the elderly.

In Captains Flat (State Suburbs) 88.2% of people only spoke English at home. Other languages spoken at home included German 0.4%, Norwegian 0.4%, Swedish 0.4%, Spanish 0.4% and Hindi 0.4%. This suggests that language barriers (e.g. during evacuation, or for flood education), are unlikely to be a significant issue in this area.

Table 7-1 Age Structure of the Catchment (ABS, 2011)

Age Group	Persons in Captains Flat	% of Total in Captains Flat	% of Total Persons in NSW
0-9 years	114	15.3	12.9
10-19 years	84	11.3	12.7
20-39 years	186	25.0	27.2
40-59 years	253	34.1	26.9
60-79 years	97	13.1	16.1
80 years and over	9	1.2	4.2
TOTAL	743	100	100

8 Environmental Issues

8.1 Topography, Geology & Soils

8.1.1 Topography and Soils

The Captains Flat Catchment consists of steeper areas, including the more vegetated slopes to the outer edges of the catchment, undulating terrain, rural development and grazing areas situated in the intervening flatter areas.

The Molonglo, Pialligo, Captains Flat and Bennison soil landscape types dominate the majority of the Molonglo River (ACT Government, 2010). The Molonglo and Pialligo landscapes are level to gently undulating floodplains on Quaternary alluvium. The Captains Flat and Bennison landscapes are undulating to rolling rises and flats on Silurian volcanics. In urban areas, building spoil has been introduced along parts of the river and consists of a mix of topsoil, subsoil, boulders and building material (ACT Government, 2010).

Large areas along the Molonglo River and its tributaries have experienced significant erosion, primarily as a result of the high incised banks which are prone to slumping from flood undercutting. Unimpeded stock access to the river and existent/ persistent nick-points have also exacerbated erosion issues (ACT Government, 2010). Erosion and sedimentation issues are highly relevant to the catchment and should be considered when identifying and implementing flood mitigation options.

In addition to the above, acid sulphate soil risk is present in the area according to CSIRO Australian Soils Classification mapping. Acid sulphate soil is the common name for soils that contain metal sulfides. The presence of these soils is to be expected due to the generally low-lying topography of the floodplain areas. In an undisturbed and waterlogged state, acid sulphate soils generally pose no or low risk. However, when disturbed, an oxidation reaction occurs to produce sulfuric acid which can negatively impact on the surrounding environment. It is likely that any proposed flood modification/engineering options may encounter acid sulfate soils and as such, it is recommended that additional studies and an acid sulfate soils management plan be prepared should such options be implemented.

8.1.2 Water Management

The Molonglo River Rescue Action Plan 2010 (ACT Government, 2010) is a key document for the management the Molonglo River Catchment (which encompasses the Captains Flat Catchment). The Action Plan describes the river profile, existing and future threats, highlights opportunities for rehabilitation and restoration, and proposes a defined monitoring program to ensure actions implemented are successful and/or adapted as necessary.

This document should be referred to when identifying and considering proposed flood mitigation measures for the Captains Flat Catchment.

8.1.3 Contaminated Land and Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the *Contaminated Land Management Act 1997*. Contamination issues need to be considered at the flood management options development and design stage.

The Office of Environment and Heritage (OEH) regulates contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online OEH Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA, on 22 December 2014. Two premises were listed for the former Palerang LGA, however these are not located within the Captains Flat Catchment.

A search of the *Protection of the Environment Operations Act 1997* (PoEO Act) licensed premises public register on 22 December 2014 identified just one premise within the catchment that has a pollution discharge licence, for a Queanbeyan-Palerang Regional Council property located at Miners Road, Captains Flat.

8.1.4 Threatened Flora and Fauna

A search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2014) undertaken in December 2014 indicated that three threatened ecological communities are likely to, or may occur in the area, namely:

- Natural Temperate Grassland of the Southern Tablelands of NSW and the Australian Capital Territory (Endangered, likely to occur);
- Subtropical and Temperate Coastal Saltmarsh (Vulnerable, likely to occur); and
- White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically Endangered, may occur).

The Captains Flat Catchment comprises one National Park and one State Forest, namely:

- Tallaganda National Park; and
- Tallaganda State Forest.

These are protected under the NSW *National Parks and Wildlife Act 1974*.
Remnants of high ecological value Snow Gum Woodland are noted to exist in a Travelling Stock Reserve on Crown land near Captains Flat, and in Captains Flat Cemetery, although these are not formally protected under any reserve system. Lightly grazed or ungrazed bushland surrounding the Captains Flat area has also been identified as potentially being an area of high conservation value, since additional remnant patches may exist (ACT Government, 2010).

SEPP 14 wetlands do not occur in the Captains Flat Catchment.

A search of the OEH (2014) Bionet database was undertaken to assess relevant biodiversity features recorded within a 10km^2 area comprising the catchment and surrounds. A total of 21 threatened flora sightings have been recorded consisting of 1 species – Black Gum (*Eucalyptus aggregata*). A total of 30 threatened fauna sightings have been recorded in the area, consisting of 7 bird species and 3 mammal species (refer **Table 8-1**)

A search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2014) undertaken in December 2014 indicated that a total 22 threatened species and 11 migratory species are known, likely or may occur in the area.

A range of threatened communities, populations and species are known or likely to occur within the catchment, and should be considered in the development and implementation of any proposed flood modification options or flood protection works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

Table 8-1 Threatened Flora and Fauna with the Captains Flat Study Area (OEH, 2014)

Family	Scientific Name	Common Name	Status (NSW)	Status (C'wealth)
Flora				
Myrtaceae	Eucalyptus aggregate	Black Gum	V,P	
Birds				
Cacatuidae	Callocephalon fimbriatum	Gang-gang Cockatoo	V,P	
Strigidae	Ninox strenua	Powerful Owl	V,P	
Acanthizidae	Chthonicola sagittata	Speckled Warbler	V,P	
Meliphagidae	Anthochaera phrygia	Regent Honeyeater	E4A,P	E
Pachycephalidae	Pachycephala olivacea	Olive Whistler	V,P	
Petroicidae	Petroica boodang	Scarlet Robin	V,P	
Petroicidae	Petroica phoenicea	Flame Robin	V,P	
Mammals				
Dasyuridae	Dasyurus maculatus	Spotted-tailed Quoll	V,P	E
Burramyidae	Cercartetus nanus	Eastern Pygmy-possum	V,P	
Vespertilionidae	Falsistrellus tasmaniensis	Eastern False Pipistrelle	V,P	

P = Protected, V = Vulnerable, E4A = Critically Endangered under the TSC Act, E = Endangered under the EPBC Act

8.2 Heritage

8.2.1 Aboriginal Heritage

'Traditional Custodians' is the term to describe the original Aboriginal or Torres Strait Islander people who inhabited an area (DLG, n.d). Traditional custodians today are descendants of the original inhabitants and have ongoing spiritual and cultural ties to the land and waterways where their ancestors lived. The traditional custodians of the land in the former Palerang LGA are the Ngarigu people.

The Molonglo River valley was an important ceremonial site and prime source of food and water for the local indigenous people prior to European settlement, and archaeological evidence suggests that the low elevation riverine and adjacent woodland and grassland environments were the focus of Aboriginal occupation of the Southern Tablelands (ACT Government, 2010). A search of the Aboriginal Heritage Information Management System database was undertaken in December 2014 for known Aboriginal heritage sites within the Captains Flat Catchment. A total of 25 sites have been recorded in the vicinity of the catchment (a 10km by 12 km rectangular search area comprising the catchment).

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and therefore any management options that will impact upon Aboriginal sites must include this in their design. Known Aboriginal sites should be left undisturbed if possible, however if a management option requires their destruction, an Aboriginal Heritage Impact Permit (AHIP) must be sought from OEH. Under the NPW Act it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area.

8.2.2 Non-Indigenous Heritage

Non-Indigenous heritage can be classified into three statutory listing classifications based on significance, namely Commonwealth, State and local. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Indigenous heritage was undertaken for the catchment. Searches were undertaken of the following databases:

- Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List);
- State Heritage Register; and
- Local Council Heritage.

Within the Captains Flat Catchment, no Commonwealth heritage items were recorded on the Australian Heritage Database.

No heritage items were identified as being listed under the NSW *Heritage Act 1977*, however three are listed by State Agencies under Section 170 of the Act:

- Captain's Flat Police Station and Official Residence, 178 Foxlow Street, Captains Flat;
- Captains Flat Railway Precinct, Captains Flat Road & Miners Road, Captains Flat; and
- Captain's Flat Railway Station Group, Captains Flat

There were 20 items of local significance noted to exist in Captains Flat, these are summarised in **Table 8-2**.

Depending on the nature of any structural floodplain risk management works proposed for the catchment, a more detailed heritage assessment may be required to assess potential impacts on these features.

Table 8-2 Palerang Local Environment Plan 2014 Heritage Items

Place Name	Location
Captains Flat Hospital	1 Blatchford Street, Captains Flat
Railway station (former)	Captains Flat Road, Captains Flat
Captains Flat Cemetery	Captains Flat Road, Captains Flat
Station Masters residence (former)	2 Copper Creek Road, Captains Flat
Roscommon	8 Copper Creek Road, Captains Flat
Bills' Trough, including granite plaque and dog water bowl	Foxlow Street, Captains Flat
The Bollard House	2 Foxlow Street, Captains Flat
Captains Flat Hotel, including bar	49 Foxlow Street, Captains Flat
Captains Flat Community Centre	53 Foxlow Street, Captains Flat
Captains Flat Post Office (former)	55 Foxlow Street, Captains Flat
Captains Flat Miners Memorial, including 4 dioramas and a jenny wheel	65 Foxlow Street, Captains Flat
Shop	70 Foxlow Street, Captains Flat
The Outsider	86 Foxlow Street, Captains Flat
Captains Flat Police Station	198 Foxlow Street, Captains Flat
RSL Club (former)	212 Foxlow Street, Captains Flat
Captains Flat railway goods shed, weighbridge, gantry and turntable	Miners Road, Captains Flat
Captains Flat Public School—original buildings	Montgomery Street, Captains Flat
Miners Cottage	1 Mulga Street, Captains Flat
Miners Cottage	11 Mulga Street, Captains Flat
Lake George Mine, including smelter site, mine processing sites, railway precinct, Fosters Gulley and Keatings Collapse	Old Mines Road, Captains Flat

9 Policies & Planning

The Captains Flat study area is located in the Queanbeyan-Palerang Regional Council LGA. At the time of writing development is controlled through the former Palerang Local Environment Plan (PLEP) 2014 and various Develop Control Plans (DCPs). The PLEP 2014 is a planning instrument which designates land uses and development in the former Palerang LGA, while DCPs regulate developments with specific guidelines and parameters.

9.1 Palerang local Environment Plan

Due to the Environmental Planning and Assessment Amendment Act 2008 and Environmental Planning and Assessment Amendment Regulation 2009, the standardisation of all NSW Local Authority LEPs is in process. Significant changes within the LGA and in the NSW Planning Reforms implemented by the NSW Government have instigated a process of updating the LEP.

The Palerang Local Environment Plan (PLEP) 2014 came into effect on 31 October 2014.

The PLEP adopts the Department of Planning and Environment's model flood planning clause as Clause 6.2. The objectives of *Clause 6.2: Flood Planning* are to:

- Minimise the flood risk to life and property associated with the use of land;
- Allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change; and
- Avoid significant adverse impacts on flood behaviour and the environment.

The land to which this clause applies is land identified in the Flood Planning Maps contained within the PLEP.

9.2 Current Land Use and Zoning

As part of this study, Council has supplied the land use mapping adopted within the PLEP.

The Captains Flat catchment is comprised predominately of rural land or bushland, with the township of Captains Flat being the only residential centre in the catchment.

The land use within the Captains Flat catchment is controlled by the PLEP 2014. The zoning of the study area is shown in **Figure 9-1**, and these zones are described in **Table 9-1** as per the PLEP 2014.

Table 9-1 Captains Flat Catchment Land Uses

Zone	Land Use	Zone Objectives
Environmental Protection	E2 Environmental Conservation	▪ To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values. ▪ To prevent development that could destroy, damage or otherwise have an adverse effect on those values. ▪ To minimise the impact of any development on the natural environment. ▪ To encourage rehabilitation and regeneration of ecosystems. ▪ To provide for a very limited range of ecologically sustainable development and land use activities that provide for small scale and low impact recreation and amenities.
Recreation	RE1 Public Recreation	▪ To enable land to be used for public open space or recreational purposes. ▪ To provide a range of recreational settings and activities and compatible land uses. ▪ To protect and enhance the natural environment for recreational purposes. ▪ To protect and enhance the environment generally and to ensure that areas of high ecological, scientific, cultural or aesthetic values are protected, managed and restored.
	RE2 Private Recreation	▪ To enable land to be used for private open space or recreational purposes. ▪ To provide a range of recreational settings and activities and compatible land uses. ▪ To protect and enhance the natural environment for recreational purposes. ▪ To protect and enhance the scenic and environmental resources of the land. ▪ To ensure that the scale and character of private recreational development is compatible with the established land uses of the locality.

Zone	Land Use	Zone Objectives
Rural	RU1 Primary Production Zone	▪ To encourage sustainable primary industry production by maintaining and enhancing the natural resource base. ▪ To encourage diversity in primary industry enterprises and systems appropriate for the area. ▪ To minimise the fragmentation and alienation of resource lands. ▪ To minimise conflict between land uses within this zone and land uses within adjoining zones. ▪ To minimise the impact of any development on the natural environment. ▪ To ensure that development does not unreasonably increase the demand for public services or facilities.
	RU5 Village	▪ To provide for a range of land uses, services and facilities that are associated with a rural village. ▪ To encourage design and development that enhances the streetscape and village character. ▪ To ensure that development has regard to the character and amenity of the locality. ▪ To ensure that non-residential uses do not result in adverse impacts on the amenity of existing and future residential premises.
Special Purpose	SP2 Infrastructure	▪ To provide for infrastructure and related uses. ▪ To prevent development that is not compatible with or that may detract from the provision of infrastructure.

9.2.2 Flood Affected Land Use Zones

A number of land uses are affected by flooding in the 1% AEP event and the PMF event, as shown in **Figure 9-2**.

Zones within the 1% AEP event flood affected area are predominately RU5 Village and RU1 Primary Production as a result of these zones being located adjacent to the water courses in the study area.

At the confluence of the Molonglo River and Kerrs Creek, the RE1 Public Recreation zone is widely inundated.

The 1% AEP extent also impacts SP2 Infrastructure zones that contain sewerage and telecommunications infrastructure, and emergency services.

9.3 Development Control Plans

Queanbeyan-Palerang Regional Council adopted a single DCP for the former Palerang LGA on 21 May 2015 to supersede a number of DCPs that were still in force. The DCP has been reviewed below.

9.3.1 DCP2015 Section B9 – Flood Planning

Section B9 is the primary source of flood controls within the DCP. The controls apply to all flood affected land within the LGA. The objectives of Section B9 are:

- To comply with the objectives of Clause 6.2 of the PLEP 2014;
- To ensure the impacts of the full range of floods, up to and including the probable maximum flood, are considered when assessing development of flood prone land;
- To take account of social, economic and ecological factors in relation to flood issues;
- To ensure development is in accordance with the principles contained in the Floodplain Development Manual, issued by the NSW Government;
- To only permit development where the full potential risk to life from flooding can be managed for all floods up to and including the Probable Maximum Flood;
- To minimise the impact of flooding and flood liability on individual owners and occupiers; and
- To ensure development and construction materials are compatible with the flood hazard.

The key controls within the DCP are:

- No development allowed within floodways or high hazard areas;
- Extensions of up to 35m^2 may be approved below the FPL provided that applicant can demonstrate no practical alternatives exist and that the level of hazard will not increase;
- Habitable floor levels are to be at or above the FPL;
- Flood safe access it to be provided up to the 1% AEP +0.5m for all residential, commercial and industrial development;
- Any development below the FPL is to be constructed of flood proof materials; and
- A flood report may be required for any proposed development within the flood planning area.

9.4 Recommended Changes to Palerang DCP

As a result of the investigation into planning controls, a number of recommendations are proposed to increase the effectiveness of the Palerang DCP.

Recommended changes to existing controls are summarised in **Table 9-2**.

Additional controls recommended for inclusion in the DCP are summarised in **Table 9-3**.

Table 9-2 Recommended Changes to Existing Flood Planning Controls in DCP2015

Existing Control	Comments
Flood planning levels	
The flood planning level is referred to throughout Section B9, but a definition is never provided.	It could reasonably be assumed that the flood planning level definition in the PLEP of 1% + 0.5m is the flood planning level referred to in DCP2015. In order to avoid confusion however, it is recommended that an explicit definition be provided in the DCP.
Flood Access	
Flood safe access and emergency egress for all flood events up to the1:100 ARI event plus 500mm freeboard is to be provided	The concern with the control as it stands is that it would result in high level driveways and access roads being constructed across the floodplain. It is recommended that this control be replaced with a requirement for a Flood Emergency Response Plan to be prepared for developments within the floodplain.

Table 9-3 Recommended Controls to be Included in Section B9 of DCP2015

Proposed Control	Comments
Carparks above ground	
Entrance to carparks should be no lower than 100 year ARI flood level plus 0.5 metres All above ground car parks should be designed taking into account vehicle stability up to the PMF event. Vehicle stability can be assessed in accordance with the NSW Floodplain Development Manual (2005). Three options are available: ▪ The floor planning level of the car park is sufficient to prevent the instability of vehicles due to flooding, ▪ The car park is flood proofed to prevent the instability of vehicles due to flooding, ▪ Bollards are provided to prevent cars being swept away.	Ensuring the stability of cars in any flood event will prevent cars from becoming debris, preventing further damage downstream in a flood event.

10 Flood Planning Level Review

10.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 – 0.5m for residential properties, and can vary for industrial and commercial properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain. Consequently, different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life;
- Land availability and needs;
- Existing and potential land use;
- Current flood level used for planning purposes;
- FPL for flood modification measures (levee banks etc.);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than the flood planning level;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Land values and social equity; and,
- Duty of care.

These issues are dealt with collectively in the following sections.

10.2 Planning Circular PS 07-003

The Planning Circular was released by the NSW Department of Planning in January 2007, and provides advice on a number of changes concerning flood-related development controls on residential lots. The package included:

- An amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in section 149 planning certificates;
- A revised ministerial direction regarding flood prone land (issued under section 117 of the Environmental Planning and Assessment Act 1979); and,
- A new Guideline concerning flood-related development controls in low flood risk areas.

The Guideline states that, unless there are exceptional circumstances, councils should adopt the 1% AEP +0.5m as the FPL for residential development. The need for another FPL to be adopted would be based on an assessment local flood behaviour, flood history, associated flood hazards or a particular historic flood, which would have to demonstrate that exceptional circumstances exist within the study area to warrant a different FPL.

The Circular establishes the 1% AEP +0.5m as the default FPL. The following sections assess the conditions in Captains Flat against a range of criteria to determine if the 1% AEP +0.5m is a suitable FPL for Captains Flat.

10.3 Likelihood of Flooding

As a guide, **Table 10-1** has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 10-1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the intangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 0.5% AEP magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 10-1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16
0.5%	30	5

10.4 Risk to life

Flooding in Captains Flat poses a significant risk to life for the community. Large flood events result in the creation of low flood islands, which can rapidly be inundated with little to no warning. This risk is compounded by a limited flood awareness within the community.

Access roads within the township are cut in events as frequent as the 20% AEP, which results in the township becoming fragmented. Access roads outside of the catchment area are also likely to be cut during flood events which will restrict the ability of emergency personnel to service the community.

These risks increase with flood severity. Unless the PMF is adopted as the FPL, there will be a residual flood risk within the community, even if all development is built at the FPL. This residual risk for Captains Flat is significant.

The community should be helped to understand that adhering to flood development controls does not mean that they are free of flood risk. A community education program is provided in **Section 12** to assist in building this community awareness.

10.5 Existing and potential land use

The hydrological regime of the catchment can change as a result of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. DCP2015 restricts building within the floodway, and recommends against filling in flood storage areas. In general, DCP 2015 limits development in flood prone regions.

Given this, and other controls within the DCPs (Section 9.3), this is not considered to be a significant issue within the catchment.

10.6 Land availability and needs

Issues of land availability are not of particular concern in the Captains Flat study area due to a slow rate of population growth, and an availability of vacant residential lots for development that are in flood free areas. Consequently, land availability is not considered an issue in setting the FPL.

10.7 FPL for flood modification measures

The flood modification measures proposed for Captains Flat (refer **Section 13**) are primarily focused on improving structures and watercourse conveyance. These options do not allow for, or require alternative FPL's to the wider study area. Consequently, the proposed mitigation measures do not influence the selection of the FPL for Captains Flat.

10.8 Changes in potential flood damages caused by selecting a particular flood planning level

Based on an approximate typical overfloor flood damage for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals is shown in **Table 10-2**. The table shows the AAD of a given property that experiences overfloor flooding in each design event, and the net present value (NPV) of those damages over 50 years at 7%.

Table 10-2 indicates that the largest incremental difference between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 50% and 20% AEP events. It can be seen that the differences between the 2% and 1% AEP event, and the 1% AEP event and the PMF are relatively small, suggesting that increasing the FPL beyond the 2% AEP level does not significantly alter the savings achieved from a reduction in damages.

Table 10-2 Differential Damage Costs between AEP Events

Event (AEP)	AAD	Change in AAD	NPV of AAD	Change in NPV
50%	$25,000	-	$345,000	-
20%	$10,000	$15,000	$138,000	$207,000

10%	$5,000	$5,000	$69,000	$69,000
5%	$2,500	$2,500	$34,500	$34,500
1%	$1,000	$1,500	$13,800	$20,700
PMF	$500	$500	$6,900	$6,900

10.9 Incremental Height Differences Between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the average incremental height difference between events is shown in **Table 10-3** for selected events. These are determined based on the flood levels determined at each of the properties within the catchment as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 2% AEP event.

Table 10-3 Average Differences Between Design Flood Levels For Flood Affected Properties

Event (AEP)	Difference to PMF (m)	Difference to 1% AEP (m)	Difference to 2% AEP (m)
1%	1.37	-	-
2%	1.70	0.33	-
5%	1.82	0.45	0.11

Table 10-3 indicates a significantly larger difference in flood level of the PMF event compared to other events. The change between the 2% and 1% AEP events is relatively small (0.33m), suggesting that the adoption of the 1% AEP event would provide an increased level of risk reduction over the 2% AEP event without a significant effect on flood planning levels.

The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 1% AEP event (in the order of 1.4 metres) and would therefore present an issue for the setting of flood planning levels in the catchment.

10.10 Consequences of floods larger than the flood planning level

As shown above, there is a significant height difference between the 1% AEP and the PMF. While the average difference across flood affected properties is 1.37m, the maximum difference, which occurs along Foxlow Street, is 2.5m. This means that for properties built at an FPL of 1% +0.5m, the PMF would result in overfloor flooding depths of 2m at some properties. As shown in **Section 5.1** most of these properties are single story, and as such, no onsite refuge would be available.

Coupled with limited, or no warning, and an under appreciation of flood risks by the community, the PMF flood depths result in a significant residual risk for properties along the Molonglo River and Kerrs Creek.

10.11 Flood warning and emergency response

A discussion on flood warning and emergency response issues relating to Captains Flat are provided in **Section 11**.

The assessment found that:

- Warning times will be limited, and potential non-existent. The first indication that many residents will have that a flood is occurring will be inundation of their dwelling. This was the experience of residents during the December 2010 event.
- The ability of emergency services to respond to flooding in Captains Flat will be limited by the flooding of roads both to and within the township.
- Flooding occurs over the course of some hours, which also inhibits the ability of emergency services to provide assistance, as by the time they are able to access Captains Flat, the flood waters are likely to have receded.
- The community will need to be flood resilient, as they will need to largely manage flood concerns themselves.

10.12 Social Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. A requirement for higher floor levels also imposes additional construction costs on new developments.

10.13 Freeboard Selection

The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in the creek/channel vegetation; and
- Accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area).

Model sensitivity:

- Local flood behaviour (e.g. due to local obstructions etc.);
- Wave action (e.g. such wind-induced waves or wash from vehicles or boats); and
- Culvert blockage.

The impact of typical elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (Gillespie, 2005);
- Local wave action (allowances of ~0.1 m are typical) (truck wash etc.);
- Accuracy of ground/ aerial survey ~ +/-0.15m; and
- Sensitivity of the model ~ +/-0.15m (based on a 10% change in model parameters).

Based on this analysis, the total sum of the likely variations is in the order of 0.5m.

Given the above, a freeboard allowance of 0.5m is appropriate.

10.14 Flood Planning Level Recommendations

The FPL investigation supports Council's current FPLs, namely:

- For existing residential developments, new residential developments and for subdivisions, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- For existing and new industrial and commercial development, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m;
- Council strongly recommends that any part of a building which extends below the minimum floor level be flood proofed in accordance with Appendix J NSW Floodplain Manual 2005.

Commercial and/or Industrial properties have adopted higher frequency flood events such as the 5% AEP planning level based on the perception of risk. These occupiers can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots don't generally provide an income to offset losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen economic loss during a flood event.

However, as there are a relatively low number of commercial and industrial sites in the study area that are affected by floods, the adoption of the 1% AEP +0.5m as the FPL for commercial and industrial properties is appropriate for the study area.

It should be noted that an FPL set at the 1% AEP + 0.5m level will still result in significant over floor flooding in the PMF event of up to 2.5m. These depths are such that properties would require a habitable second floor if residents were to be able to safely shelter in the building during a flood event. However, the majority of flood affected properties in the PMF are single storey, and as such, not currently able to provide a safe refuge during the PMF. It is therefore important that other strategies are put in place, such as education and community awareness measures and the provision of flood refuges, to address this risk to life. These responses to the residual risk are further discussed in **Section 11**.

The flood planning area (FPA) arising from this FPL is shown in **Figure 10-1**.

10.15 Duty of care

As noted above the adoption of the 1% AEP +0.5m level as the FPL for Captains Flat, while suitable, results in a residual flood risk for properties affected by the PMF. It is important that these properties be made aware of the this residual risk, and that they are assisted in developing appropriate strategies to manage their safety during large flood events.

Further information on the options available to manage this residual risk are provided in **Section 11**, and strategies for engaging with the community to educate them on this risk are provided in **Section 12**.

11 Emergency Response Arrangements

Flood emergency measures are an effective means of reducing the risks of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in former Palerang LGA are discussed below.

11.1 Emergency Response Documentation

11.1.1 Local Disaster Plan

Flood emergency management for the former Palerang LGA is outlined in the Lake George Local Disaster Plan (2011) which has been issued under the authority of the *State Emergency and Rescue Management Act, 1989* (as amended). The Plan covers the former LGAs of Palerang and Queanbeyan (now the Queanbeyan-Palerang Regional Council LGA).

The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- Roles and responsibilities in emergencies;
- Preparedness measures;
- Conduct of response operations; and,
- Co-ordination of immediate recovery measures.

The Local Disaster Plan outlines the key responsibilities of the different organisations involved in emergency management. It is generally the responsibility of the NSW SES, as the "combat" agency, to respond to and coordinate the flood emergency response. It is the responsibility of Council and OEH to manage flood prevention / mitigation through development controls, the floodplain management process and mitigation schemes.

The Plan identifies flood hazard as an extreme risk with the region. It should be noted that this categorisation is a general one for the whole LGA. The Plan also identifies failure of Captains Flat Dam to have a high risk rating.

11.2 Emergency Service Operators

The NSW SES is listed as the "Combat Agency" for flooding and storm damage control in the Local Flood Plan, as well as the primary coordinator for evacuation and the initial welfare of affected communities.

The ability of the NSW SES to respond to large flood events in Captains Flat will be restricted by the closure of access roads, both within and external to the study area. The flooding response in Captains Flat is also relatively quick, with flood waters rising and falling over the course of hours, not days. Local NSW SES volunteers may be able to provide some assistance, but it is likely that the community would be largely isolated, and be required to operate self-sufficiently, until flood waters recede.

There is a Rural Fire Brigade station in Captains Flat, located at 108 Foxlow Street. There is a local Police Station within Captains Flat, however, this station has low staffing levels and services a large area and cannot be relied upon to assist in evacuation situations. The Queanbeyan Police Station provides operational support.

There are no hospitals in Captains Flat, and the nearest hospital is located in Queanbeyan.

11.3 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation of residents from flood affected areas, medical personnel attempting to provide aid, or NSW SES personnel installing flood defences.

11.3.1 Access Road Flooding

Access is lost along two key roads in the Captains Flat Township; Foxlow Street / Jerangle Road at the Molonglo River and Foxlow Street at Kerrs Creek. The location at which overtopping first occurs is Foxlow Street, at the beginning of the Kerrs Creek pipe due to flows in Kerrs Creek, although the most significant road overtopping occurs at the Foxlow Street Bridge due to overbank flows from the Molonglo River.

A summary of the road overtopping behaviour for the Molonglo River and Kerrs Creek are shown below in **Table 11-1** for each design event. Overtopping was said to occur when a flow depth of greater than 0.2m occurred on the road way.

The table shows that both the Molonglo River and Kerrs Creek result in road overtopping and loss of access in all events, Overtopping depths rise from 0.54m and 0.36m respectively in the 20% AEP to 3.6m and 1.9m respectively in the PMF.

In line with the flow timings above, the table shows that the Kerrs Creek flows cause road overtopping 2 – 3 hours before those from the Molonglo River. Road access at Foxlow Street Bridge is lost for 8 to 9 hours in events larger than the 20% AEP event. Overtopping durations at Kerrs Creek are less but still significant; generally 6 to 7 hours.

A flood free access can be provided between the area of Captains Flat south of the Molonglo River and the remainder of the town. This route, via Miners Road and Captains Flat Road, is currently unsuitable for use as an evacuation route. The Miners Road section is unsealed, steep and has significant unprotected batter slopes. Upgrade of this route would provide those located south of the Molonglo River with a route to self-evacuate during minor flooding events. It should be noted that in larger events Foxlow Street will be inundated and evacuation along this route will not be possible.

It is noted that roads outside of the study may also be flood affected during storm events, so that even if roads within the study area are flood free, access may still be lost between adjacent townships.

Table 11-1 Road Overtopping

Design Event (AEP)	Foxlow Street / Jerangle Road - Molonglo River			Foxlow Street - Kerrs Creek		
	Time to road overtopping (hours)	Duration of overtopping (hours)	Peak overtopping depth (m)	Time to road overtopping (hours)	Duration of overtopping (hours)	Peak overtopping depth (m)
20%	6.5	3	0.54	3.5	8	0.36
10%	7	8.5	0.64	5.5	6	0.39
5%	5.5	7.5	0.77	3.5	6.5	0.43
2%	4.5	8.5	0.90	3	6	0.46
1%	4	9	1.0	2.5	6.5	0.50
0.5%	4	9	1.1	2	7	0.52
PMF	0.5	>12	3.6	0.5	>12	1.9

11.3.2 Driving Condition Analysis

Movement during a storm event is likely to be undertaken by car, or similar vehicle. The safety of operating such a vehicle needs to be determined if movement options are to be recommended.

During an extreme rainfall event, the intensity of rainfall as well as other factors (such as wind and debris), would make driving either difficult or potentially more dangerous than sheltering in place. These factors would not be unique to a floodplain, and would be equally as dangerous if an extreme event were to occur in any location. It would be expected that the risk to life of driving in these conditions would increase with lower frequency rainfall events.

A review was therefore undertaken on driver safety related to rainfall events.

A study into rainfall effects on single-vehicle crash severities based on an analysis of crash and traffic data for the Wisconsin, USA area for the period 2004-2006 found that rainfall events with a mean rainfall intensity of 3.16 mm/hr resulted in an increased likelihood of crashes ranging in severity from fatal to possible injury (Jung, Qin, & Noyce, 2009).

An analysis of data for the cities of Calgary and Edmonton, Canada during 1979-1983 concluded that the overall accident risk during rainfall conditions was found to be 70% higher than normal (Andrey, 1993).

Andreescu and Frost (1998) in an analysis of data for Montreal, Canada 1990-1992, found that a best fit line of data found a linear increase in number of accidents in relation to increased daily rainfall intensity (mm/day). This is reproduced in **Figure 11.2**. It is noted that there is significant scatter in the source data and that the correlation is relatively low. However, the data does demonstrate a link between daily rainfall and accidents.

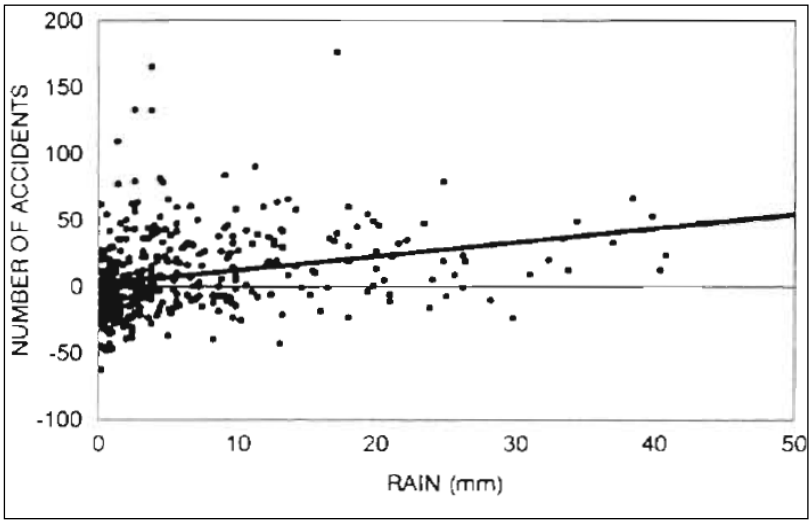

Figure 11.2 Accidents per day vs daily rainfall (Andreescu & Frost, 1998)

The NSW Governments Roads and Traffic Authority (RTA) *Road User's Handbook* (2010) states that "Driving during extreme weather events or conditions should be undertaken with care and caution. Driving should be avoided in extreme conditions."

The rainfall intensity temporal distribution for the 1% AEP 9 hour event is shown in **Figure 11.3**. It is noted that these are exclusive of climate change impacts on rainfall intensities.

The figure shows that rainfall intensities are generally greater than 10mm/hr, with peaks of 13mm/hr, 21mm/hr and 15mm/hr at 3 hours, 5 hours, and 5.5 hours into the storm respectively.

The literature evaluated does not give a definitive threshold of rainfall intensity for which unsafe driving can be expected (with the exception of Jung (2009) which suggests a very low intensity of only 3 mm/hr, which can be expected in relatively frequent events).

However, average rainfall intensities for the 1% AEP 9 hour event are well in excess of the values identified in the literature as beginning to have an effect on driving risk.

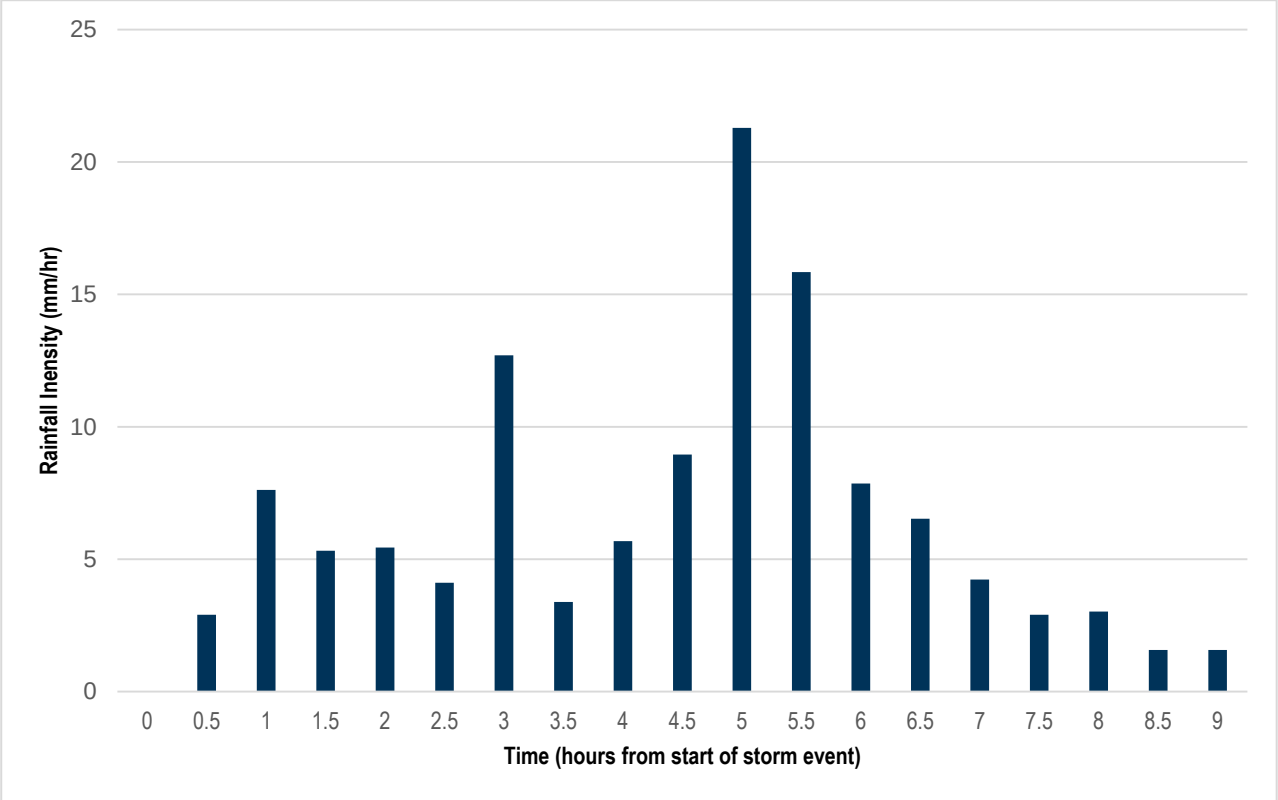

Figure 11.3: Captains Flat 1% AEP 9hr Temporal Rainfall Distribution

From the above, it is not recommended that people attempt to drive during a significant rain event. As the most intense rainfall will be associated with short duration storms, the safer option is to wait for the rain to lessen before attempting to drive. During longer duration events where flood warning may be possible, the rainfall intensity will be reduced, and may allow evacuation whilst the rain is falling. However, in general, it is recommended that driving not be undertaken during intense rainfall periods unless there is a risk to life at the property resulting from rising flood waters.

11.4 Flood Emergency Response

11.4.1 Flooding Behaviour

Flood behaviour with the study area is geographically diverse, depending on the watercourse that causes the flooding. Discussed below are the flooding behaviours of the major flowpaths within the study area.

11.4.1.1 Molonglo River

The Molonglo River is the major flowpath in the study area. It runs through the south western region of the study area, flowing north from Captains Flat Dam, along the eastern side of a number of residential properties. It passes under Foxlow Street, alongside a region of open space, before passing under Captains Flat Road and continuing to the north.

It is a high hazard flow path, due to both depths and velocities, which reach 3.8m and 5m/s in the 1% AEP event.

In events as small as the 20% AEP event, the river breaks its banks on the western side and inundates a number of private lots. The depth and extent of this breakout flow increases for larger events.

The Molonglo River also causes road overtopping, particularly in the vicinity of the Foxlow Street Bridge. This overtopping was found to occur in all design events (refer **Section 11.3.1**).

11.4.1.2 Keatings Collapse

Keatings Collapse is a steep narrow gully that joins with the Molonglo River via a pipe under Jerangle Road 200m downstream of the Dam. In events larger than the 2% AEP event, flows from Keatings Collapse overtop Jerangle Road due to insufficient capacity of the pipe. This flow proceeds north and east along Foxlow Street before crossing through a number of properties into the Molonglo River.

This overtopping flow is typically less than 0.3m even in large events.

Flow within Keatings Collapse is high hazard; however, the overtopping flows are low hazard. The high hazard regions only affect bushland or open space.

11.4.1.3 Kerrs Creek

Kerrs Creek runs from the south east of the study area, through residential areas, before being directed to a piped reach at Foxlow Street, which carries the flow past the swimming pool and discharges into the Molonglo River.

In events larger than the 20% AEP event, the flow overtops Foxlow Street where it transitions to the piped reach.

A portion of the flow breaks out of the creek at the pedestrian bridge at Wilson Road. This flow moves west along Kurrajong Street, crosses Foxlow Street, before draining into the Molonglo River.

The flowpath results in flooding of residential lots between Kurrajong Street and Wattle Avenue. The creek flow and Kurrajong Street flows are high hazard, though all property flooding is low hazard.

11.4.1.4 Town Creek

Town Creek is an informal open channel that runs behind properties on the western side of Foxlow Street, north of the Captains Flat Road intersection. The flowpath drains the hills on the east and west of the study area to the Molonglo River. The flowpath inundates a number of properties adjacent to it. However, the flows are shallow and slow moving, and the flowpath is classified as low hazard.

11.4.2 Catchment Response Time

The Australasian Fire and Emergency Service Authorities Council (AFAC) define flash flooding as:

> *Flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity.*

Within the Captains Flat study area, all major flowpaths experience flooding that results in road overtopping or property inundation within 6 hours. The subcatchment with the longest critical duration, the Molonglo River, reaches peak flooding 5.5 hours after the storm commences.

Therefore, for the purposes of considering response to flooding in this study it is concluded that the rate of rise for all floodplains within study area can be classed as flash flooding.

Flash flooding poses flood risk with regards to responding to flooding. The available response time is likely to be in the scale of hours, or in many cases sub-hourly, placing more emphasis on the ability to evacuate compared to shelter-in-place as a flood response strategy.

11.4.3 Flood Warning

There is no official flood warning system currently available for the catchment. Furthermore, the catchment is susceptible to flash flooding, meaning that the effectiveness of warning systems are limited due to the relatively short interval between the peak of the flood and the causative rain. However, sources of real-time flood intelligence during times of flooding are:

- Bureau of Meteorology (BoM), and
- State Emergency Service (NSW SES).

Warnings are provided as:

- BoM Flood Watches: NSW SES Flood Bulletins are issued by the Southern Highlands NSW SES Region Headquarters to various media outlets and agencies each time the BoM issues a Flood Watch.
- BoM Severe Weather Warnings: For the management of coastal erosion and inundation, BoM will issue Sever Weather Warnings to the NSW SES, radio stations and other organisations prior to and during potential and actual coastal erosion events.
- NSW SES Livestock and Equipment Warnings: following heavy rain, or when there are indications of significant creek or river rises, the NSW SES Local Operations Controllers will advise NSW SES Region Headquarters which will issue NSW SES Livestock and Equipment Warnings.

- Evacuation Warnings by radio, door-knocks and telephone.

An option assessed as part of this study was the installation of a flood warning system tied to a water level gauge installed on the Molonglo River downstream of the dam. Having the gauge located in the township reduces the warning time available compared to upstream gauges, but it ensures that warning of township flooding is given regardless of where the rainfall event occurs throughout the upstream catchment.

The trigger level adopted should be determined in consultation with the community. Lower trigger levels will provide more warning time, but will result in the alarm being triggered more frequently. Given the relatively short evacuation distances required (as all evacuation will be local, within the township), significant warning times are not required.

As a starting point for discussion with the community, a trigger level set just prior to the Molonglo River breaking its banks at the Foxlow Street Bridge would provide 30 minutes warning before access to Foxlow Street was lost for properties immediately upstream of the bridge. Properties located further upstream would have a warning time of approximately 1 hour before their access to Foxlow Street was lost.

11.4.4 Flood Response

The study area is largely characterised by a quick flood response to rainfall. This limits the options available to the community. The options available may be broadly grouped into local evacuation and shelter in place.

To minimise the flood risk to residents, it is important that properties have provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people within the floodplain:

- Shelter-in-place: The movement of residents to a building that provides vertical refuge on the site or near the site before their property becomes flood affected; and,
- Evacuation: The movement of residents out of the floodplain before their property becomes flooded.

Each of these options have particular requirements given the nature of flooding within the study area, and associated advantages and disadvantages. Each option is discussed below.

11.4.4.1 Shelter in Place

The use of shelter in place requires a place within the building to be above the PMF level. Given the significant difference between the PMF and the other design events, a key concern with the use of shelter in place within Captains Flat is that it would require buildings to be constructed with 2 storeys, in order to ensure that the top flood is above the PMF. The top flood may be a loft or attic space rather than a complete floor. Such a space would have to accessible during a flood event, which would necessitate safe, flood proof internal access.

The primary advantage of shelter in place is that it does not require any special understanding of flood response on behalf of the residents. People would naturally move higher in the property as flood levels raise. Shelter in place does however result in people becoming isolated during flood events, which create risks around reaching people in case of medical emergencies during flood events.

It should be noted that shelter in place would only be suitable for new buildings. Existing properties that are flood effected would not be able to adopt a shelter in place response to flooding as many do not have habitable space above the PMF level.

Controls to achieve shelter in place for new developments would require Council to be able to enforce flood related development controls outside of the flood planning area, which would require special approval under PS 07-003.

Existing properties for which shelter in place may be feasible (habitable floor levels above the PMF flood level) are shown in **Figure 11-1**.

NSW SES have expressed concerns about the use of shelter in place in the use of this and several other floodplain risk management plans. Their concerns relate to the safety of residents during the flood, with the potential for medical emergencies, fire and structural deficiencies in the building leading to increased risk of death or emergency response by SES. NSW SES does not support the use of shelter in place.

11.4.4.2 Evacuation

The two key requirements for an evacuation strategy are appropriate prior warning to allow evacuation, and a safe refuge to evacuation to.

At present, the community does not have sufficient warning time to allow evacuation. The first knowledge many will have of flooding will be inundation of their property, by which time either access from their property, or access to the refuge, may be lost.

Unlike shelter in place that would require significant redevelopment to existing properties in order to be effective, evacuation could be facilitated for existing properties by ramps or regraded front yards, in order to provide rising access from flood affected properties.

As evacuation will be undertaken on a local scale, significant warning time would not be required, as residents will be able to evacuate relatively rapidly. A warning time of 30 to 60 minutes would give residents sufficient time to relocate some household objects, pack some belongings, and walk to the refuge centre. This warning could be provided by a warning linked to a water level gauge on the Molonglo River (refer **Section 13.5**).

In order for an evacuation strategy to be effective, a flood refuge would need to be constructed somewhere in the township that is above the PMF level, and of a suitable size to shelter those residents whose properties are flood affected in the PMF event.

In the case of Captains Flat, multiple shelters would be required as road inundation results in the township becoming fragmented during flood events. In order for all residents that experience overfloor flooding in the PMF to have access to a flood shelter, three shelters would need to be provided within the township. The location of properties within each of these evacuation regions is shown in **Figure 11-1**.

Flood shelters may be existing buildings, or be newly constructed buildings for the purpose of flood refuge. The local primary school could serve as a refuge for those properties north of Kerrs Creek. New shelters would need to be

constructed outside of the PMF flood extent for the remaining two evacuation regions. The location of the school, as well as possible locations for new evacuation centres, are shown in **Figure 11-1**.

For the Molonglo River evacuation area, it would be advised to construct the shelter on Miners Road, rather than Jerangle Road if possible. It was shown in the 2010 event that flows from Keatings Collapse can overtop Foxlow Street before the Molonglo River rises, which may restrict residents' ability to evacuate to a refuge south of Keatings Collapse on Jerangle Road.

11.5 Recovery

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long term welfare of the affected community. However, the immediate action is likely to be undertaken by the NSW SES Local Controller.

12 Community Education and Awareness

Community awareness of flood behaviour and flood risks is essential to minimise risk to life during flood events. An aware and educated population will be able to respond to flood events quickly and appropriately, reducing risks to themselves, their property and to others.

12.1 Current Community Awareness of Flood Behaviour and Risk

Community consultation (refer **Section 4**) has been undertaken throughout this study through:

- A questionnaire that was distributed to residents at the commencement of the study that collected information on respondents' history, awareness and expectations of flooding; and,
- Community workshops held at key stages of the study.

The questionnaire results showed that 86% of respondents were living in Captains Flat at the time of the 2010 flood event. However, the questionnaire and further discussions at the community workshops, revealed that the community felt that the 2010 flood event was a significant and rare event. The 2010 event was in the order of a 5% AEP, so was not a particularly large or rare event.

This highlights that while the community are aware that the local rivers and creeks are subject to flooding, and that there is a flood risk within the study area, they are underestimating the severity of this risk to people and property.

It is an advantage that the community understands that flooding will occur along the rivers and creeks within the study area. The key aim of education and awareness actions is to build on this understanding in order to develop within the community an awareness of the severity of possible future flooding, so that community flooding expectations are more closely aligned with the actual flood risks and impacts of future flood events.

12.2 Building Community Awareness

Discussed below are strategies that may be implemented to raise community knowledge and awareness of flooding within the study area.

12.2.1 Short Term

12.2.1.1 Targeted Correspondence with High Risk Properties

The investigations undertaken as part of this study have shown that properties upstream of the Foxlow Street Bridge are at particular risk in flood events. These properties begin to experience high hazard flows and loss of access in the 5% AEP, and have peak flood depths of over 3.5m in the PMF. It is recommended that these properties be contacted following the adoption of this study in order to inform them of the outcomes, and what these outcomes mean for residents. It is suggested that part of the correspondence include:

- A summary of peak flood levels for properties for the design events, along with the level observed in the 2010 event for comparison,

- A summary of flood timings for their region, noting that there will be very little warning of imminent flooding,
- Direction to the NSW SES FloodSafe resources; and,
- Contact details for sources of additional information.

The purpose of this initial correspondence would be begin a discussion with these high risk residents, to assist them in understanding the flooding risks in their location and to guide them in developing a personal flood plan.

12.2.1.2 Develop a Post-Flood Data Collection and Mail-out Strategy

The collection of post-flood data was recommended as part of the Captains Flat Floodplain Risk Management Study. In addition to this, it is recommended that the data collected be expanded to create information that will help the community to better understand the flood event and general catchment flood behaviour. This may include the collection / determination of data such as:

- The approximate recurrence internal of the rainfall intensity and peak river / creek flows;
- The approximate recurrence interval of any major overground flooding;
- A comparison of the storm event with previous historical events and design events. Comparison could be made against rainfall, flows or depths;
- Timings of peak flows or levels; and,
- The timing and duration of road overtopping / closures.

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 1% AEP or PMF event, would give them a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event.

12.2.2 Medium Term

12.2.2.1 Flood Height Indicators within the Study Area

A recommendation of this study is to place flood depth markers at key flooding locations, such as the Foxlow Street Bridge (refer **Section 13.5**). In order to further increase the flood information conveyed from these markers, it is recommended that the flood height of the 2010 event be marked, along with the design flood event heights. The purpose of these markings would be to demonstrate to the community both the relatively size of the 2010 event, as well as the flood depths that can be expected in large flood events.

Similar markings could also be applied to telegraph poles or the entrance to the community centre, either in addition to the flood depth markers, or in the interim before the markers are installed.

The height markings would serve as a visual aid to assist the community in understand the significant flood heights that occur along the Molonglo River during large flood events.

12.2.2.2 Develop a Flood Information Package for New Residents

The documents prepared for the Flood Safe initiative will provide new residents an introduction to flood behaviour and risks within the study area. It is recommended that an information package be distributed to new residents that contains a short letter from Council discussing the current flood management program, the flood safe documents, links to further information, and contact details of Council staff should they have any further queries or concerns.

12.2.2.3 Develop FloodSafe Brochure and FloodSafe Toolkit

The NSW SES has developed Local FloodSafe Guides, which give specific information for areas at risk of floods. These guides are produced in collaboration with Council and regional and local NSW SES units. The NSW SES recommends that these guides are reviewed every 5 years.

The NSW SES has also prepared templates allowing Local Guides to be prepared for individual regions. Different guides may be prepared for general township flooding, flash flooding and rural flooding. Development of the forms can be organised through contacting the NSW SES.

The NSW SES FloodSafe website (www.floodsafe.com.au) also allows for the creation of personal plans and business plans. Variations of plans are also available for riverine and flash flooding regions. It is recommended that a reference to this tool be made in the FloodSafe Guide to make residents and owners aware of this tool, and that residents and business NSW SES are encouraged to prepare a personal or business plan.

12.2.2.4 Hold a FloodSafe Launch Event

Following the development of the FloodSafe documents, a public launch may be held to inform the community of the availability of this material and to provide an opportunity for the community to discuss flooding issues with Council and NSW SES.

12.3 Triggers for Education & Awareness Actions

12.3.1 Actions resulting from a large flood event

Immediately following a large flood event is a good time to encourage residents to take an interest in flood behaviour in the catchment. At this time many residents actively seek flood information on the event and general flood behaviour. This should also be seen as an opportunity to encourage residents to develop personal flood response plans with the flood event still clear in their minds.

It is recommended that the following actions be undertaken following a large flood event in the catchment:

- Undertake the post-flood data collection;
- If mitigation strategies have been adopted, asses their effectiveness in the flood event;

- Prepare the post flood mail-out for the event; and,
- Undertake the post flood mail-out to inform residents about the recent flood.

12.3.2 Actions resulting from a Period of 5 years without a large flood event

After a period of time without a large flood event, there is a risk that community flood awareness will begin to fall.

As such, it is recommended that if a period of five years elapses without a large flood event, a community mail-out be undertaken to inform / remind residents of flood risks within the catchment.

This mail-out may include a short letter from Council detailing the reasons for the mail-out and discussing historical flood events, the FloodSafe brochures, any previous post-flood mail-out forms, and links to other information sources.

The aim of this exercise is to ensure that residents remain aware of both flood risks within the catchment and appropriate risk management actions to take in flood events.

13 Floodplain Risk Management Measures

Flood risk can be categorised as existing, future or residual risk:

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding
- **Future Flood Risk** – buildings and developments that may be built on flood prone land, or on land that may become flood affected in the future. Such buildings and developments would be exposed to a flood risk when they are built
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it will be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 13-1**.

Table 13-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding
Transferring risk	Via insurance – may be applicable in some areas depending on insurer
Financing risk	Natural disaster funding
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management;

- **Flood modification measures** – Flood modification measures are structural options aimed at preventing / avoiding or reducing the likelihood of flood risks through modifying the flood behaviour
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks through modifying the way the community and emergency services respond during a flood event

13.2 Base Case

In order to assess the various mitigation options, it is necessary to define a base case. This base case provides a reference against which the effectiveness of various options can be assessed.

In this case, the base case is the existing Captains Flat catchment, as defined in the Flood Study (Cardno, 2013).

13.3 Flood Modification Measures

Based on the flood model results, historical information, community feedback and engineering judgement, possible flood modification options (i.e. structural options) for the study area were identified. These options are outlined in **Table 13-2** and shown in **Figure 13-1**.

These options were discussed with the community at the first community workshop. Following these discussions, a number of options were developed for assessment with the hydraulic flood model.

These options are summarised in **Table 13-3**.

Table 13-2 Captains Flat Flood Mitigation Options

Option ID	Option	Details	Expected Benefit	Major Constraints	Assess in Hydraulic Model?
Drainage Augmentation These options primarily focus on increasing capacity and efficiency of culverts throughout the study area. It is noted that for modelling purposes, it was generally assumed that the existing pipe would be duplicated, or doubled in capacity. This could be optimised during the detailed design process.					
D.1	Keatings Collapse Culvert Upgrade	Augmentation of culvert draining Keatings Collapse under Jerangle Road.	Prevention / reduction of overtopping flows from Keatings Collapse over Jerangle Road.	No major constraints. Effectiveness may be limited by downstream conditions in the Molonglo River.	Yes
D.2	Kerrs Creek Culvert Upgrade	Augmentation of culvert draining Kerrs Creek under Foxlow Street.	Prevention / reduction of overtopping flows from Kerrs Creek over Foxlow Street.	No major constraints. Effectiveness may be limited by downstream conditions in the Molonglo River.	Yes
D.3	Town Creek Pipe	Construction of a piped system for Town Creek.	Removal / reduction in property flooding along the Town Creek Reach.	Would require works on private property. Would require inlets located within private property.	Yes
D.4	Kerrs Creek Bridge Upgrade	Upgrade of Wilson Road Pedestrian Bridge over Kerrs Creek. Works would lift and widen bridge to reduce channel restrictions at this location.	A reduction in peak flood levels and overbank flows upstream of the structure.	No major constraints.	Yes
D.5	Foxlow Street Bridge Upgrade	Upgrade of Foxlow Street Bridge over Molonglo River. Works would lift and widen bridge to reduce channel restrictions at this location.	A reduction in peak flood levels and overbank flows upstream of the structure.	Extent of raising and widening possible may be limited by adjacent road ways.	Yes
D.6	Blockage Control for Structure	Provision of blockage control structures on the Foxlow Street bridge and Wilson Road bridge, in order to improve flow conveyance.	A reduction in peak flood levels and overbank flows upstream of the structure.	Space may be limited for a structure on Kerrs Creek. No major constraints for the Foxlow Street Bridge.	Yes
Detention Basins These options propose to create detention basins upstream of flooding issues to detain flood waters and release them in a controlled manner					
B.1	Kerrs Creek Basin	Construction of a detention basin on Kerrs Creek, at the end of Kurrajong Street.	Reduction in peak flood levels downstream through residential properties along Kerrs Creek.	No major constraints.	Yes
B.2	Dam as a Basin	Use of Captains Flat Dam as a flood mitigation structure.	Reduction in peak flood levels downstream.	Assessed in flood study - dam has insufficient capacity to influence downstream flooding.	No
B.3	Dam Augmentation	Increase capacity of Captains Flat Dam.	A reduction in downstream peak flood levels, as a result of detention within the dam.	Given previous assessment, storage increases would likely need to be substantial to have any affect.	No

Option ID	Option	Details	Expected Benefit	Major Constraints	Assess in Hydraulic Model?
Channel Works These options are focused on improving the efficiency or increasing the capacity of channels within the study area.					
C.1	Vegetation Management	Vegetation management along Molonglo River and Kerrs Creek. Would involve removal of debris, clearing of invasive species and bank stabilisation.	Improved conveyance of the channels, with a reduction in overbank flows.	No major constraints.	Yes
C.2	Molonglo River regrading	Widening and deepening of Molonglo River. Widening may be restricted to downstream of Foxlow Street bridge given existing development.	Improved conveyance of the channels, with a reduction in overbank flows.	Possible environmental constraints. Would also require widening the Foxlow Street bridge.	Yes
C.3	Town Creek Formalisation	Formalisation of Town Creek. May also include relocation to the rear of properties.	Removal / reduction in property flooding along the Town Creek Reach.	Would require works on private property.	Yes
C.4	Kerrs Creek Regarding	Regrading of Kerrs Creek from Culpepper Lane to Foxlow Street to provide additional channel capacity and to prevent further erosion of channel.	Improved conveyance of the channels, with a reduction in overbank flows.	Possible environmental constraints. Would require works on private property.	Yes
Road Raising These options primarily focus on increasing capacity and efficiency of culverts throughout the study area. It is noted that for modelling purposes, it was generally assumed that the existing pipe would be duplicated, or doubled in capacity. This could be optimised during the detailed design process.					
R.1	Foxlow Street Raising	Raising of Foxlow Street at Kerrs Creek culvert to provide flood free access in the 1% AEP event.	Allows emergency access and evacuation in the 1% AEP event.	May also require upgrading culvert under road to prevent ponding behind raised road.	Yes
R.2	Jerangle Road Raising	Raising of Jerangle Road alongside the Molonglo River, up to the Foxlow Street Bridge, to provide flood free access in the 1% AEP event.	Allows emergency access and evacuation in the 1% AEP event.	Requires substantial raising, up to 1m in some locations, which is unlikely to be possible given existing development. Could be considered as part of post-flood reconstruction.	No
Lot Filling These options focus on lifting the terrain above the peak flood levels so that any development on the lot is flood free					
F.1	Jerangle Road Lot Raising	Filling of properties on the west side of Jerangle Road along the Molonglo River to the FPL height.	Would protect these properties from flooding in events up to the 1% AEP event.	Would also require the raising of Jerangle Rd to provide access during flood events. Not feasible with current development. May be considered as part of post-flood reconstruction.	No

Table 13-3 Preliminary Options for Assessment

ID	Option	Option Details	Changes to Hydraulic Model
FM 1	Drainage upgrade	Augment culverts at Keatings Collapse and Kerrs Creek, and pipe town creek.	Double capacity of culverts, assume by adding additional pipe, therefore blockage remains the same.
FM 2	Structure upgrade	Increase capacity and install blockage control devices on the Foxlow St Bridge and the Kerrs Creek Bridge.	Where possible, the bridges will be widened. Blockage rates will be reduced to account for the control structures.
FM 3	Detention Basin	Construct a detention basin on Kerrs Creek upstream of the Township.	A basin will be placed on the upstream reach of Kerrs Creek. The basin extent will be restricted to available open space. A typical depth of 1.2m will be adopted with 1 in 6 sides to allow a grassed basin.
FM 4	Vegetation Management	Undertake vegetation management (debris clearing, weed removal, bank stabilisation) along the Molonglo River and Kerrs Creek. Assume works will reduce blockages on culverts and bridges.	The roughness values along the reaches will be reduced to reflect the new river and creek state. The blockage rates on downstream culverts and bridges will be reduced to account for the reduced sediment and debris load.
FM 5	Channel works	Regrade, widen and deepen (if possible) the Molonglo River, regrade Kerrs Creek and formalise the Town Creek.	The Molonglo River sections will be adjusted to increase the river capacity. Foxlow St bridge will also be widened but retain the same blockage rates. Changes will be dependent on local topography. Kerrs Creek will be regraded to provide a constant grade from Culpepper Lane to Foxlow Street. A typical trapezoidal channel will be used to formalise town creek.
FM 6	Road Raising	Raise the levels of Foxlow Street in the vicinity of Kerrs Creek to prevent overtopping in the 100yr ARI event.	The road levels will be lifted to be 0.2m above the 100yr ARI flood level.

13.3.2 Preliminary Option Assessment

To test the feasibility of each of the hydraulically assessed structural options, they were first run for the 10% AEP and 1% AEP events to ensure they worked as expected and did not result in adverse flooding behaviour. The results of this analysis are summarised below in **Table 13-4**. The table summarises the outcome of the 10% and 1% AEP runs, and whether the option should be considered for further analysis. Impact plots for the 1% AEP have been prepared for each option, and the figure numbers are shown in the table.

Table 13-4 Preliminary Options Assessment Outcome

ID	Assessment Outcome	Suitable for further assessment?	1% AEP Impact Figure
FM 1 Drainage Upgrade	Levels along the lower reaches of Town Creek were reduced by up to 0.35m. Upstream reaches had smaller reductions in the order to 0.03 – 0.05m. Upstream of the Foxlow Street culvert on Kerrs Creek, peak levels were reduced by 0.08m. Reductions did not extend significantly upstream. Reductions were also observed downstream of both Kerrs Creek and Town Creek. These reductions were due to the peak flows being slightly shifted for both systems to that they were no longer coincident.	Yes	13-2
FM 2 Structure Upgrade	Reductions observed immediately upstream of the Foxlow Street Bridge of 0.27m in the 1% AEP. Reductions of more than 0.1m extended for 75m upstream of the bridge. Peak water levels increased downstream as a result of increased capacity. Increases occurred on open space and do not impact properties. Only a small region of changes were observed around the Kerrs Creek pedestrian bridge.	Yes	13-3
FM 3 Detention Basin	Minor reductions across developed properties of less than 0.05m in the 10% and 1% AEP. Increases within Kerrs Creek and on some adjacent properties as a result of the basin overtopping when full. Overall, not very successful in reducing flood levels for properties.	No	13-4

ID	Assessment Outcome	Suitable for further assessment?	1% AEP Impact Figure
FM 4 Vegetation Management	Peak water levels along the Molonglo River showed reductions of 0.12m immediately upstream of the Foxlow Street bridge, although 0.02 – 0.05 reductions were typical along the upstream river. From the community consultation workshop, the vegetation management was extended to include Kerrs Creek.	Yes	13-5
FM 5 Channel Works	Reductions were observed along the Molonglo River between the dam and the Foxlow Street bridge of typically 0.15 to 0.2m. At Keatings Collapse, these reductions were up to 0.36m. Reductions were also observed on Kerrs Creek, though of a smaller magnitude; up to 0.05m.	Yes	13-6
FM 6 Road Raising	The increased culvert capacity was insufficient to offset the detention behaviour of the raised road. Flood levels across properties on Foxlow Street increased by up to 0.5m. Increased levels also extended up Kerrs Creek.	No	13-7

13.3.3 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works which applies to most of the flood mitigation options in **Table 13-4**. Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors.

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

- Flood mitigation works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997,
- Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999,
- A licence to harm threatened species, population or ecological community or damage habitat under the Fisheries Management Act 1999.

13.4 Property Modification Options

A number of property modification options were identified for consideration for implementation in Captains Flat. These options fall into two categories; those for which OEH support is available, and those which would be required to be implemented fully by Council.

Options for which funding may be available from OEH are:

- House Raising
- Voluntary Purchase

Details of the OEH grants available may be found at: www.environment.nsw.gov.au/coasts/Floodgrants.htm
Additional property modification options that may be pursued by Council are:

- Building and Development controls
- House Rebuilding
- Land Swap
- Council Redevelopment
- Flood Proofing

Of these options, those that were found to be suitable for Captains Flat were:

- Voluntary Purchase;
- Building and Development Controls; and,
- Flood proofing.

Further information on the reasons for the other options being considered unsuitable for Captains Flat are provided in **Appendix B**.

13.4.1 P 1 – Voluntary Purchase

Voluntary purchase is a scheme where by the affected property is purchased by Council. Council would then demolish the building and re-zone the land to a more flood appropriate zone. It is an option of last resort, and would be undertaken to remove residents and properties from high risk locations for which other structural and property modification options are not feasible.

OEH has prepared the *Guidelines for voluntary purchase schemes* (OEH, 2013) to assist in determining when and where voluntary purchase schemes may be suitable. The guideline recommends that voluntary purchase be considered where:

- There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers;
- A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function; and/or

- Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

Within the Captains Flat Township, the first scenario of highly hazardous conditions make voluntary purchase a suitable option for those properties located along the eastern side of Foxlow Street, adjacent to the Molonglo River. Properties immediately upstream of the Foxlow Street Bridge begin to be affected by high hazard flows and loss of access in the 20% AEP. All properties adjacent to the Molonglo River are affected by high hazard flow and loss of access in the 5% AEP event.

While some structural options were found to reduce peak flood levels for these properties (refer to **Section 13.3**), none of the structural options investigated were able to substantially reduce the flood hazard of this area, with residual flood depths of 0.9m occurring across these properties in the 1% AEP event even with structural options in place. The structural options also had a limited benefit in the PMF, which results in flood depths for these properties of 3.5m.

Participation of residents in the scheme is entirely voluntary. It is understood from the consultation process that current support for voluntary purchase by the community is limited. It is likely that a part of this limited support is that the community is underestimating the flood risk of the township, given that the community has not experienced a significant flood event in recent memory.

It is recommended that following this study that a letterbox drop or similar be conducted for properties along Foxlow Street, adjacent to the Molonglo River to:

- Highlight the highly hazardous nature of flooding along the Molonglo River and to provide residents with the peak flood depths for the 1% AEP and PMF events; and,
- Ask the residents if they would be interested in participating in a voluntary house raising scheme.

It is not expected that residents would be amenable to the scheme at this time. However, support may change in the future following a large flood event that highlights to the community the flood risks of this region. If the scheme gains future support, it is recommended that initial priority be given to those properties closest to the Foxlow Street Bridge, as they are the first to be affected by high hazard flooding and loss of access.

13.4.2 P 2 – Building and Development Controls

The key document for flood related controls in the Palerang LGA is DCP2015 Section B9, and recommended updates to this document are discussed in **Section 9.3**.

13.4.3 P 3 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce the damage caused to the property by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

- All structural elements below the flood planning level shall be constructed from flood compatible materials
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the flood planning level

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties. It is noted that there are 3 commercial / industrial properties that experience flooding in the 5% AEP event or greater.

These measures should be carried out according to a pre-arranged plan. These measures may include:

- Raising belongings by stacking them on shelves or taking them to a second storey of the building
- Secure objects that are likely to float and cause damage
- Re-locate waste containers, chemical and poisons well above floor level
- Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings

The NSW SES business *Flash Flood Tool Kit* (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures. It is recommended that this tool kit is distributed to the flood affected businesses within the floodplain.

13.5 Emergency Response Modification Options

A number of emergency response modification options are suitable for consideration within the Captains Flat floodplain. These are:

- Information transfer to the NSW SES EM 1
- Flood warning system EM 2
- Public awareness and education EM 3
- Flood warning signs at critical locations EM 4
- Upgrade Miners Road EM 5

These options are discussed in detail below.

13.5.1 EM 1 – Information transfer to NSW SES

The findings of the Flood Study and the Flood Risk Management Study and Plan provide an extremely useful data source for the State Emergency Service. Transfer of the flood intelligence from this study, such as road overtopping

depths and timings, the locations of flood affected properties, and the flood behaviour of high risk regions, would be communicated to the NSW SES to assist in their flood response strategies.

13.5.2 EM 2 – Flood Warning System

There are two existing flow stations in upstream of the Township, the first at Captains Flat dam, and the second at Kobada, approximately 5km upstream**,** which may be utilised for flood warning systems.

Warnings issued from the Kobada Gauge upstream of the dam on the upper reaches of the Molonglo River catchment could provide warnings times of approximately 2 – 3 hours, depending on the trigger levels used to issue warnings. The warning time would reduce for stations located closer to the township.

However, as shown in **Section 11** events of shorter durations are still capable of causing flooding within the study area, and a flood warning system will be less effective as storm durations decrease. As a result, flood warnings from these gauges are not recommended.

It may be feasible to install a water level gauge with a warning siren on the Molonglo River downstream of the dam. The siren would be triggered when either overfloor flooding of properties or loss of access to properties was imminent. Such a warning would only allow the immediate evacuation of residents to local flood refuges. It would not provide sufficient time to move or evacuate belongings.

The community has expressed an interest in a flood warning system. Should a system be implemented, it will be important for the community to understand the operation of the system and its limitations. A key point to inform the community of will the likely frequency of warnings issued from the gauge. In order for the warning to be effective, it will need to be issued before property flooding commences. This will result in small events triggering the warning. The community will need to understand that there will be frequent false positives reported from the system, and that for the system to be effective, they will need to continue to respond to the evacuation warning, even after a number of issued warnings that were not followed by subsequent flooding.

It should also be noted that the warnings will only be applicable to flooding occurring from the Molonglo River. The smaller, local tributaries experience short duration flooding that is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

13.5.3 EM 3 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

A strategy to manage and improve public awareness and education is discussed in **Section 12**.

13.5.4 EM 4 – Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that additional depth gauges be installed at road crossings which are subject to inundation in frequent events, such as those along Foxlow Street, Jerangle Road and Captains Flat Road.

13.5.5 EM 5 – Upgrade Miners Road

A flood free access can be provided between the area of Captains Flat south of the Molonglo River and the remainder of the town. This route, via Miners Road and Captains Flat Road, is currently unsuitable for use as an evacuation route. The Miners Road section is unsealed, steep and has significant unprotected batter slopes. Upgrade of this route will provide those located south of the Molonglo River with a route to self-evacuate during minor flooding events. It should be noted that in larger events Foxlow Street will be inundated and evacuation along this route will not be possible.

This measure received strong support from the community during the consultation period and is also strongly supported by Council.

13.6 Data Collection Strategies

This would involve the preparation of a flood data collection form and the use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

14 Economic Assessment of Options

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated.

This calculation is described below.

14.1 Preliminary Costing of Options

Cost estimates were prepared for those options which allow for an economic assessment. A summary of these estimated capital costs are provided in **Table 14-1**. Details of these costings are provided in **Appendix B**.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the option, the costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

Table 14-1 Costs of Quantitatively Assessed Options

Option ID	Option	Capital Cost	Ongoing Costs
FM 1	Drainage upgrade	$3,143,300	$5,000
FM 2	Structure upgrade	$1,088,400	$15,000
FM 4	Vegetation Management	$780,000	$15,000
FM 5	Channel works	$2,523,100	$10,000

14.2 Average Annual Damage for Quantitatively Assessed Options

The total damage costs were evaluated for each of the options assessed by hydraulic modelling (quantitative assessment). The average annual damage (AAD) for each of the options is shown comparatively against the existing case in **Table 14-2**.

The results in **Table 14-2** show that the four options all resulted in relatively comparable reductions in damages. The most effective option in reducing damages was the channel works for the Molonglo River and Kerrs Creek, closely followed by the vegetation management option. Both the structure upgrade and drainage upgrade also resulted in reasonable reduction in flood damages.

Shown in **Table 14-3** is the reduction in the number of properties experiencing overfloor flooding in each AEP event for the various options. As expected from the damage reductions, the channel works and the vegetation management resulted in similar reductions. The channel works had a greater impact in the more frequent events, which is the reason for this option having a slightly higher reduction in AAD.

Also, whilst the options are successful in reducing flood levels, these reductions do not result in significant numbers of properties moving from having over-floor flooding, to no over-floor flooding. Whilst the AAD is reduced to various degrees for different options, this reduction needs to be offset against the capital and recurrent costs of the option. This is investigated below.

Table 14-2 Average Annual Damage for Quantitatively Assessed Options

Option ID	Option	AAD	Reduction In AAD Due to Option
Existing	Current study area conditions	$376,075	-
FM 1	Drainage upgrade	$249,075	$118,000
FM 2	Structure upgrade	$257,976	$109,099
FM 4	Vegetation Management	$220,051	$147,024
FM 5	Channel works	$213,489	$153,586

Table 14-3 Number (and reduction) of Properties with Overfloor Flooding under Different Options

Option	PMF	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP
Existing	102	43	37	32	22	19
FM 1	94 (8)	37 (6)	33 (4)	27 (5)	21 (1)	17 (2)
FM 2	100 (2)	37 (6)	33 (4)	28 (4)	20 (2)	14 (5)
FM 4	100 (2)	31 (12)	26 (12)	22 (10)	18 (4)	12 (7)
FM 5	100 (2)	33 (10)	28 (9)	23 (9)	17 (5)	11 (8)

14.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option.

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled options. The PMF, 1% AEP, 2% AEP 5%AEP, 10% AEP, 20% AEP and 50% AEP events were considered for this evaluation. Preliminary costs of each option were prepared and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 14-4 summarises the overall economics for each option that was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

The B/C ratio provides an insight into how the damage savings from an option relate to its cost of construction and maintenance:

- Where the B/C is greater than 1 the economic benefits are greater than the implementation costs;
- Where the B/C is less than 1 but greater than 0, there is still an economic benefit from implementing the option but the cost of implementing the option is greater than the economic benefit;
- Where the B/C is equal to zero, there is no economic benefit from implementing the option; and,
- Where the B/C is less than zero, there is a negative economic impact of implementing the option.

The benefit-cost analysis showed that the vegetation management option and the structure upgrade had ratios above 1. In the case of the vegetation management option, the benefit cost ratio was 2.1, suggesting that the option will deliver damage reductions twice as large as the construction and maintenance costs.

The channel works had a benefit cost ratio of 0.8, while the drainage upgrade had the lowest ratio of 0.5.

It should be noted that the benefit cost ratio is not the only metric by which to measure the merits of the options. As part of the Floodplain Risk Management Study, the options will be assessed using a multicriteria assessment that will also examine the social and environmental aspects of the projects. The floodplain risk management plan will also investigate property and emergency response modification options.

Table 14-4 Summary of Economic Assessment of Management Options

Option	AAD	Reduction in AAD	NPW of Benefit *	Capital Cost	Recurrent Cost	NPW of Option *	B/C Ratio	Rank
FM 1	$249,075	$118,000	$1,628,488	$3,143,300	$5,000	$3,212,304	0.5	4
FM 2	$257,976	$109,099	$1,505,648	$1,088,400	$15,000	$1,295,411	1.2	2
FM 4	$220,051	$147,024	$2,029,041	$780,000	$15,000	$987,011	2.1	1
FM 5	$213,489	$153,586	$2,119,601	$2,523,100	$10,000	$2,661,107	0.8	3

* NPW – Net Present Worth is calculated using 7% interest over 50yrs.

15 Multi-Criteria Assessment

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the *Floodplain Development Manual* (2005). This approach to assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute "right" answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion as shown in **Table 15-1**.

15.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion. The criterion adopted includes:

Economic	Benefit cost ratio
	Capital and operating costs
	Reduction in risk to property
Social	Reduction in social disruption
	Reduction in risk to life
	Community acceptance
	Council support
Environmental	Meeting of flow and water quality objectives
	Fauna / Flora

The scoring system is shown in **Table 15-1** for the above criteria.

Table 15-1 Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio	2	0 to 0.2	0.2 to 1	1	1 to 1.5	>1.5
		Capital and Operating Costs	1	Extreme >$2 million	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Very Low $10,000 - $50,000
		Reduction in Risk to Property*	1	Major increase in AAD	Slight increase in AAD	No Improvement	Slight decrease in AAD	Major decrease in AAD
Social	1	Reduction in Risk to Life	1	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
		Council Attitude	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Community support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	1	Compatible with Water Quality and Flow Objectives	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Fauna/Flora Impact	1	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit

* Values of likely AAD reduction assumed where actual assessment not undertaken

15.1.2 Economic Assessment Overview

The economic assessment involved an appreciation of:

- Benefit Cost Ratio;
- Capital and Operating Costs; and
- Reduction in Risk to Property.

Capital and operating costs for options were quantitatively assessed for the hydraulically modelled options, whilst a judgement of the likely capital and recurrent costs was made for the remaining options by experienced engineers.

It is noted that the Benefit Cost Ratio incorporates both the capital & operating costs, and the reduction in the Risk to Property. However, these are included to provide an overall measure of both the affordability of an option (the magnitude of the cost) as well as the overall benefit of the option. The Benefit Cost Ratio, while providing a representation of the economic efficiency of the option, does not provide this information.

15.1.3 Social Impact Assessment

The social impact assessment involved an appreciation of:

- Reduction in Social Disruption;
- Reduction in Risk to Life;
- Council Attitude; and
- Community Support.

In general, there is a high level of flood awareness in the community. The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

The community support for a particular option was derived by converting the community responses received in the consultation period into a numerical score. This will be updated following community workshops and exhibition of the draft report, and feedback from the community

The attitudes of Council to different options were subjectively assessed based on discussions with representatives over the course of the study.

15.1.4 Environmental Assessment

The environmental impact assessment involved an appreciation of both:

- Compatibility of the option with Water Quality and Flow Objectives, and
- Fauna/flora impact.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system.

15.2 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix C**. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 15-1**.

The overall score for the option is then calculated by the weights for each of the categories.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix C**.

Of the options investigated, the top three identified by the multi-criteria analysis were:

1. F 4 Vegetation Management
2. P 2 Building and Development Control Plans
3. P 3 Flood Proofing Guidelines

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1. FM 4 Vegetation Management
2. FM 2 Structure Upgrade
3. FM 1 Drainage Upgrade

This ranking is proposed to be used as the basis for prioritising the components of the *Floodplain Risk Management Plan*. It must be emphasised that the scoring shown in **Appendix C** is not “absolute” and the proposed scoring and weighting should be reviewed at regular intervals to ensure they are still representative.

16 Floodplain Risk Management Plan

The results of the Floodplain Risk Management Study were used to form the Captains Flat Floodplain Risk Management Plan (Cardno, 2015), which has been prepared as a supplementary document to this Floodplain Risk Management Study.

17 Conclusion

Cardno were commissioned by Queanbeyan-Palerang Regional Council to undertake the Floodplain Risk Management Study and Plan for the Captains Flat Township.

Flooding in Captains Flat can pose a hazard to some residents and properties near creeks and overland flowpaths. The purpose of this study is to identify and examine options for the management of flooding within the study area.

An assessment was undertaken on the number of properties to be affected under different frequency storm events, as well as an estimate of the appropriate economic damage for that event. The following table summarises these results.

Table 17-1 Flood affected properties and damages under existing conditions

Flood Event	Properties with Over-floor flooding	Properties with Over-ground flooding	Flood Damage
20% AEP	0	0	$0
10% AEP	19	47	$1,503,827
5% AEP	22	61	$2,184,615
2% AEP	32	72	$3,813,480
1% AEP	37	76	$4,505,429
0.5% AEP	43	84	$5,333,093
PMF	102	110	$12,071,225
Average Annual Damage			**$367,075**

Options to reduce or manage the effects of flooding in the catchment were investigated, and recommendations of a mix of strategies to manage the risks of flooding were developed.

Under the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and stakeholders, a number of potential options for the management of flooding were identified.

These options included:

- Flood modification measures
- Property modification measures
- Emergency response measures

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The assessment found, of the all the options investigated (including flood, property and emergency measures), the top three identified by the multi-criteria analysis were:

1. F 4 Vegetation Management
2. P 2 Building and Development Control Plans
3. P 3 Flood Proofing Guidelines

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1. FM 4 Vegetation Management
2. FM 2 Structure Upgrade
3. FM 1 Drainage Upgrade

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring is not “absolute” and the proposed scoring and weighting should be reviewed in light of any additional future information.

18 Qualifications

This report has been prepared by Cardno for Queanbeyan-Palerang Regional Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided.

Study results should not be used for purposes other than those for which they were prepared.

19 References

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Floodplain Risk Management Study

FIGURES

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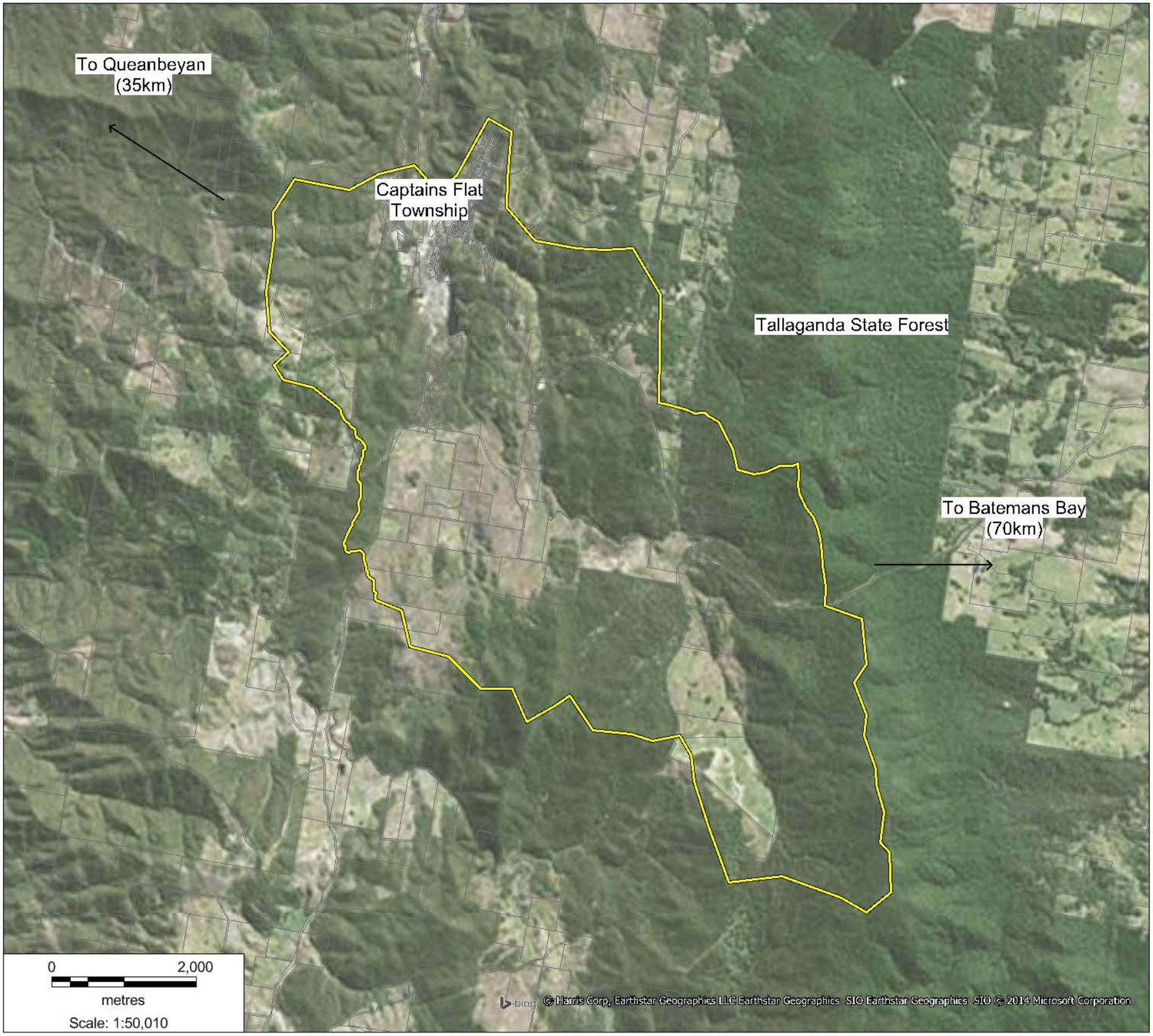

FIGURE 2-1

CATCHMENT AREA

CAPTAINS FLAT
FRMSP

Cadastre

Catchment Area

N

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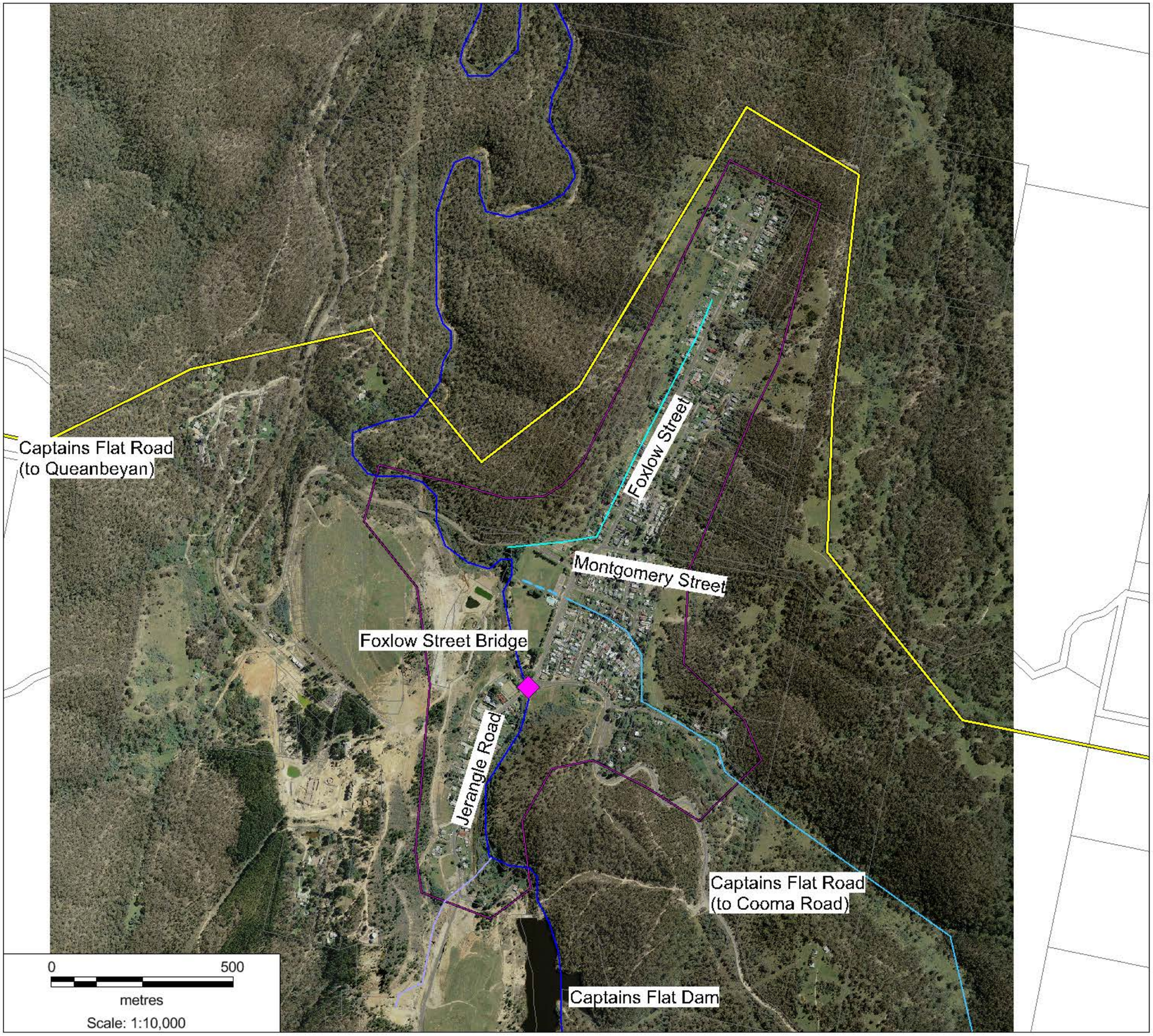
Date: December 2014
Coordinate System: Zone 56/1 ISG

FIGURE 2-2

STUDY AREA

CAPTAINS FLAT
FRMSP



- Cadastre
- Catchment Area
- Study Area
- Kerrs Creek - Piped
- Molonglo River
- Kerrs Creek
- Town Creek
- Keatings Collapse

N

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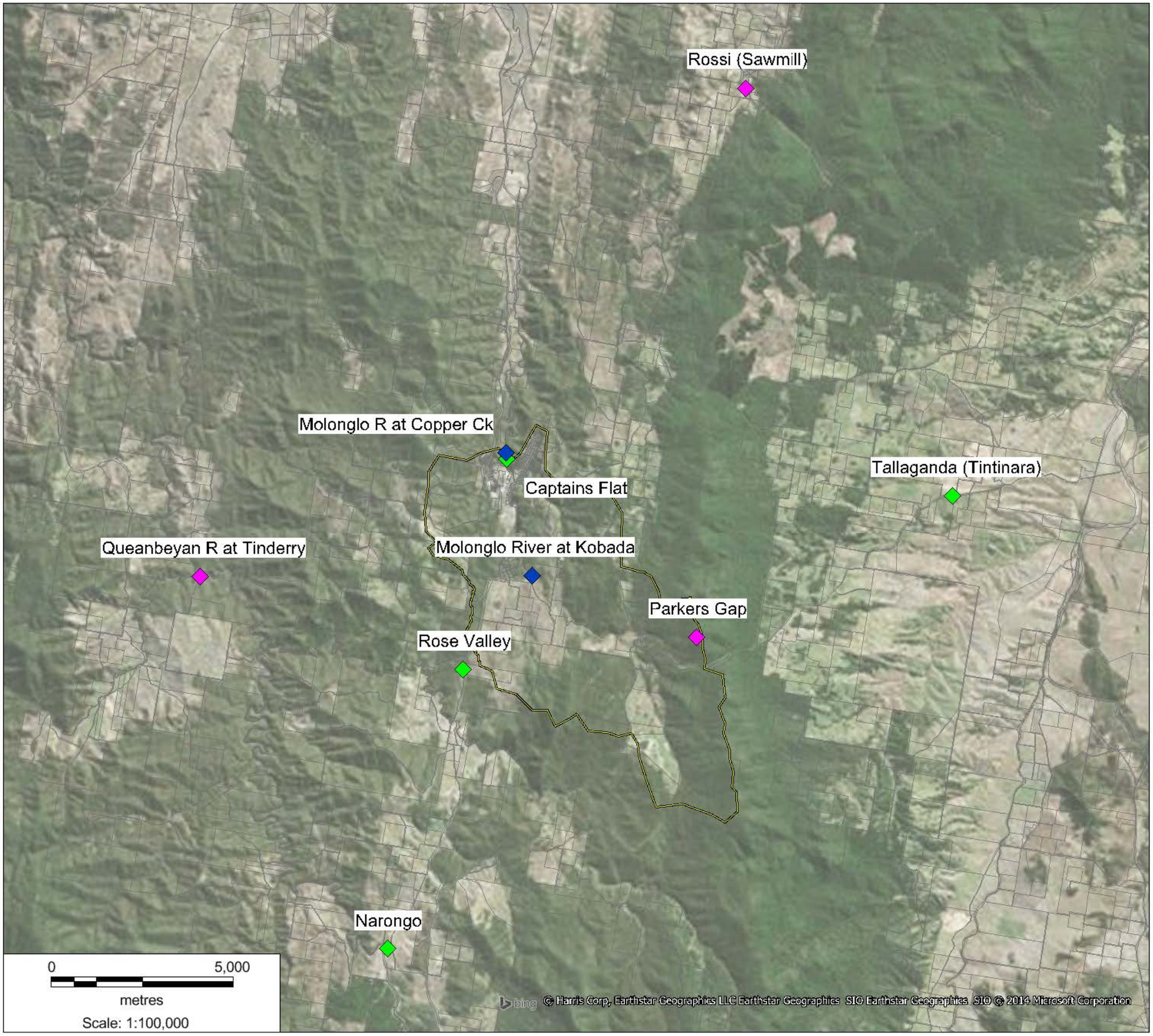

Figure 3-1

Gauge Locations

CAPTAINS FLAT
FRMSP

Cadastre
Catchment Area
Daily Rainfall
Pluviograph
River Flow

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Map Produced by Cardno NSW/ACT Pty Ltd
Date: December 2014
Coordinate System: Zone 55/1 ISG

Figure 5-1

1% AEP True Hazard

CAPTAINS FLAT
FRMSP

- Study Area
- Cadastre
- High Hazard - Depth and Velocity
- High Hazard - Flood Access
- Low Hazard
- Residual Hazard

0 500

metres

Scale: 1:10,000

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Date: July 2015
Coordinate System: Zone 55/1 ISG

Figure 5-2

PMF True Hazard

CAPTAINS FLAT
FRMSP

- Study Area
- Cadastre
- High Hazard - Depth & Velocity
- High Hazard - Flood Access
- Low Hazard

0 500
metres
Scale: 1:10,000

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Date: July 2015
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Figure 5-4

Flood Emergency Response Classification

CAPTAINS FLAT
FRMSP

Study Area

PMF Extent

Flood Emergency Response Classification

- Not Flood Affected
- Indirectly Flood Affected
- Rising Road Access
- Overland Escape Route
- High Flood Island
- Low Flood Island

0 500

metres

Scale: 1:10,000

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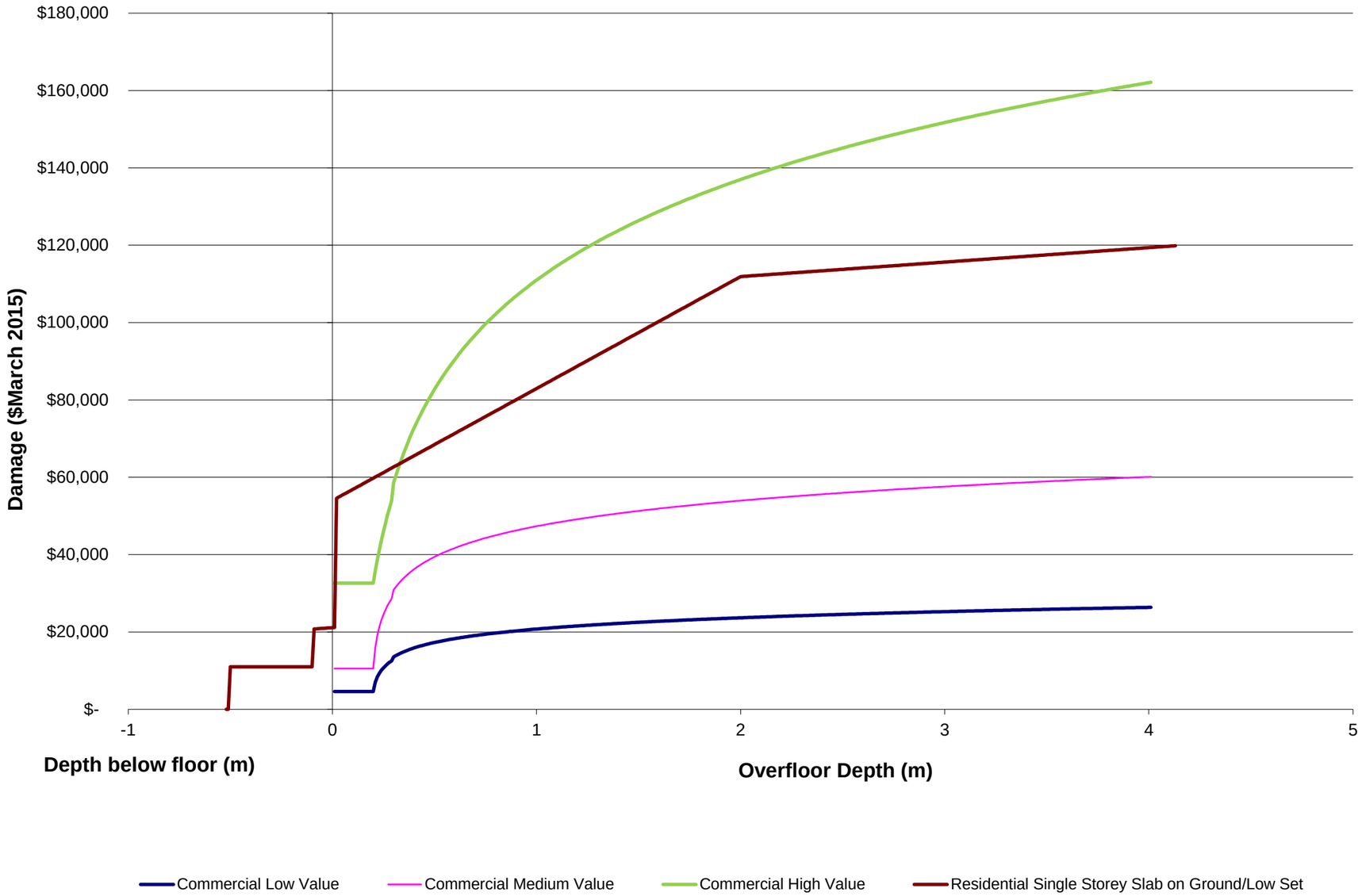
Coordinate System: Zone 55/1 ISG

Figure 6-1

Damage Curves

Captains Flat FRMSP



Note: Data for Commercials and Industrials is shown for a 150m2 floor area, for demonstration only. Garden damage ($3000) for residentials is not shown in these curves.

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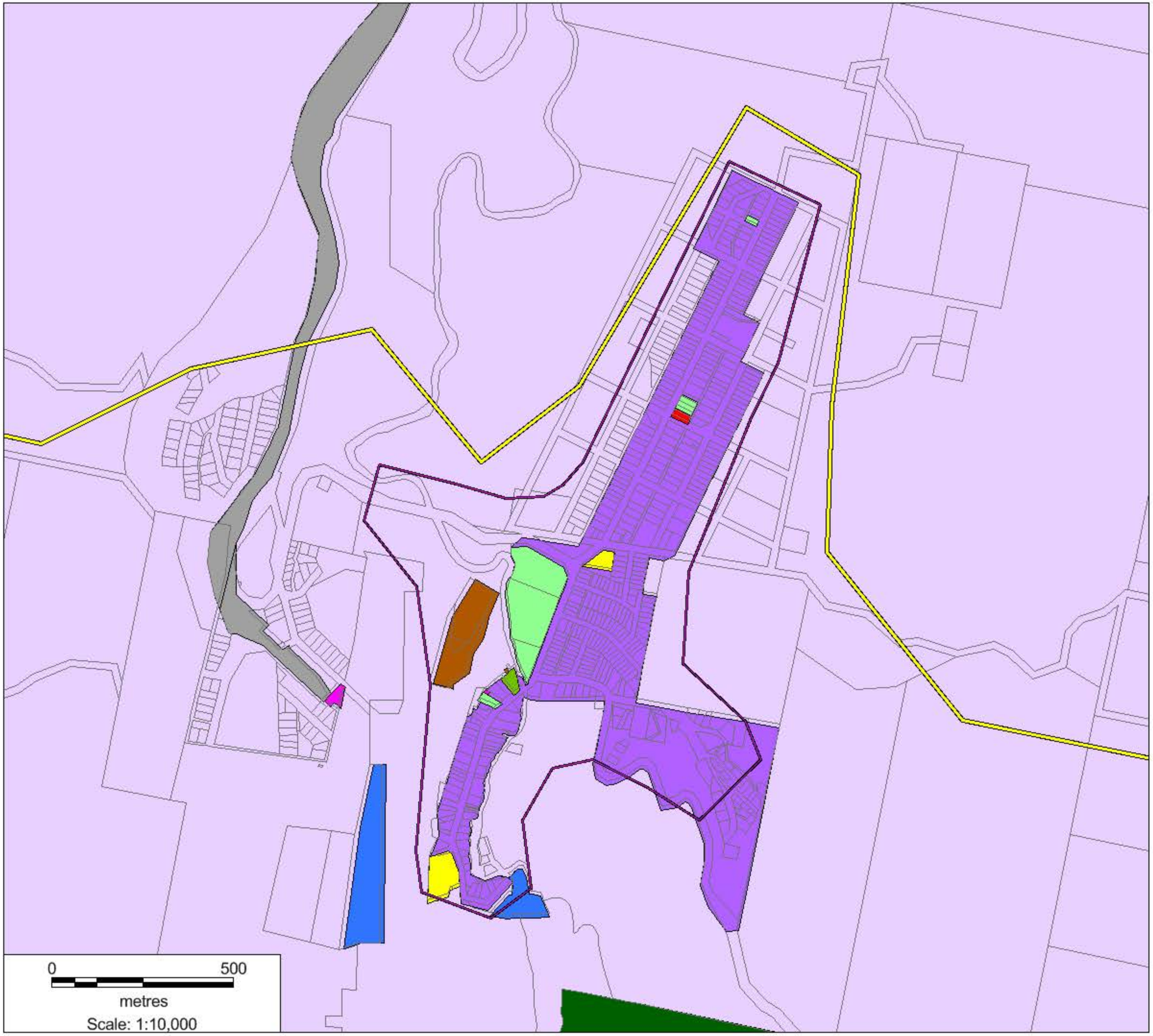
Map Produced by Cardno NSW/ACT Pty Ltd
Date: 04 / 05 / 2015
Project: Captains Flat FRMSP
Coordinate System: NA

FIGURE 9-1

ZONING

CAPTAINS FLAT
FRMSP



- Catchment area
- Study Area
- Cadastre
- E2 Env. Conservation
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU5 Village
- SP2 Emerency Services
- SP2 Water Facility
- SP2 Electricity
- SP2 Community Health
- SP2 Sewerge Treatment
- SP2 Railway

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Date: December 2014
Coordinate System: Zone 56/1 ISG

FIGURE 9-2

FLOOD AFFECTED ZONES

CAPTAINS FLAT
FRMSP

- Catchment area
- Study Area
- Cadastre
- E2 Env. Conservation
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU5 Village
- SP2 Emerency Services
- SP2 Water Facility
- SP2 Electricity
- SP2 Community Health
- SP2 Sewerge Treatment
- SP2 Railway
- 1% AEP Extent

0 500
metres
Scale: 1:10,000

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Coordinate System: Zone 56/1 ISG

FIGURE 10-1

FLOOD PLANNING AREA

CAPTAINS FLAT
FRMSP

Study Area
Cadastre
Flood Planning Area

0 500
metres
Scale: 1:10,000

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Date: October 2015
Coordinate System: Zone 56/1 ISG

FIGURE 11-1

EMERGENCY RESPONSE OPTIONS

CAPTAINS FLAT
FRMSP

- PMF Flood Extent
- Properties that could adopt Shelter in Place (Floor level > PMF)
- Properties that would be requried to evacuate in PMF (Northern Region)
- Properties that would be requried to evacuate in PMF (Central Region)
- Properties that would be requried to evacuate in PMF (Southern Region)
- School - Possible Northern Region Evacuation Centre
- Possible Evacuation Centre Locations

N

0 500
metres

NOTE: Lots that are not shaded are either outside of the PMF flood extent, or are currently vacant

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Date: October 2015
Coordinate System: Zone 56/1 ISG

Figure 13-1

Preliminary Mitigation Options

CAPTAINS FLAT
FRMSP

- Cadastre
- 100yr Flood Extent
- Model Region
- Culvert Upgrade
- Bridge Upgrade
- Pipe Town Creek
- Vegetation Management
- Formalisation of Town Creek
- Road Raising
- Blockage Control Structure
- Channel Works
- Detention Basins
- Lot Raising

N

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Date: November 2014
Coordinate System: Zone 55/1 ISG

FIGURE 13-2

FM1 DRAINAGE UPGRADE

CAPTAINS FLAT
FRMSP

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

N

0 250
metres
Scale: 1:5,001

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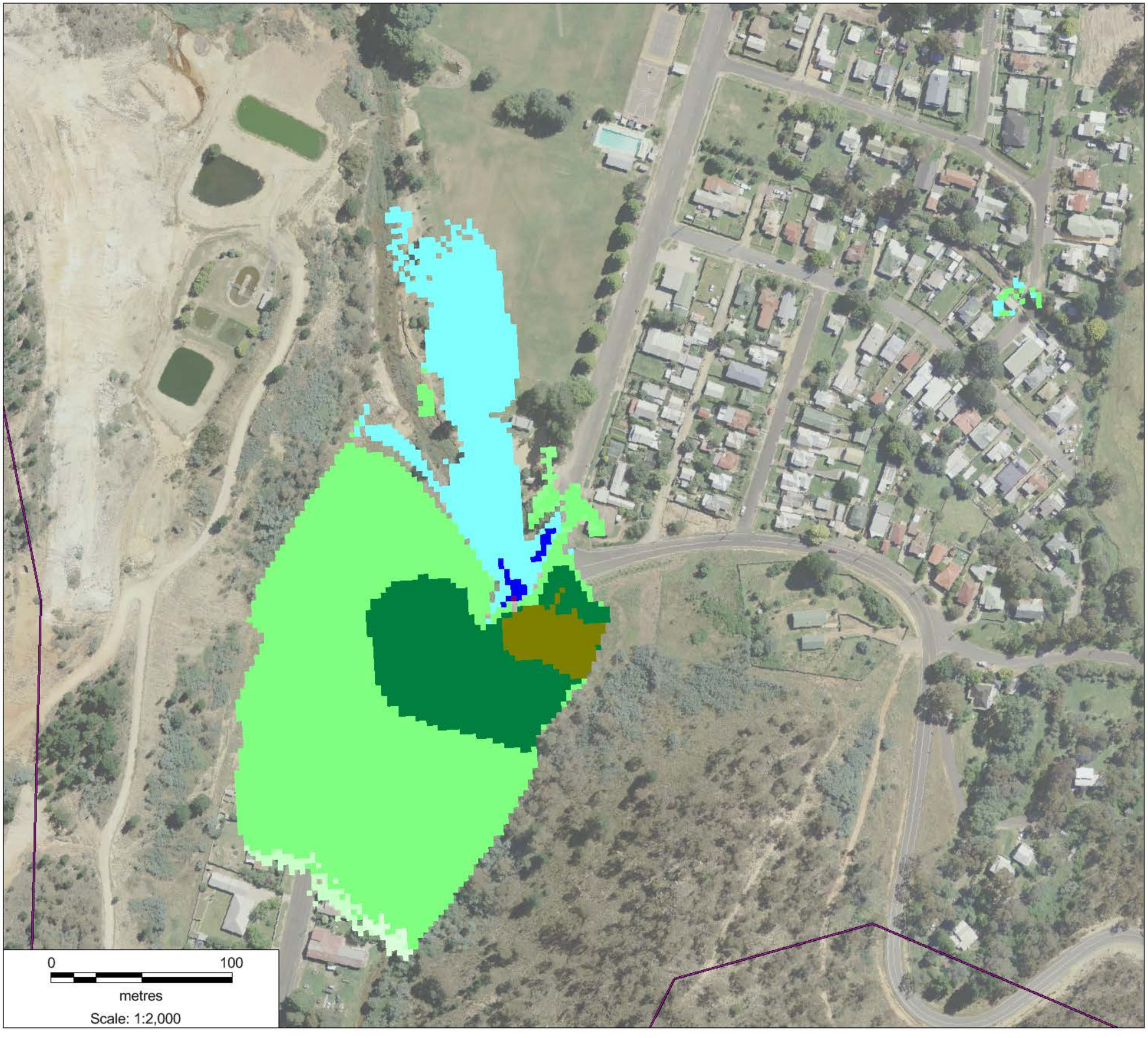

FIGURE 13-3

FM2 STRUCTURE UPGRADE FLOOD IMPACTS

CAPTAINS FLAT
FRMSP

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

N

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Coordinate System: Zone 56/1 ISG

FIGURE 13-4

FM3 BASIN FLOOD IMPACTS

CAPTAINS FLAT FRMSP

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

N

0 100
metres
Scale: 1:2,000

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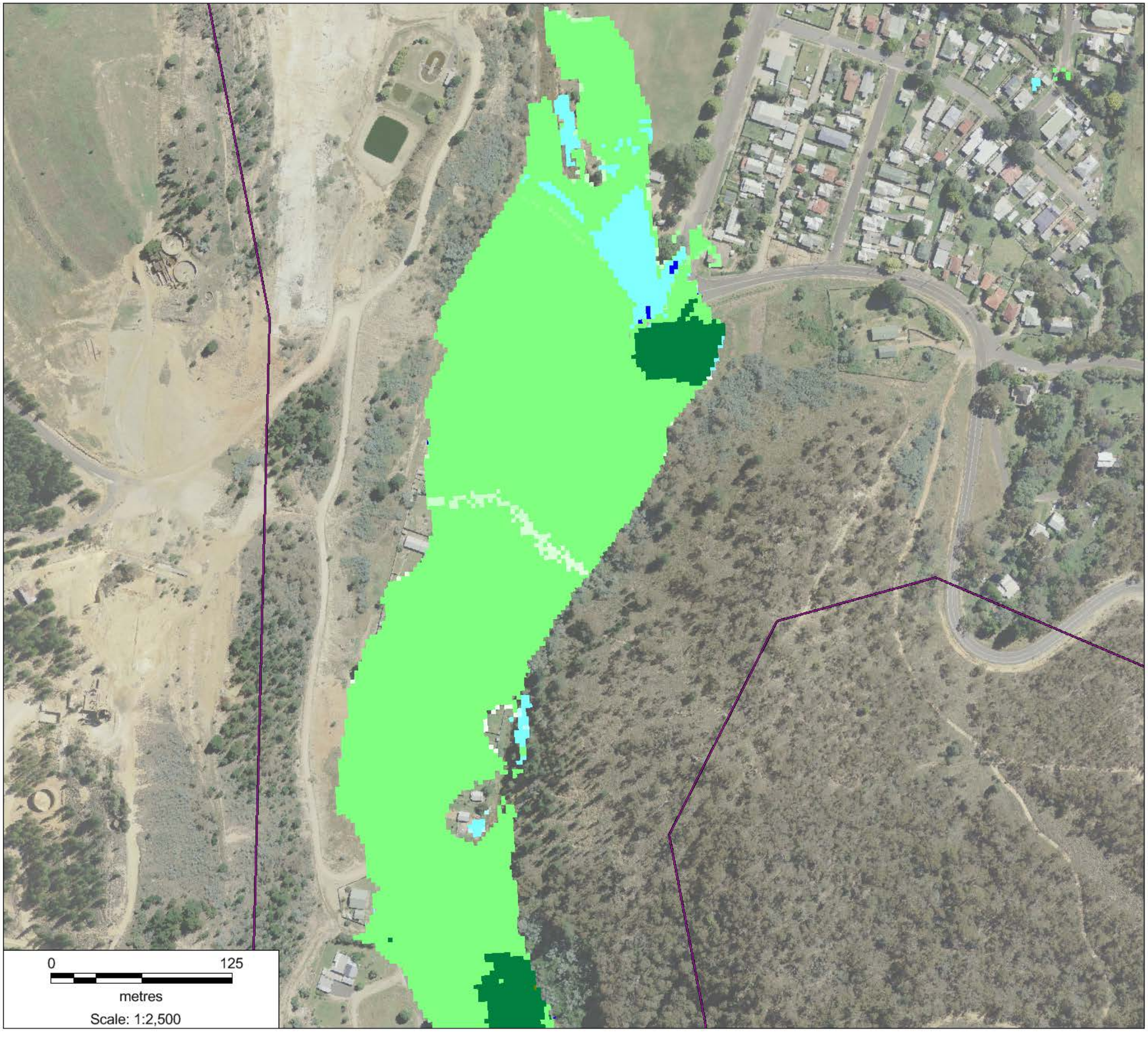

FIGURE 13-5

FM4 VEGETATION MANAGEMENT FLOOD IMPACTS

CAPTAINS FLAT FRMSP

Study Area

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

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Coordinate System: Zone 56/1 ISG

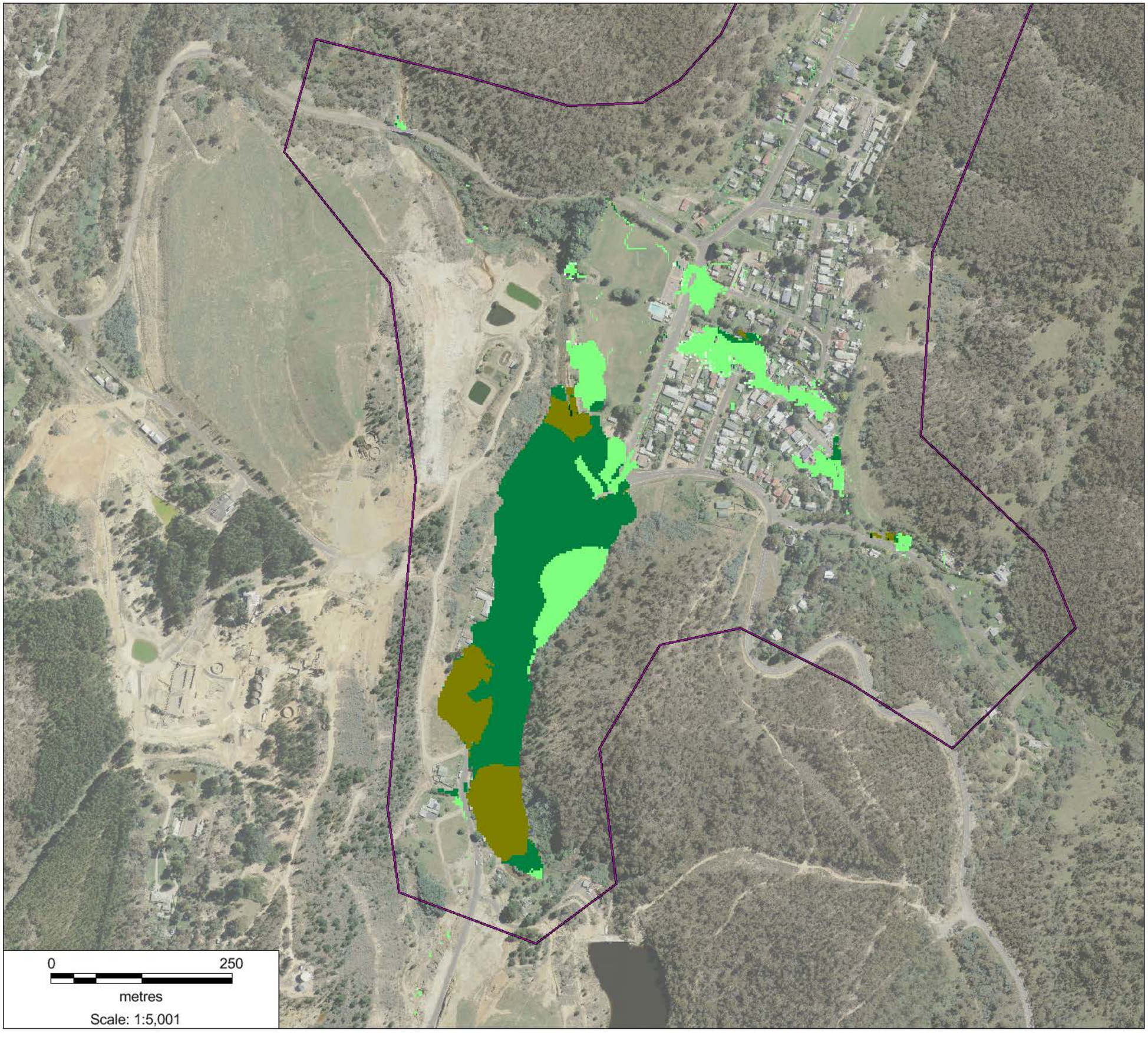

FIGURE 13-6

FM5 CHANNEL WORKS

CAPTAINS FLAT
FRMSP

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

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Date: December 2014
Coordinate System: Zone 56/1 ISG

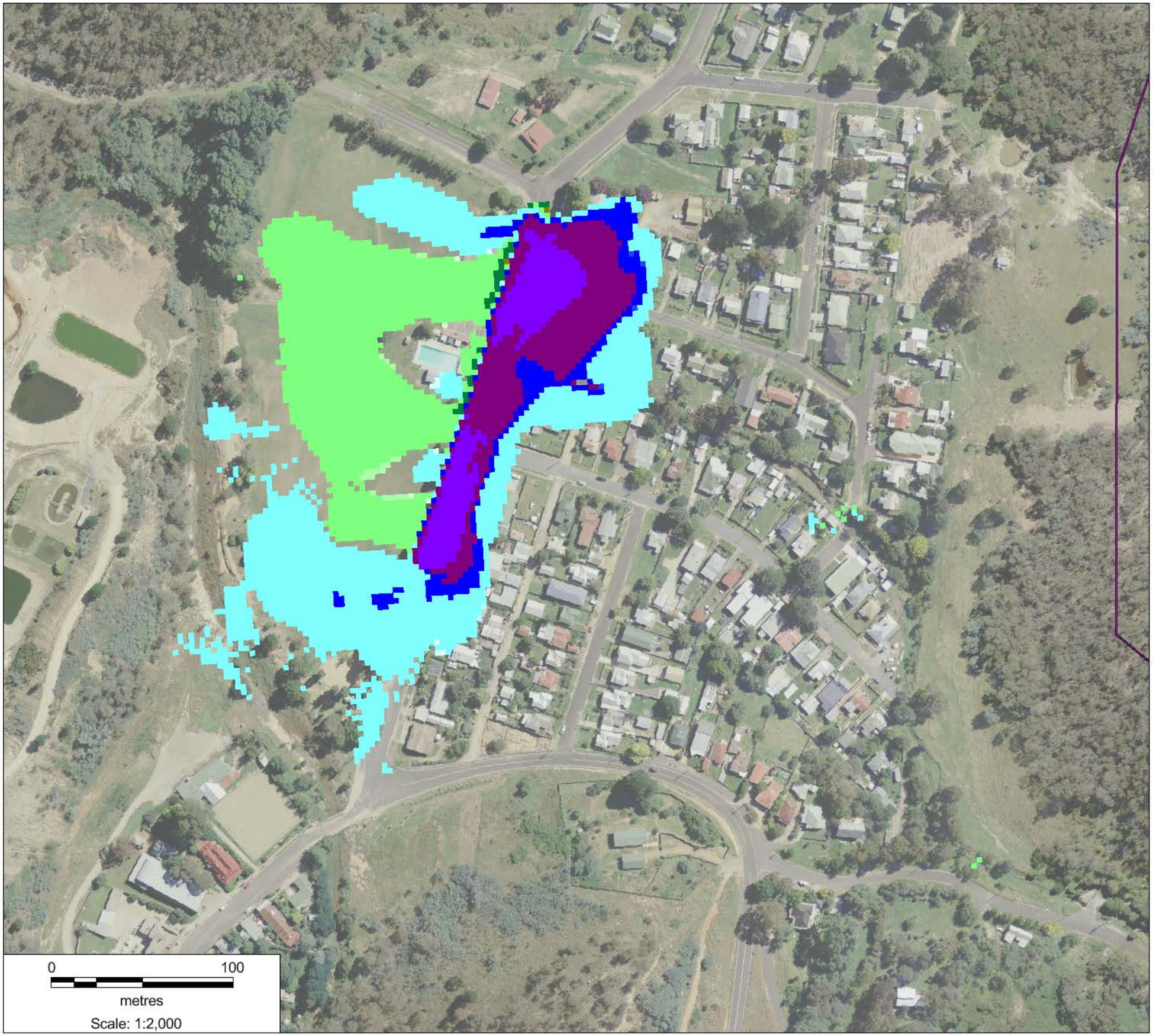

FIGURE 13-7

FM6 ROAD RAISING FLOOD IMPACTS

CAPTAINS FLAT FRMSP

Study Area

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

N

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Date: December 2014
Coordinate System: Zone 56/1 ISG

Floodplain Risk Management Study

APPENDIX A
COMMUNITY CONSULTATION DOCUMENTS

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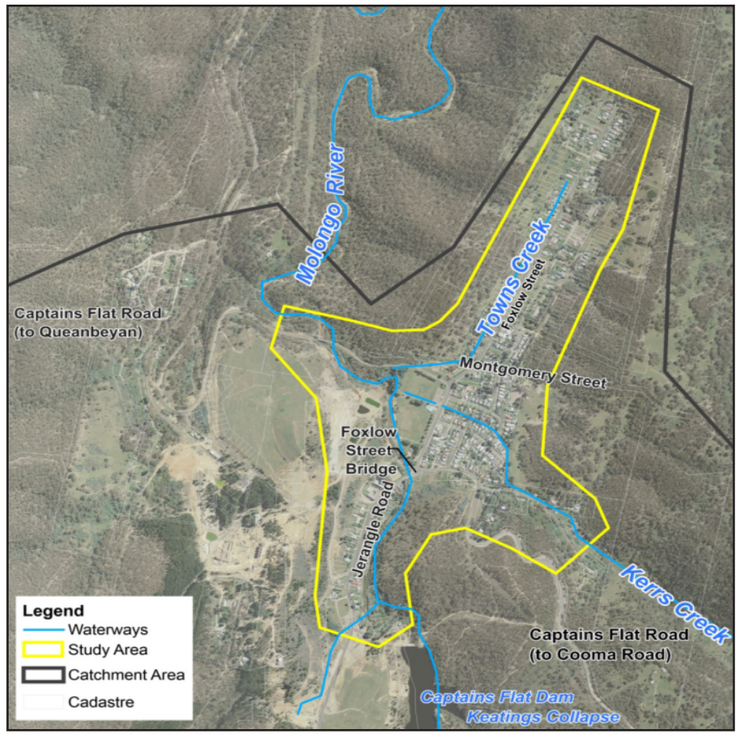
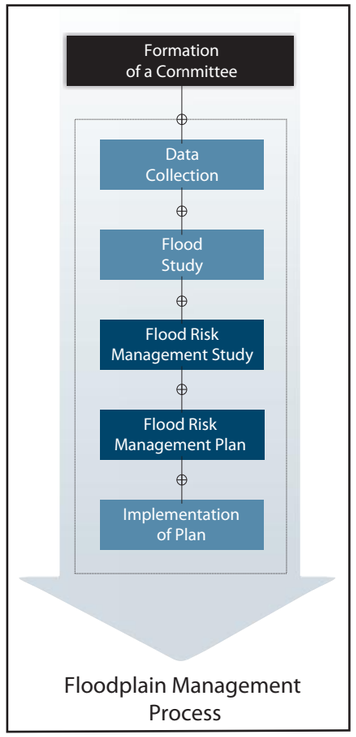


Figure: The Study Area



Floodplain Management Process

If you have any further comments that relate to the Management Study and Plan, please provide them in the space below (or attach any additional pages if necessary):

Thank you for providing the above information. Please return all pages in the the reply paid envelope by 19 December 2014. A representative from Cardno or Council may contact you in the near future to discuss your response.

Contact Us

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact

Palerang Council

Brendan Belcher

P: (02) 6238 8111
F: (02) 6238 1290
E: records@palerang.nsw.gov.au

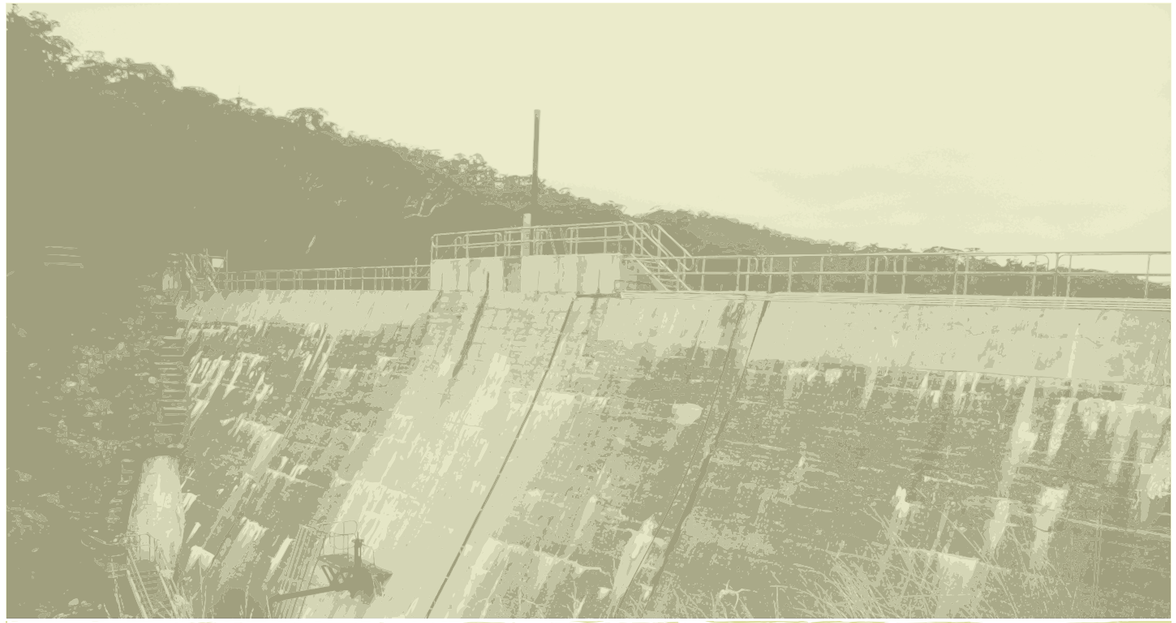
Cardno

Luke Evans

P: (02) 9496 7713
F: (02) 9499 3902
E: luke.evans@cardno.com.au

This project is supported by the NSW Government's Floodplain Management Program.

PALERANG COUNCIL | NSW GOVERNMENT Office of Environment & Heritage | Cardno Shaping the Future



Captains Flat Floodplain Risk Management Study and Plan

Local Resident / Land Owner Survey | November 2014

Council recently completed a Flood Study for the Captains Flat township. The study was undertaken to define the existing flood behaviour of the township. You would have received a survey for this study, which asked you for information on historic flooding. This information was utilised in validating the results of the flood assessment.

This current study builds on the previous investigation. The current Floodplain Risk Management Study and Plan will examine a range of flood mitigation strategies aimed at reducing the flood risks and damages to residents and properties within Captains Flat. Council will utilise the results of this study to prioritise those mitigation strategies that were found to be most effective.

We would appreciate your input to this new study. In particular, we would like your feedback on possible flood mitigation options for the Captains Flat Township. Some options were investigated as part of the flood study in response to community feedback. The results, available in the Flood Study Report, showed that regrading and clearing of the Molonglo River reduced peak flood levels for adjacent properties. The use of the dam as a flood mitigation structure was also investigated, but the storage volume was found to be too small to affect flood behaviour. These options, as well as a range of others, will be investigated in greater detail as part of the current study.

Further information is available on a dedicated project website at https://extranet.cardno.com/CaptainsFlatFRMSP. It is also possible to complete this survey online at this address should you prefer.

Council would appreciate your participation in this survey and ask that you fill in and return this questionnaire form in the enclosed reply paid envelope by 19 December 2014.

PALERANG COUNCIL | NSW GOVERNMENT Office of Environment & Heritage | Cardno Shaping the Future

Local Resident / Landowner Survey

Q1. Could you please provide us with the following details (optional)? We may wish to contact you to discuss some of the information you have provided.

Name: .....

Address: .....

.....

Daytime Ph: .....

Email: .....

Q 2. Is your property (please tick)

☐ Owner occupied ☐ Rented - by yourself ☐ Rented - by others

☐ A business ☐ Other .....

Q 3. How long have you lived, worked and/or owned your property?

..... Months ..... Years

Q 4. How many people live / work at your property?

.....

Q 5. Number of permanent residents at this address aged:

☐ 0 - 4 years ☐ 5 - 24 years

☐ 25 - 64 years ☐ 65+ years

Q 6. What do you think are the best ways to get input and feedback from the local community about this project? (please tick relevant boxes)

☐ Council's website

☐ Emails from Council

☐ Council's Floodplain Management Committee

☐ Formal Council meetings

☐ Council's information page in the local paper

☐ Other articles in the local paper

☐ Information days in the local area

☐ Community meetings

☐ Mail outs to all residents / business owners in the study area

GLOSSARY

Culvert	A drain or covered channel that passes under a road or railroad.
Levee Banks	An embankment usually constructed from earth or concrete built along the banks of a river to help prevent overflow of its waters.
Retarding / Detention Basin	A naturally occurring or constructed depression in the land surface that detains stormwater runoff by allowing it to slowly drain out of the basin into the adjoining natural drainage line or creek.

Q 7. As a local resident who may have witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for the Captains Flat area (where 1 = most preferred, 5 = least preferred)?
Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please tick) Most preferred → Least preferred	Location / Other Comments
EXAMPLE: Retarding or detention basins; these temporarily hold water and reduce peak flows	1 ☑ 3 4 5	A basin somewhere in the southern part of the town would reduce flooding for the rest of the town
Retarding or detention basins; these temporarily hold water and reduce peak flows	1 2 3 4 5	
Improved flood flow paths through creek regrading and/or vegetation and debris removal	1 2 3 4 5	
Culvert / bridge / pipe enlarging	1 2 3 4 5	
Levee banks (note Glossary on opposing page)	1 2 3 4 5	
Diversion of creeks and channels	1 2 3 4 5	
Environmental channel improvements, including removal of weeds & bank stabilisation	1 2 3 4 5	
Voluntary raising of houses to reduce flood damages by raising floor levels above a design flood	1 2 3 4 5	
Voluntary purchase of highly affected properties by Council and demolition of any buildings on the property	1 2 3 4 5	
Planning and flood related development controls to ensure future development does not add to the existing flood risk	1 2 3 4 5	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response such as early warning systems, improved local SES capabilities/ resources or improved radio and phone communications	1 2 3 4 5	
Other (please specify any options you believe are suitable). Please attach extra pages for other suggestions	1 2 3 4 5	

Floodplain Risk Management Study

APPENDIX B
DETAILS OF UNSUCCESSFUL PROPERTY MODIFICATION OPTIONS

Cardno
Shaping the Future

B Details of Unsuitable Property Modification Options

A number of property modification options to help address flood risks within the Captains Flat were assessed as part of this study. The successful option were discussed in Section 13.4. Due to the flooding behaviour of the township, a number of property modification options were found to be unsuitable within the study area.

Details of these options, and the reasons for their unsuitability, are provided below.

B.1 House Raising

House raising is a possible option to reduce the incidence of over floor flooding in properties. However, whilst house raising can reduce the occurrence of over floor flooding, there are issues related to the practise, including:

- Difficulties in raising some houses, such as slab on ground buildings. In some slab on ground situations it may be possible to install a false floor, although this is limited by the ceiling heights;
- The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages, etc;
- Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists – i.e. there will still be a residual risk;
- Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounds a property;
- The need to ensure the new footings or piers can withstand flood-related forces;
- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area; and,
- Potential heritage constraints.

OEH has prepared the *Guidelines for voluntary house raising schemes* (OEH, 2013) to assist in determining when and where house raising schemes may be suitable. As noted above, house raising may result in people becoming trapped in the property by surrounding flood waters. As such, the Guidelines recommended that house raising be generally restricted to low hazard areas.

As those properties affected by flooding in the 20% are all located within floodways, and that a significant risk to life will remain even after raising, house raising is not recommended as a viable option for Captains Flat.

B.2 House Rebuilding

Under a re-building scheme, the property owner would elect to re-build their property in order to construct a more flood applicable development. In a number of cases, the ability to raise properties can be difficult and therefore rebuilding may

be the only option. The advantage of this option is that the new structure can also be built in a flood compatible way (such as including a second storey for flood refuge).

An issue associated with this option is that there is still a significant cost for the property owner to redevelop their land

Similar to the house raising option, the fact that those properties that are affected by frequent flooding are all within floodways, and that a significant risk to life would still remain after redevelopment, make this option unviable in the Captains Flat catchment.

B.3 Land Swap

A land swap program would see Council swap a parcel of land in a non-flood prone area, such as an existing park, for the flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land rezoned to open space.

As there are no Council owned sites (such as parks or recreations areas) within the study area that are flood free and suitable for swapping, this option is not considered viable for Captains Flat.

B.4 Council Redevelopment

Under a Council redevelopment scheme, Council would purchase the worst affected properties, and would redevelop these properties in a flood compatible manner and re-sell them with a break even objective.

As any properties purchased would be within the floodway zone, it is not recommended that they be redeveloped and consequently, this option is not considered viable for the Captains Flat area.

Floodplain Risk Management Study

APPENDIX C
OPTION COSTINGS

Cardno
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Captains Flat FRMSP

FM1 - Drainage Upgrade
Cost Estimate

30.03.2014

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**248,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	5,200	sq. m	10	52,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	780	cu. m	20	15,600
2.3	Dispose of excess topsoil (nominal 10% allowance)	78	cu. m	50	3,900
	SUBTOTAL				**71,500**
3.0	**EARTHWORKS**				
3.1	Nominal cost for minor earthworks at headwalls	1	item	25000	25,000
	SUBTOTAL				**25,000**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.8m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	40	lin.m	2200	88,000
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.2m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	300	lin.m	1800	540,000
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø600mm RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	800	lin.m	1100	880,000
	SUBTOTAL				**1,508,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	5,200	sq. m	10	52,000
	SUBTOTAL				**52,000**
	CONSTRUCTION SUB-TOTAL				**1,905,000**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**952,500**
	CONSTRUCTION TOTAL, excluding GST				**2,857,500**
	GST				**285,750**
	CONSTRUCTION TOTAL, including GST				**3,143,250**
	CONSTRUCTION TOTAL, rounded				**3,143,300**

DISCLAIMER:

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Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management

2. Assume existing drainage at sufficiently deep level to remain undisturbed.

3. Estimate / rates in 2010 dollars and does not allow for inflation

Captains Flat FRMSP

FM 2 - Structure Upgrade
Cost Estimate

30.03.2014

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**86,100**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	5,200	sq. m	10	52,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	780	cu. m	20	15,600
2.3	Dispose of excess topsoil (nominal 10% allowance)	78	cu. m	50	3,900
	SUBTOTAL				**71,500**
3.0	**EARTHWORKS**				
3.1	Nominal cost for minor earthworks at structures	1	cu. m	25000	25,000
	SUBTOTAL				**25,000**
4.0	**STRUCTURES**				
4.1	Construction of 15m x 2m RCBC for Foxlow Street bridge, including costs to demolish and remove existing bridge, tie in of culvert surface to existing road surface	1	item	250000	250,000
4.3	Construction of blockage control device upstream of Foxlow Street bridge (nominal amount, based on bollard type control structure)	1	item	100000	100,000
4.4	Construction of blockage control device upstream of Kerrs Creek pedestrian bridge (nominal amount, based on bollard type control structure)	1	item	75000	75,000
	SUBTOTAL				**425,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	5,200	sq. m	10	52,000
	SUBTOTAL				**52,000**
	CONSTRUCTION SUB-TOTAL				**659,600**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**329,800**
	CONSTRUCTION TOTAL, excluding GST				**989,400**
	GST				**98,940**
	CONSTRUCTION TOTAL, including GST				**1,088,340**
	CONSTRUCTION TOTAL, rounded				**1,088,400**

DISCLAIMER:

1. This estimate of cost is provided in good faith using information available at this stage. This estimate of cost is not guaranteed.

Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

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2. Assume existing drainage at sufficiently deep level to remain undisturbed.

3. Estimate / rates in 2010 dollars and does not allow for inflation

Captains Flat FRMSP

FM 4 - Vegetation Management
Cost Estimate

31.03.2014

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**61,700**
2.0	**CLEARING AND WEEDING**				
2.1	Removal of trees and debris from within river (nominal cost)	1	item	25,000	25,000
2.2	Weeding / clearing of creek sections with overgrown banks or invasive / exotic species.	1800	lin.m	200	360,000
	SUBTOTAL				**385,000**
3.0	**PLANTING**				
3.1	Plant species as listed by ecologist, at stocking densities as defined by landscape architect to stabilise banks and channel	600	lin.m	35	21,000
	SUBTOTAL				**21,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed bank areas in accordance with landscape architects requirements (nominal allowance)	500	sq. m	10	5,000
	SUBTOTAL				**5,000**
	CONSTRUCTION SUB-TOTAL				**472,700**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**236,350**
	CONSTRUCTION TOTAL, excluding GST				**709,050**
	GST				**70,905**
	CONSTRUCTION TOTAL, including GST				**779,955**
	CONSTRUCTION TOTAL, rounded				**780,000**

DISCLAIMER:

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Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2010 dollars and does not allow for inflation

Captains Flat FRMSP

FM5 - Channel Works
Cost Estimate

30.03.2014

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**329,100**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	38,000	sq. m	10	380,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	5700	cu. m	20	114,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	570	cu. m	50	28,500
	SUBTOTAL				**522,500**
3.0	**EARTHWORKS**				
3.1	Excavate channels - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	22500	cu. m	35	787,500
	SUBTOTAL				**787,500**
4.0	**BRIDGE WORKS**				
3.1	Construct new bridge crossing, including removal and disposal of exsiting bridge, construction of new bridge, and tie into to exsiting roadway	15	lin.m	30000	450,000
	SUBTOTAL				**450,000**
4.0	**PLANTING**				
3.1	Plant species as listed by ecologist, at stocking densities as defined by landscape architect to stabilise banks and channel	1,800	lin.m	30	54,000
	SUBTOTAL				**54,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	38,000	sq. m	10	380,000
	SUBTOTAL				**380,000**
	CONSTRUCTION SUB-TOTAL				**2,523,100**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**1,261,550**
	CONSTRUCTION TOTAL, excluding GST				**3,784,650**
	GST				**378,465**
	CONSTRUCTION TOTAL, including GST				**4,163,115**
	CONSTRUCTION TOTAL, rounded				**4,163,200**

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NOTES:

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3. Estimate / rates in 2010 dollars and does not allow for inflation

Floodplain Risk Management Study

APPENDIX D
MULTICRITERIA MATRIX

Cardno
Shaping the Future

Captains Flat FRMSP - Multi Criteria Assessment

ID	Category of Measure	Description	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 years)	Reduction in AAD	NPV of Reduction in AAD	Benefit - Cost Ratio	Score on Benefit Cost Ratio	Reduction in Risk to Property	EconomicScore	Reduction in Risk to Life	Reduction in Social Disruption	Community Criteria	Council Support	Social Score	Water Quality and Flow	Fauna & Flora	Environmental Score	TOTAL SCORE	RANK on TOTAL SCORE
F1	Flood Modification	Drainage upgrade	$3,143,300	$5,000	$3,212,304	$118,000	$1,628,488	0.5	-1	1	**-0.3**	0	0	1	1	**0.5**	0	0	**0.0**	**-0.2**	**12**
F2	Flood Modification	Structure upgrade	$1,088,400	$15,000	$1,295,411	$109,099	$1,505,648	1.2	1	0	**0.7**	0	1	1	1	**0.8**	0	0	**0.0**	**2.1**	**9**
F3	Flood Modification	Kerrs Creek Detention Basin	*Not suitable for Captains Flat - refer report for further details*																		
F4	Flood Modification	Vegetation Management	$780,000	$15,000	$987,011	$147,024	$2,029,041	2.1	2	1	**1.7**	0	1	2	1	**1.0**	1	2	**1.5**	**5.8**	**1**
F5	Flood Modification	Channel works	$2,523,100	$10,000	$2,661,107	$153,586	$2,119,601	0.8	-1	0	**-0.7**	0	0	1	1	**0.5**	0	1	**0.5**	**-0.3**	**13**
F6	Flood Modification	Use of Captains Flat Dam as detention structure	*Not suitable for Captains Flat - refer report for further details*																		
F7	Flood Modification	Lot raising along Foxlow Street	*Not suitable for Captains Flat - refer report for further details*																		
P1	Property Modification	Voluntary Purchase	$4,800,000	$0	$4,800,000	$280,960	$3,877,458	0.8	-1	2	**0.0**	2	2	-2	1	**0.8**	1	0	**0.5**	**1.3**	**11**
P2	Property Modification	Building and Development Controls	$15,000	$500	$21,900	NC	N/A	N/A	2	2	**2.0**	1	1	0	1	**0.8**	0	0	**0.0**	**4.8**	**2**
P3	Property Modification	Flood Proofing Guidelines	$15,000	$1,000	$28,801	NC	N/A	N/A	2	1	**1.7**	0	0	1	1	**0.5**	0	0	**0.0**	**3.8**	**3**
P4	Property Modification	House raising	*Not suitable for Captains Flat - refer report for further details*																		
P5	Property Modification	House rebuilding	*Not suitable for Captains Flat - refer report for further details*																		
P6	Property Modification	Land swap	*Not suitable for Captains Flat - refer report for further details*																		
P7	Property Modification	Council redevelopment	*Not suitable for Captains Flat - refer report for further details*																		
EM1	Emergency Response Modification	Infomation transfer to the SES	$3,000	$0	$3,000	NC	N/A	N/A	2	0	**1.3**	0	0	2	2	**1.0**	0	0	**0.0**	**3.7**	**4**
EM2	Emergency Response Modification	Flood warning system	$250,000	$1,000	$263,801	NC	N/A	N/A	0	2	**0.7**	2	2	2	2	**2.0**	0	0	**0.0**	**3.3**	**5**
EM3	Emergency Response Modification	Public awareness and education	$10,000	$2,000	$37,601	NC	N/A	N/A	1	1	**1.0**	1	1	2	1	**1.3**	0	0	**0.0**	**3.3**	**6**
EM4	Emergency Response Modification	Flood warning signs	$5,000	$200	$7,760	NC	N/A	N/A	1	0	**0.7**	1	0	1	1	**0.8**	0	0	**0.0**	**2.1**	**9**
EM5	Emergency Response Modification	Upgrade Miners Road	$500,000	$2,500	$534,502	NC	N/A	N/A	0	0	**0.0**	2	1	2	2	**1.8**	2	0	**1.0**	**2.8**	**7**
DC1	Data Collection Strategy	Data collection following a flood event	$5,000	$3,000	$46,402	NC	N/A	N/A	1	0	**0.7**	0	0	2	2	**1.0**	0	0	**0.0**	**2.3**	**8**

NC - Not Costed