COOTAMUNDRA GUNDAGAI REGIONAL COUNCIL

GUNDAGAI FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

wma water

DECEMBER 2018

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: (02) 9299 2855
Fax: (02) 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

GUNDAGAI FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT

DECEMBER 2018

Project Gundagai Floodplain Risk Management Study and Plan	**Project Number** **116054**
Client Cootamundra Gundagai Regional Council	**Client's Representative** Phil McMurray
Authors Catherine Goonan Kieran Smith	**Prepared by** 
Date 4 December 2018	**Verified by** 

Revision	Description	Distribution	Date
4	Final Report	CGRC, NSW OEH	Dec 2018
3	Draft for Public Exhibition	CGRC, NSW OEH	Oct 2018
2	Stage 3 Report	CGRC, NSW OEH	Aug 2018
1	Stage 2 Report	CGRC, NSW OEH	July 2018

Cover photo: Gundagai District Services Club, March 2012 (Photo J Lico, provided to WMAwater April 2018)

ACKNOWLEDGEMENTS

Cootamundra Gundagai Regional Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

COPYRIGHT NOTICE

Cootamundra – Gundagai Regional Council
PO Box 34 Gundagai NSW 2722
mail@cgrc.nsw.gov.au
1300 459 689

DISCLAIMER

EXECUTIVE SUMMARY

This document details the Gundagai Floodplain Risk Management Study; and the Gundagai Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Gundagai Flood Study (the Flood Study, Reference 5), adopted in March 2018, which determined the nature and extent of the flood problem in the township of Gundagai under existing conditions. Flood behaviour has been defined across a range of event sizes and include those which have been recorded in the past, as well as larger events which may occur in the future. This Floodplain Risk Management Study seeks to identify flood risk, investigate methods by which to reduce the flood risk in Gundagai, and ultimately develop a Floodplain Risk Management Plan which can be implemented by Council.

Existing Flood Environment

Gundagai is situated in the foothills of the Great Dividing Range upstream of the Riverina Plain. At Gundagai, the Murrumbidgee River has a catchment area of 21,000 km² and Jones Creek a catchment area of 60 km². Flooding at Gundagai is due predominantly to Murrumbidgee River flooding, however anecdotal evidence suggests that flooding may also occur due to Jones Creek. Gundagai has experienced numerous large flood events since it was founded in the early 1800's. It is the site of Australia's worst natural disaster which occurred in 1852 with a large Murrumbidgee River flood that led to the death of 89 people. It was this flood that led to the relocation of Gundagai from the floodplain between the Murrumbidgee River and Morleys Creek to its current location on higher ground.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties. The assessment was based on surveyed and estimated flood levels for all properties in the Study Area. The annual average damages for residential and commercial/industrial properties was found to be $796,750. This figure is based on the enveloped peak flood results of both Murrumbidgee River and Jones Creek flooding.

Flood Risk Management Options

The Gundagai Floodplain Risk Management Study assessed a range of potential options for the management of flooding. Options were identified by considering ways to improve flooding "hotspots" identified using modelled flood results, inspection of areas of property affectation using outputs from the damages assessment, and via discussions with the local community and SES personnel. Recommended options centre around improving the community's response to flooding and reducing the operational demands on the SES, who play a key role in Gundagai's flood emergency management. A number of property modification measures are also recommended, including raising the Flood Planning Level for areas affected by mainstream flooding to the 1% AEP level + 0.5 m freeboard, and applying a freeboard of 0.3 m for areas subject to overland flow. A feasibility study to further investigate voluntary house raising and voluntary purchase is recommended, as is the provision of flood information to residents via Section 10.7 Planning Certificates, and inclusion of flood related development controls in the comprehensive Cootamundra – Gundagai Development Control Plan.

Flood modification options were generally not found to be effective in Gundagai. The assessment investigated works including converting the Otway Street causeway to a bridge over Morleys Creek, increasing culvert capacity beneath Middleton Drive, and installing a levee between Sheridan Lane and Morleys Creek. Excavation of a flood channel beneath Sheahan Bridge had been thought to assist in reducing inundation durations, however was shown to backwater initially and flood Ferry Street earlier than otherwise would have occurred, and did not reduce property damages.

Options were additionally assessed via a multi-criteria matrix assessment, to establish a comparative assessment of options across a range of factors. The assessment criteria included economic benefits, social factors, environmental factors and other aspects relating to compatibility with existing Council priorities, policies and projects. Options were scored from -3 to +3 on each factor, and scores totalled to establish a ranking of each options. Options that had a positive overall score indicate that their benefits outweighed the negative aspects associated with the option, and have been recommended for implementation via the Floodplain Risk Management Plan. The recommended options are listed in Table 1.

Table 1 Recommended Flood Risk Mitigation Options

Option ID	Option	Report Reference
RM01	Gundagai Flood Intelligence Improvements	6.5.1
RM02	Improve Flood Emergency Management	6.5.2
RM03	Improve Flood Warning Systems	6.5.3
RM04	Improve Evacuation Management	6.5.4
RM05	Improve Community Flood Awareness	6.5.5
PM01	Voluntary House Raising and Voluntary Purchase Feasibility Study	6.6.1 & 6.6.2
PM03	Flood Proofing Measures for Commercial Properties	6.6.3
PM04	Revision of Flood Planning Level and Flood Planning Area	6.6.4
PM05	Inclusion of flood related information on Section 10.7(2) and (5) Planning Certificates	6.6.5
PM06	Inclusion of Flood Related Development Controls in new Cootamundra – Gundagai DCP	6.6.6
FM10	Install flap valve on culvert draining the Gundagai McDonalds carpark	6.7.2.3
FM09	Vegetation Management	6.7.5.1

At the Ordinary Council Meeting on Tuesday the 11th of December 2018, Council resolved to adopt the Gundagai Floodplain Risk Management Study and Plan.

GUNDAGAI FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE OF CONTENTS

PAGE

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

APPENDIX F: Floodplain Risk Mitigation Option Impact Maps

LIST OF PHOTOGRAPHS

LIST OF DIAGRAMS

LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DECC	Department of Environment and Climate Change (now OEH)
DNR	Department of Natural Resources (now OEH)
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

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

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a

20% AEP is not the same as a 0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6-month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

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

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

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

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits flowing from the use, occupation and development of flood prone land (Reference 2).

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

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

1. Flood Study

- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management

- Determines options in consideration of social, ecological and economic factors relating to flood risk.

3. Floodplain Risk Management Plan

- Preferred options are publicly exhibited and subject to revision in light of responses. Formally approved by Council after public exhibition and any necessary revisions due to public comments.

4. Implementation of the Plan

- Implementation of flood, response and property modification measures (including mitigation works, planning controls and flood warnings for example) by Council.

1. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Cootamundra – Gundagai Regional Council (Council). The Study is composed of two phases:

1. Gundagai Floodplain Risk Management Study; and
2. Gundagai Floodplain Risk Management Plan.

This document details the Gundagai Floodplain Risk Management Study; and the Gundagai Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Gundagai Flood Study (the Flood Study, Reference 5) which determined the nature and extent of the flood problem in the township of Gundagai under existing conditions. Flood behaviour has been defined across a range of event sizes and include those which have been recorded in the past, as well as larger events which may occur in the future. This Floodplain Risk Management Study seeks to investigate methods by which to reduce flood risk in Gundagai and ultimately develop a Floodplain Risk Management Plan which can be implemented by Council. Detailed objectives of the Study are outlined in subsequent sections.

All levels provided in this report are to Australian Height Datum (AHD) or relate to the Gundagai gauge stage (m) at Gundagai (site number: 410004) which will be referred to as the Gundagai Gauge in this report for ease of reference. A glossary of terms is provided in Appendix A.

1.1. Study Objectives

1.1.1. Floodplain Risk Management Study Objectives

The objective of the Floodplain Risk Management Study is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy and the "Floodplain Development Manual: the management of flood liable land", New South Wales Government, April 2005 (Reference 2). This includes the following elements as prescribed in the Brief:

- Review of the current Gundagai flood scoping and flood studies, and if necessary, re-assess the design flood discharges, velocities and flood levels for the Study Area using the latest available data and technology, as appropriate. Up to date information is required for the full range of potential flood events i.e. up to the Probable Maximum Flood or an appropriate extreme flood;
- Review Council's existing environmental planning policies and instruments including Council's long-term planning strategies for the study 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 circumstances are appropriate for flood related development controls on residential development on land above the residential flood planning area;
- Review the local flood plan, identify deficiencies in information and address the issues identified in the DECCW Guideline "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 development 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.

1.1.2. Floodplain Risk Management Plan Objectives

The Floodplain Risk Management Plan makes a range of recommendations relating to flood mitigation works and measures that address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy and the Floodplain Development Manual (Reference 2). The recommended works and measures presented in the Plan aim to:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the river and floodplain environment.
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979.
- Ensure that the floodplain risk management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.
- Ensure actions arising out of the plan are sustainable in social, environmental, ecological and economic terms.
- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.
- Establish a program for implementation and suggest a mechanism for the funding of the plan and include priorities, staging, funding, responsibilities, constraints, and monitoring.

1.2. Study Area

Gundagai is located in the southern inland area of NSW approximately 390 km west south west of Sydney in the Cootamundra - Gundagai Regional Council Local Government Area (LGA). The township straddles the Murrumbidgee River and is situated 20 km downstream of the Tumut River confluence (see Figure 1).

Gundagai has a population of approximately 1,700 (2016 census) with land use in the township predominantly composed of low-density residential development with some commercial development along the main street (Sheridan Street). In addition, there are large areas of open space along the Murrumbidgee River that include the Bidgee Banks Golf Course, Anzac Park, the Racecourse and Gundagai River Caravan Park.

Gundagai is situated in the foothills of the Great Dividing Range upstream of the Riverina Plain. At Gundagai, the Murrumbidgee River has a catchment area of 21,000 km² and Jones Creek a catchment area of 60 km². The topography of the region is presented as a Digital Elevation Model (DEM) and is shown on Figure 3. The figure illustrates hills rising steeply not far from town, resulting in a relatively constrained floodplain near Gundagai.

The study area (displayed on Figure 2) covers the floodplain near Gundagai for areas affected by both Murrumbidgee River and Jones Creek flooding. For the Murrumbidgee River floodplain, the study area extends from upstream of the Muttama Creek confluence to downstream of the Adelong Creek confluence (29 km reach). Morleys Creek, an anabranch of the Murrumbidgee River can influence flood behaviour in the study area and accordingly has also been included in the area considered. For the Jones Creek floodplain the study area extends approximately 600 m upstream of the Hume Highway to its confluence with the Murrumbidgee River near the northern abutment of Sheahan Bridge. The total study area covers an area of approximately 80 km².

1.3. Land Use

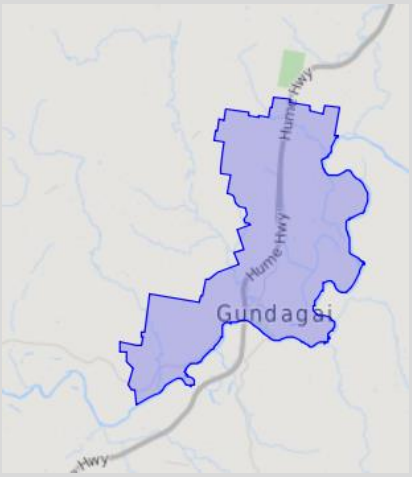
Land use zoning is defined by the Gundagai LEP 2011 is shown on Figure 4. The majority of residential development within Gundagai is comprised of lots zoned *R1 General Residential* with pockets of *R3 Medium Density Residential* and *R5 Large Lot Residential*. A *B2 Local Centre* area which allows for commercial/industrial uses is situated along Sheridan Street. Much of the floodplain between the Murrumbidgee River and Morleys Creek is zoned as *RE1 Public Recreation* and *RE2 Private Recreation* allowing for multiple uses such as golf courses and a racing track. Land use outside of the township of Gundagai is generally zoned *RU1 Primary Production* with usage primarily devoted to grazing and cropping endeavours.

Outside the town boundaries, the only structures on the floodplain are roads and rail, individual farmhouses and other farm related infrastructure. Most roads are unsealed and creek and stream crossings are generally formed by low level causeways.

1.4. Demographic Overview

Understanding the social characteristics of the Study Area can help in ensuring appropriate risk management practices are adopted, and shape the methods used for community engagement. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness. The following information has been extracted from the 2016 Census for the town of Gundagai and is considered relevant, while Table 2 below shows some of the characteristics of Gundagai LGA compared to the NSW average.

Gundagai Demographic Overview



Population: 1,676
No. of Private Dwellings: 819
No. of lone person households: 225
Property Tenure:

- 68.9% owned (either outright or with a mortgage)
- 25.5% rented

Language

- 91.3% of people speak only English at home

No. persons over the age of 75: 220
Elderly people are often more frail and may be unable to respond as quickly to flood emergencies without requiring some assistance.

No. single parent families: 68
Single parent families can mean a low adult-to-child ratio within the household and therefore can make evacuation more difficult.

Statistics from: http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/SSC11803?opendocument

Table 2: Characteristics of Gundagai (Australian Bureau of Statistics, 2016)

	Gundagai	NSW
Population Age:		
0 – 14 years	17.4%	18.5%
15 - 64 years	55.6%	65.1%
> 65 years	27.0%	16.2%
Average people per dwelling	2.3	2.6
Own/mortgage property	68.9%	64.5%
Rent property	25.5%	31.8%
Other tenure type/not stated	5.6%	3.7%
Moved into area:		
- within last year	13.8%	-
- within last five years	32%	-
No cars at dwelling	7.4%	9.2%
Speak only English at home	91.3%	68.5%

The characteristics noted above are taken into account in the community engagement strategy and when considering response modification options, such as flood education, warning or evacuation systems. Given the high proportion of English-only households, the delivery of community consultation material and flood warnings/ information in English is deemed appropriate. With a significant proportion of residents over the age of 65 years, online engagement strategies are not as likely to be as effective as face-to-face or postal communications. This was

demonstrated in the initial community consultation period, discussed in Section 3.6. Furthermore, aged residents are more likely to be frail and unable to respond as quickly to flood emergencies. Provision of assistance to such residents should be a key consideration when developing flood evacuation systems and the lead time with which warnings are provided.

The family composition within a residence can also affect flood awareness and capacity to respond. In Gundagai there are 225 lone person households, who are at greater risk of being unaware of flood warnings or evacuation orders. There are also 68 single parent families, which can mean a low adult-child ratio and result in difficulties preparing for and safely undertaking evacuations.

1.5. Local Environment

The environment surrounding Gundagai is modified from its original state. Early settlement of the area saw extensive clearing of native vegetation for farming and grazing and, eventually, development of the urban infrastructure. The Gundagai township is currently situated on both sides of the Murrumbidgee River with extensive urban development and commercial development on both the north and south sides. Large sections of cleared lands occupying the space between the major water bodies (the Murrumbidgee River and Morleys Creek) and the townships (particularly North Gundagai) serve primarily as recreational and farming areas and are referred to as the Gundagai commons.

In rural areas, the productive farming land faces a range of environmental pressures including dryland salinity, soil acidity and soil erosion (Reference 3).

Tributaries such as Morleys Creek have been subject to heavy degradation due to the construction of road crossings, creek infilling, planting of exotic vegetation and heavy livestock grazing. This has led to regular algal blooms and fish deaths. Major works were undertaken on Morleys Creek in the mid-2000s which achieved an improvement in waterway health (Reference 4).

2. PREVIOUS INVESTIGATIONS

2.1. Gundagai Flood Study, WMAwater, March 2018 (Reference 5)

The main objective of the Flood Study was to define the flood behaviour at Gundagai due to both Murrumbidgee River and Jones Creek flooding. Prior to this study, the design 1% AEP flow at Gundagai was defined by the 1980 NSW State Government study (1980 Study) (Reference 6). The 1980 Study 1% AEP flow estimate was based on flood frequency work that considered the joint probability of flooding due to the Murrumbidgee River and Tumut River. The 1980 Study did not incorporate major floods prior to 1893 in its estimation of design flows. There were a number of large flood events recorded prior to 1893, including the 1852 event which caused 89 deaths and instigated the relocation of the Gundagai town centre. These larger events give an indication of the upper range of floods that have occurred in Gundagai, and were used in the Flood Frequency Analysis described below. Furthermore, since the report's completion, there have been two significant flood events, substantial increases in available topographic data and advances in the flood modelling tools available. These factors led to the Gundagai Flood Study being commenced in 2014.

The floodplain elevation was defined using LiDAR data supplemented with bathymetric survey of 19 km of the Murrumbidgee River. A Flood Frequency Analysis (FFA) undertaken on gauged and estimated flows (estimated by Water NSW stage-discharge relationships) along the Murrumbidgee River provides design flow estimates to the model. The model was calibrated to the 2012 flood event and validated to the 2010 flood event. The Flood Study was presented to Council in April 2015 with a 1% AEP design flow that was 500 m^3 higher than the estimate from the 1980 study (Reference 6). Council chose to receive but not adopt the flood study, requesting that the 1% AEP flood level and the appropriate flood planning level for future development be further investigated.

The subsequent investigation identified that there had been a change in the Murrumbidgee River Stage/Discharge Relationship due to a combination of the following factors:

- Construction of Sheahan Bridge;
- Blockage of floodplain runners;
- Development of Anzac Park;
- Increased vegetation density;
- Changes to Murrumbidgee River bathymetry; and
- Changes in general floodplain roughness.

Identification of these changes allowed for the calibration of the model to the 1974 flood event. This calibration suggested that the stage-discharge relationship above the highest recorded gauging was overestimated by the Water NSW stage-discharge relationship. As a result, flows for the highest recorded gaugings (in 1925 and 1974) were revised and utilised in an updated FFA. This revision led to a change in the 1% AEP flow from the initial 6,900 m^3/s presented in the April 2015 Flood Study, to the current value of 6,100 m^3/s. Following the revision of the design flow estimates, Council chose to adopt the Gundagai Flood Study at a Council meeting on the 12th of December 2017, with the report finalised in March 2018.

2.1.1. Murrumbidgee River Flooding - Flood Intelligence Collection - March 2012 - Draft (Reference 7)

WMAwater were engaged by the SES in order to collect flood data associated with the March 2012 flood event with the brief being to collect flood intelligence associated with Murrumbidgee River flooding from Jugiong to Hay. Flood intelligence describes flood behaviour and the consequence flooding has for the community. Flood intelligence enables the SES to determine the likely impacts (or consequences) of flooding and what actions should be undertaken by response agencies.

In particular, this study provided 20 peak flood level marks for the 2012 flood within the Gundagai model domain. These marks were used during model calibration in the Flood Study (Reference 5).

2.1.2. Murrumbidgee River Flooding - Flood Data Collection - December 2010 (Reference 8)

This study was similar to the Reference 7 study in that it aimed to obtain flood intelligence pertinent to the December 2010 Murrumbidgee River flood event. This study provided 19 peak flood level marks for the 2010 flood event. These marks were able to be used during model validation in the Flood Study (Reference 5).

2.2. Other Previous Studies

A number of reports and investigations contributed to the development of the Gundagai Flood Study, which forms the basis of this current study. For brevity, the reports are listed below and are summarised and referenced within the Flood Study report (Reference 5):

- Gundagai Flood Scoping Study, WMAwater, 2013;
- Murrumbidgee River at Gundagai: Flood Frequency Studies – NSW State Government, 1980;
- Gundagai Flood Inundation Map – NSW State Government, 1980;
- The Flood of May, 1925, in the Murrumbidgee River – Water Conservation and Irrigation Commission, 1925;
- Murrumbidgee River Flooding – Flood Intelligence Collection – WMAwater, March 2012 – Draft;
- Murrumbidgee River Flooding – Flood Data Collection – WMAwater, December 2010;
- Burrinjuck Dam PMF Assessment – NSW State Government, 2001;
- Burrinjuck Dam Failure Study – NSW State Government, 1994.

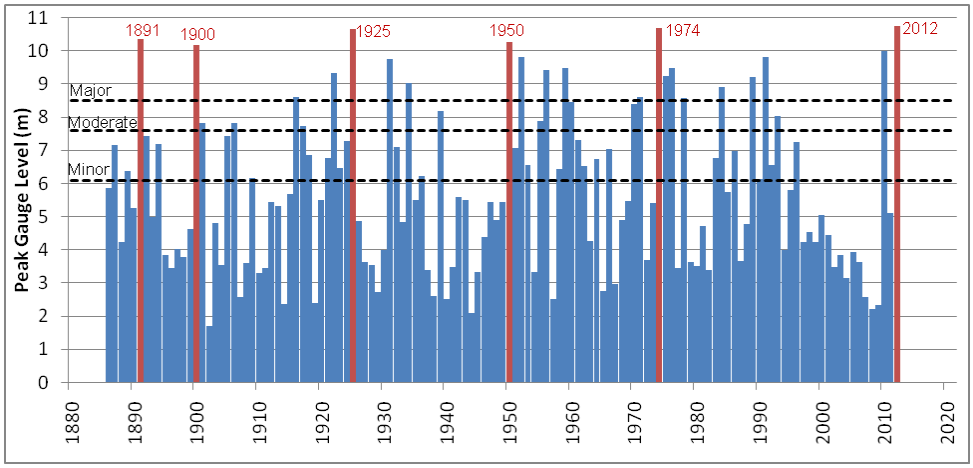
3. EXISTING FLOOD ENVIRONMENT

3.1. Flood History

Flooding at Gundagai is due predominantly to Murrumbidgee River flooding, however anecdotal evidence suggests that flooding may also occur due to Jones Creek. Gundagai has experienced numerous large flood events since it was founded in the early 1800's. It is the site of Australia's worst natural disaster which occurred in 1852 with a large Murrumbidgee River flood that led to the death of 89 people. It was this flood that led to the relocation of Gundagai from the floodplain between the Murrumbidgee River and Morleys Creek to its current location.

Chart 1 displays the annual series of peak flood levels recorded at the Gundagai gauge from 1886 until 2012. The Minor (6.1 m), Moderate (7.6 m) and Major (8.5 m) flood levels are also displayed to give some indication of the magnitude of these events and all events over 10 m at the gauge are displayed in red.

Chart 1: Gundagai Peak Flood Levels – Annual Series



The five largest floods on record at Gundagai occurred prior to construction of Burrinjuck Dam with the largest flood post-construction occurring in 1925[1]. More recently, flood events in 2012 (Section 3.1.1), 2010 (Section 3.1.2) and 1974 (Section 3.1.3) caused significant inundation of property. Table 3 displays events that exceeded 9 m on the Gundagai gauge with the flood of record occurring in July 1853 with a gauge height of 12.6 m.

[1] Note that Burrinjuck Dam was under construction in 1925 and not complete, however it still did pose a significant flow obstruction resulting in large attenuation during this event (Reference 5).

Table 3 Summary of historic and design peak flood levels and flows

Flood Event	Gauge Height (m)	Level (mAHD)	Flow (m^3/s)
PMF	19.8	226.97	29,900
0.20%	13.0	220.09	8,600
1853	12.6	219.73	na*
0.50%	12.3	219.46	7,000
1852	12.3	219.43	na
1870	12.3	219.43	na
1%	11.9	219.06	6,100
1900	11.7	218.83	na
2%	11.5	218.65	5,200
June 1891	11.5	218.63	na
1925	11.3	218.43	5,914
1974	11	218.13	5,253
1879	11	218.13	na
2012	10.9	218.03	3,999
5%	10.8	217.93	3,800
1950	10.4	217.53	4,035
January 1891	10.3	217.43	na
2010	10.2	217.33	2,553
10%	10.1	217.21	2,600
1952	10	217.13	3,004
1959	9.9	217.03	3,022
1931	9.9	217.03	3,161
1991	9.8	216.93	2,689
1976	9.6	216.73	2,334
1934	9.6	216.73	2,557
1956	9.6	216.73	2,091
1922	9.4	216.53	2,025
1989	9.3	216.43	1,952
0.2 EY	9.12	216.25	1,300
1984	9.1	216.23	1,751

Note: Gundagai gauge zero = 207.13 mAHD

Design Flood Event (Reference 5)

na: Flow has not been calculated as an appropriate rating curve for pre-dam conditions was not available.

3.1.1. Murrumbidgee River Flood Event – 2012

The most significant Murrumbidgee River flood event in recent history occurred in March 2012. Homes, businesses and land were inundated from Jugiong to Darlington Point. After two days of river levels exceeding minor and moderate flood levels at Gundagai, river levels exceeded the major flood level classification on 4th March. In the early hours of 5th March flow began to increase dramatically. This increase in flow raised the flood level by 0.8 m from the initial predicted level of 10.2 m (peak level of the 2010 flood) to a gauge height of 10.92 m at 12 noon 5th March 2012. This meant that in the space of 12 hours the March 2012 flood event escalated from being a relatively minor flood to a flood event only 100 mm lower than the 1974 flood. The March 2012

flood event was used to calibrate the Murrumbidgee River hydraulic model in the Flood Study (Reference 5).

3.1.2. Murrumbidgee River Flood Event – 2010

The 2010 flood peaked at 10.2 m on the Gundagai gauge at 1:00 pm on the 4th December and was the largest Murrumbidgee River flood since 1974. During the event approximately four houses were flooded along with a number of commercial properties as well as large areas of agricultural land. The December 2010 flood event was used to validate the Murrumbidgee River hydraulic model in the Flood Study.

3.1.3. Murrumbidgee River Flood Event – 1974

The 1974 flood event peaked at 11.0 m on the Gundagai gauge at 1:00 am on the 30th August and is the largest flood in recent history. It is estimated to have an AEP of between 5% and 2%. During the event approximately 12 houses were flooded over floor. It is estimated that the 1974 event was attenuated by 16% by the Burrinjuck Dam, which was close to 100% capacity at the start of the event (Reference 5). This event was used to calibrate the Murrumbidgee River hydraulic model in the 2018 Flood Study (Reference 5).

3.2. Jones Creek Flooding

Anecdotal evidence indicates that there has been little flooding of home or property due to Jones Creek since construction of the drain that runs parallel to Hanley Street in the 1960's. Prior to this, flooding was reported to have occurred along Punch Street and in the surrounding regions on a number of occasions in both the 1930's and 1950's. One community consultation respondent noted that "Flooding has not occurred in Punch Street since the early seventies" and that at this time flood depths were "only about 8 – 10 inches deep".

Flooding due to Jones Creek was not reported to have affected homes in 1974, 2010 or 2012 with the mitigating effects of the Hanley Street drain likely reducing peak flood levels. Community consultation indicated that recent Council works on the creek bed downstream of Punch Street have also assisted to alleviate flooding in the upstream reaches.

3.2.1. Jones Creek Flood Event - 2012

In the 2012 event, the local Jones Creek catchment received significant rainfall (78.4 mm recorded at 9 am on the 4th of March) resulting in high flows in the early hours of the same day. However, these flows occurred prior to, and did not exceed, the Murrumbidgee River peak, and were not the cause of over floor flooding. High water levels in Jones Creek itself were a result of back-watering from the Murrumbidgee River, as the Jones Creek catchment experienced only minor rainfall (2.4 mm at the William Street gauge) during the 24 hours prior to the Murrumbidgee River peak, which occurred at midday on the 5th March.

3.3. Changes to the Flood Model since the Flood Study

At the July 2017 Council Meeting, funding was announced for the new Sewage Treatment Plant in Gundagai. At the time of writing, Cootamundra – Gundagai Regional Council resolved to proceed with the concept design (for subsequent detailed design and construction) of a new sewage treatment plant (STP) on the existing site, which would involve decommissioning some of the existing STP buildings/tanks. Council indicated that the concept design would be very similar to that proposed at Tumbarumba.

As the concept design plans were not available at the time of the model review, WMAwater assumed a building with a footprint of 0.45 hectares (75 m diameter) would be constructed on the site. The flood model was modified to represent the potential obstruction that would be caused. The impact of the building in the 1% AEP event is shown below, and indicates that flood level impacts are localised to the area immediately adjacent to the STP site, while flood levels in the broader study area and town centre are not sensitive to this development. This footprint assumption is considered suitable for the purposes of the Floodplain Risk Management Study, however subsequent updates should refine the building assumption using design drawings or works as executed plans as available.

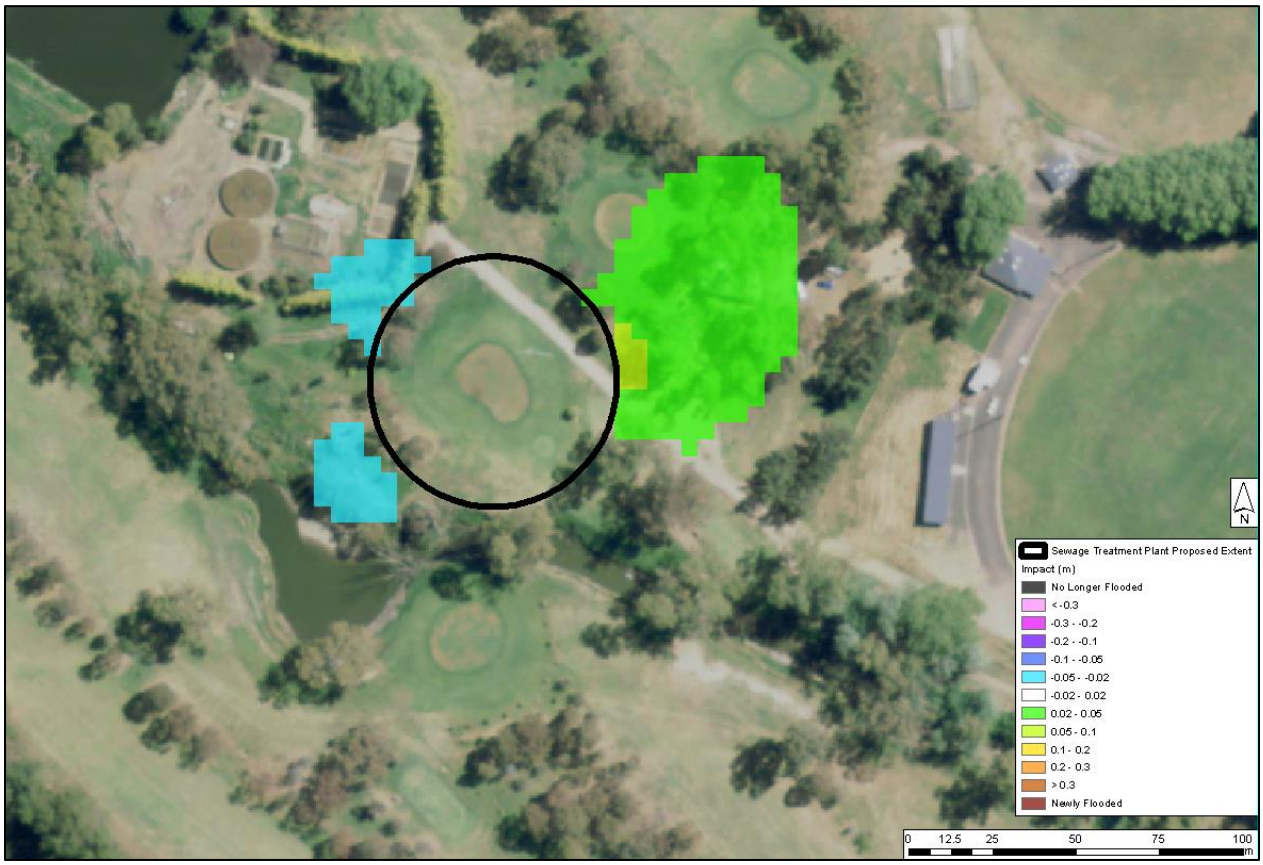


Diagram 1 1% AEP flood impact of assumed STP building footprint (75 m diamater building) (Figure 44 from Reference 5).

Council noted that the new STP would be designed to be fully operational in flood events up to and including the 0.2% AEP (500 year ARI) event (which would reach 12.96 m on the Gundagai gauge).

3.4. Design Flood Behaviour

The design flood behaviour for Gundagai based on Murrumbidgee River and Jones Creek flooding was defined in the Gundagai Flood Study (Reference 5). Peak flood depths and levels for the design events (0.2 EY, 10%, 5%, 2%, 1%, 0.2% AEP and the PMF) are displayed on Figure 5 to Figure 11. It should be noted that all depths less than 200 mm have been trimmed from the Jones Creek model results.

Table 4 displays the peak flood heights and flows at the Gundagai gauge for the range of design flood events. Note this data is provided alongside data from historic events in Table 3.

Table 4: Gundagai Gauge – Design Peak Flood Heights and Flows

Event	Peak Gauge Height (m)	Event Peak Flow (m^3/s)	Event Peak Flow (ML/day)
0.2 EY	9.1	1,500	130,000
10% AEP	10.1	2,600	225,000
5% AEP	10.8	3,800	328,000
2% AEP	11.5	5,200	449,000
1% AEP	11.9	6,100	527,000
0.2% AEP	13.0	8,600	734,000
PMF	19.9	29,000	2,506,000

Flood extents and depths across the Gundagai catchment scale rapidly in frequent events although the majority of the floodplain is inundated from the 5% AEP event and above. Thereafter flood depths and extents increase only marginally with event rarity event before a larger increase to both in the PMF event.

3.4.1. Hydraulic Categorisation

Hydraulic categorisation of the floodplain is used in the FRMS&P process as a tool to assist in the assessment of the suitability of future types of land use and development, and the formulation of floodplain risk management plans. The Floodplain Development Manual (Reference 2) defines land inundated in a particular event as falling into one of the three hydraulic categories listed in Table 5.

Table 5 Hydraulic Categorisation Definitions (*Floodplain Development Manual* (Reference 2))

Category	Definition
Floodway	• Those areas where a significant volume of water flows during floods; • Often aligned with obvious natural channels; • Areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which my adversely affect other areas; and • Often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
Flood Storage	• Parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood; • If the capacity of a flood storage area is substantially reduced, for example by the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased; and • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
Flood Fringe	• Remaining area of land affected by flooding after floodway and flood storage areas have been defined; • Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The Flood Study (Reference 5) determined the floodway independently for the Murrumbidgee River and Jones Creek flooding for the 1% AEP event, and then applied the same methodology for the 5% AEP and 0.2% AEP events. The two waterways were investigated separately due to having two distinct flooding mechanisms (i.e. mainstream and overland), and it was recognised that characteristics (such as velocity, depth and velocity-depth products) suitable for defining hydraulic categories in the Murrumbidgee River would not be appropriate to apply to Jones Creek.

To define the floodway, the Flood Study used the Howells et al. (Reference 11) methodology, which differentiates the floodway from other hydraulic categories by selecting a velocity-depth product criteria that exceeds a specific threshold. These parameters were confirmed iteratively through encroachment analysis, in which all areas not defined as 'floodway' were totally excluded from the modelling domain, and the subsequent impact on flood levels examined. If the reduction in conveyance area resulted in an increase in greater than 0.1 m to existing flood levels, the floodway area was increased. This approach is informed by Section L4 of the Floodplain Development Manual (Reference 2), which defines Flood Storage areas as *"those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%."* The resulting parameters are provided in Table 6.

Table 6 Floodway Definition Parameters

Waterway	Floodway Definition Parameters
Murrumbidgee River	a) VD > 0.6 m^2/s and V > 0.6 m/s; or V > 0.6 m/s b) VD > 0.65 m^2/s and V > 0.65 m/s; or V > 0.65 m/s
Jones Creek	a) VD > 0.15 m^2/s and V > 0.15 m/s; or V > 1.0 m/s b) VD > 0.35 m^2/s and V > 0.35 m/s; or V > 1.0 m/s c) VD > 0.7 m^2/s and V > 0.7 m/s; or V > 1.0 m/s

The 2012 paper by Thomas et al. (Reference 12) presented an investigation which observed that "the 'corridor' required to convey approximately 80% of the peak 1% AEP flow correlated well with most of the other parameters that are relied upon to estimate the floodway extent" (e.g. the 0.1 m afflux approach described above). The Flood Study (Reference 5) further verified the selected parameters (shown in Table 6) by investigating the percentage of flow conveyed within the floodway, and confirmed it met the ~80% total flow criteria described in Reference 12. A full description of the approach is included in Appendix F of the Flood Study (Reference 5).

Hydraulic Categorisation for the 5% AEP, 1% AEP and 0.2% AEP events are shown on Figure 12, Figure 13 and Figure 14 respectively. The analysis indicates that much of the inundated land is classified as floodway in both the 1% AEP and 5% AEP events. The in-bank areas of Jones Creek itself are generally classified as floodway in both the 1% AEP and 5% AEP event and out of bank flooding on properties between Sheridan Street and West Street is generally classified as flood fringe.

In Gundagai in the 1% AEP event, several commercial premises on Sheridan Street between Jones Creek and West Street lie within the floodway extent. The 1% AEP floodway also impinges on several lots (mostly commercial) that back onto Sheridan Lane. In addition to this, the Jones Creek floodway includes a number of properties along Punch Street and Hanley Street, with some lots completely within the floodway extent. In South Gundagai, one residential property on Brungle Road lies within the floodway. The floodway encroaches on the backyards of several residential properties on Tumut Street, as well as the Gundagai Water Treatment Plant located just upstream of the Middleton Drive bridge.

3.4.2. Hydraulic Hazard Classification

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development and people. In the Floodplain Development Manual (Reference 2) hazard classifications are essentially binary – either Low or High Hazard as described on Figure L2 of that document. However, in recent years there has been a number of developments in the classification of hazard especially in *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 9). The Flood Study (Reference 5) presents hazard categorisation mapping based on the Floodplain Development Manual, while this study presents revised mapping based on the methodology outlined in Reference 9. The classification is divided into 6 categories (H1-H6), listed in Table 7, which indicate constraints of hazard on people, buildings and vehicles appropriate to apply in each zone.

Table 7: Hazard Categories

Category	Constraint to people/vehicles	Building Constraints
H1	*No constraints*	*No constraints*
H2	Unsafe for small vehicles	*No constraints*
H3	Unsafe for all vehicles, children and the elderly	*No constraints*
H4	Unsafe for all people and all vehicles	*No constraints*
H5	Unsafe for all people and all vehicles	Buildings require special engineering design and construction
H6	Unsafe for people or vehicles	All building types considered vulnerable to failure

The criteria and threshold values for each of the hazard categories are presented in Diagram 2.

Diagram 2: Hazard Classifications

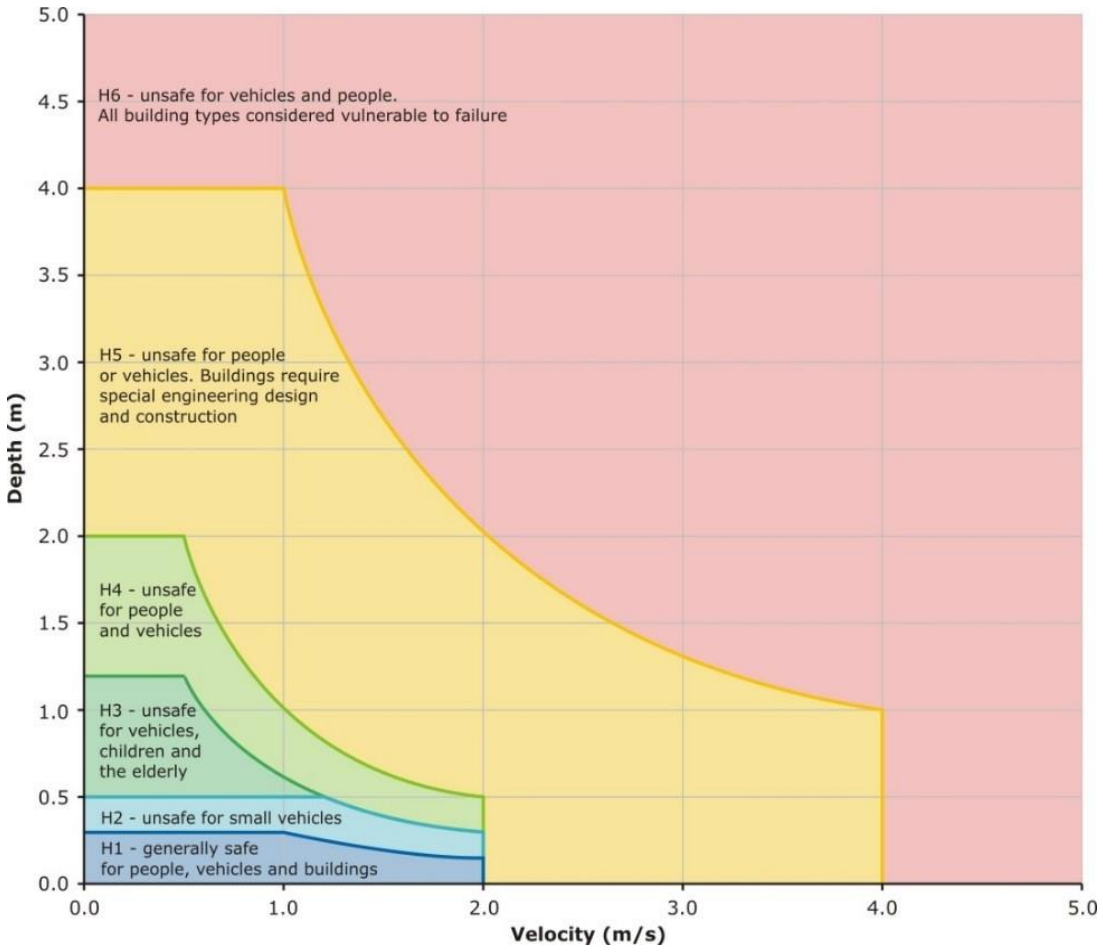


Figure 15, Figure 16 and Figure 17 present the hazard classifications based on the H1-H6 delineations for the 5% AEP, 1% AEP and 0.2% AEP events respectively. Under this classification for a 1% AEP event much of the floodplain outside the town centre is classified as either:

- H5, which is considered unsafe for people or vehicles and buildings require special engineering design and construction; or
- H6, which is considered unsafe for people or vehicles and buildings are considered vulnerable to failure.

Areas in the Gundagai township range from H1 (generally safe for people, vehicles and buildings) to H3 (unsafe for vehicles, children and the elderly).

3.5. Economic Impacts of Flooding

A flood damages assessment has been undertaken to determine the economic costs of flooding due to the Murrumbidgee River and Jones Creek in Gundagai. Damages can be defined as either tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Damages are further categorised as being either direct or indirect. Direct damages are caused by direct contact with flood water, for example damage to buildings and their contents. Indirect damages refer to the knock-on effects of flood events, such as loss of wages, traffic disruption.

The below assessment focuses on the direct tangible damages caused by flooding in Gundagai and forms the basis of quantifying the benefits of certain mitigation measures investigated later in this study. Analysis of intangible aspects are captured via a multi-criteria matrix assessment (see Section 7). The methodology and results have been summarised below, while a detailed description of the assessment methodology is provided in Appendix C.

3.5.1. Assessment Methodology

The flood damages assessment followed the below steps:

- **Establish design flood modelling results** for the 0.2 EY, 10%, 5%, 2%, 1%, 0.2% AEP and the PMF events. Flood modelling results are derived from the model established in the Flood Study (Reference 5) and updates made in this FRMS&P (described in Section 3.3), and are enveloped to include the peak flood affectation from both Jones Creek and the Murrumbidgee River;
- **Obtain floor level data**
    - Surveyed floor level data was obtained for 82 properties that were estimated to be located within the 1% AEP flood extent;
    - Floor levels for the remaining 93 properties situated within the Murrumbidgee River PMF extent were estimated by site visit and LiDAR data (Reference 5);
- **Determine the peak flood depth** that would occur at each property during each design flood event;
- **Apply stage – damage curves** (derived from OEH Guidelines, Reference 10) to relate the depth of flooding to a monetary cost in each design flood event;
- **Calculate the Average Annual Damage (AAD)**. The AAD represents the estimated tangible damage sustained every year (on average), over a long period of time.

Note that the results are not an indicator of individual flood risk exposure, but part of a regional assessment of flood risk. Furthermore, the purpose of the damages assessment amount is not to calculate the actual damage that would be incurred in a flood, but to forms a basis of comparison

with other flood prone communities throughout NSW, and a baseline against which mitigation options can be assessed.

3.5.2. Results

The flood damages in Gundagai due to flooding in Jones Creek and the Murrumbidgee River are summarised in Table 8 to Table 10. In addition to assessing potential costs due to flooding, the damages assessment is useful in identifying the frequency of event in which residential and commercial properties are likely to be first flooded above floor level. Figure 18 shows all properties in the Study Area that are flooded above floor, categorised by the design event in which they would first be subject to over-floor flooding. The figure shows only a few properties either on or near Sheridan Lane would be affected in events less than a 10% AEP event, while the majority of commercial properties in Sheridan Street are not inundated until above a 2% AEP event. Residential properties north of Sheridan Lane and around Jones Creek and South Gundagai are generally not overtopped in events less than the PMF.

Table 8 Combined (Residential and Commercial/Industrial) Flood Damages for Gundagai

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	52	14	$ 1,255,333	24	$ 24,141
10% AEP	60	22	$ 2,213,251	22	$ 36,888
5% AEP	75	30	$ 3,121,191	17	$ 41,616
2% AEP	92	44	$ 4,807,761	15	$ 52,258
1% AEP	103	59	$ 6,876,474	7	$ 66,762
0.2% AEP	127	85	$ 11,761,843	9	$ 92,613
PMF	267	244	$ 38,236,225	6	$ 143,207
Average Annual Damages (AAD)			**$ 796,747**		**$ 2,984**

Table 9 Residential Flood Damages for Gundagai

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	41	10	$ 801,728	25	$ 19,554
10% AEP	47	16	$ 1,324,544	22	$ 28,182
5% AEP	60	23	$ 1,929,137	17	$ 32,152
2% AEP	72	31	$ 2,721,561	14	$ 37,799
1% AEP	79	42	$ 3,828,427	7	$ 48,461
0.2% AEP	98	62	$ 6,591,962	9	$ 67,265
PMF	215	192	$ 25,410,772	7	$ 118,190
Average Annual Damages (AAD)			**$ 483,949**		**$ 2,251**

Table 10 Commercial Flood Damages for Gundagai

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	11	4	$ 453,606	22	$ 41,237
10% AEP	13	6	$ 888,707	21	$ 68,362
5% AEP	15	7	$ 1,192,055	17	$ 79,470
2% AEP	20	13	$ 2,086,200	16	$ 104,310
1% AEP	24	17	$ 3,048,046	8	$ 127,002
0.2% AEP	29	23	$ 5,169,881	11	$ 178,272
PMF	52	52	$ 12,825,453	6	$ 246,643
Average Annual Damages (AAD)			**$ 312,798**		**$ 6,015**

[1]'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)
[2]'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.

3.6. Management of Future Flood Risk

The Floodplain Risk Management Study examines not only the current flood risk, but takes into account flood management into the future by considering elements such as climate change, future development areas and the impacts of cumulative development across the floodplain.

3.6.1. Climate Change

Human-induced climate change is expected to have (and to be having) an effect on rainfall intensities, and should therefore be incorporated in the assessment of design flood behaviour for a particular area. However, there is uncertainty over the ways in which climate change will manifest itself in Australia. In the case of flood estimation, there is uncertainty over how much rainfall intensities will increase by (in the long term), and how changes in other variables (e.g. evaporation and temperature) will influence runoff.

The impact of climate change on flood behaviour in the study area has been assessed in the Flood Study (Reference 5). The sensitivity of riverine flooding was assessed by increasing Murrumbidgee River flows by 10%. An increase in flow of 10% yielded an average increase in peak flood levels (in the 1% AEP event) of 0.25 m. Local catchment flooding is typically controlled by rainfall, and as such the Flood Study (Reference 5) assessed the sensitivity of the local catchment (Jones Creek) model by varying the rainfall intensity. Results showed that, for an increase in rainfall of 10%, the peak flood levels would increase by 0.06 m on average. In parts of the Jones Creek catchment adjacent to properties (particularly Punch Street), variations of up to 0.15 m were noted.

These variations are within the freeboard allowance for flood planning levels for mainstream areas. Refer to the freeboard assessment in Appendix E and discussion of flood planning levels in Section 6.6.4.

3.6.2. Future Development

At this time of writing, Council noted that the main type of development occurring in Gundagai was 'infill development', rather than 'new development'. Infill development refers to the development of vacant blocks of land that are generally surrounded by developed properties, and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development (Reference 2). Development controls for this type of development are recommended in Section 6.6.6.

'New Development' refers to development of a completely different nature to that associated with the former land use, and often involves re-zoning and major extensions of existing urban services, such as roads, water supply, sewerage and electricity. The establishment of future 'new development' strategies in Gundagai should not be undertaken without consideration of the mainstream and overland flood risk defined in the Flood Study (Reference 5) and this Floodplain Risk Management Study.

4. CONSULTATION

One of the central objectives of the FRMS&P process is to actively liaise with the community and stakeholders throughout the process to achieve the following key outcomes:

- Inform the community about the current study;
- Identify community concerns in regard to flooding;
- Gather ideas and information on potential management options for the floodplain; and
- Seek feedback on recommended options via Public Exhibition.

4.1. Community and Stakeholder Consultation

"Community" refers to government (both state and local departments), business, industry and the general public. Consultation with the community is an important element of the Floodplain Risk Management process facilitating community engagement, building confidence in flood modelling tools, and leading to acceptance and ownership of the overall project.

An inception meeting was held with staff from Cootamundra- Gundagai Regional Council, SES, Fire and Rescue, and the NSW Ambulance Service and WMAwater. Following the inception meeting WMAwater prepared a community newsletter and questionnaire (online and hardcopy) which was advertised to all residents via the Council newsletter. The questionnaire asked residents for suggestions of potential flood risk mitigation options to be investigated as part of the study, however only three responses were received. A copy of the newsletter and questionnaire is provided in Appendix B.

Much greater insight into the flood issues in Gundagai was gained via speaking directly to several community members. WMAwater held interviews (either face to face or over the phone) with representatives from the following organisations:

- Gundagai Services Club;
- Gundagai SES;
- Gundagai Newsagency;
- Gundagai Anglers Club;
- Gundagai River Camping and Caravan Park;
- Riverina Local Land Services;
- Gundagai Flood Association; and
- Mitre 10 (corner Byron Street and Sheridan Lane).

The following trends were observed across all interviewees:

- Respondents did not expect Council to "fix" flood issues, and were generally very happy with the way flooding is managed in Gundagai;
- Strong relationships existed between affected parties and the SES and Council;
- Widespread understanding that Gundagai, being on the Murrumbidgee River, is subject to flooding. Large events are managed well enough with evacuations;
- Frequent events (less than say 10% AEP, where evacuations are not required but flooding does cause some inconvenience) are where improvements could be made;

- Otway St Causeway is closed frequently due to overtopping in local rain events as well as larger floods. This was noted to be a nuisance and inconvenience amongst residents, but not a major issue; and
- Many respondents identified that a levee along Sheridan Lane may delay/ prevent inundation from Morleys Creek in small events, but it was generally agreed that it would not be a viable option. There was some interest in temporary flood barriers that could be utilised by commercial premises along Sheridan Street to exclude floodwaters from the properties.

4.2. School Engagement

As described above, engagement with the community is vital to involving residents in the FRMS&P process, gathering their suggestions for flood risk mitigation strategies, and building a sense of ownership of the study and its outcomes. As a way to engage with young people in the Gundagai community and extend the reach of community consultation to students, teachers and parents, WMAwater and Council staff visited Gundagai High School. An hour-long lesson on flooding and flood risk management was presented to two Year 9 Geography Classes in early April, 2018. The session included a local knowledge quiz, discussion on the types of damages that floods can cause, a brief introduction to flood modelling, and a brief overview of types of mitigation measures (flood modification, response modification and property modification, described further in Section 6.1). Students were then asked students to brainstorm potential mitigation options that could reduce flood risk in Gundagai. Some photos from the session are shown in Plate 1.

Ideas ranged from major flood modification measures such as construction of a new dam on the Murrumbidgee River and excavation of a detention basin on the Gundagai Commons, to response measures such as better management of moving livestock to dry ground during a flood event. Some student suggestions are listed below:

- Divert the Murrumbidgee River around Gundagai;
- Use levees and barriers (permanent or temporary, e.g. sandbags)*;
- Retarding/Detention basins in various locations, e.g. Gundagai Commons*
- Build houses on high ground and “live on the hills”;
- Construct more dams/ raise existing dam walls*;
- Vegetation and debris management “Clean out trees and stuff”*;
- Deepen/ widen rivers*

*Suggestions marked with an asterisk are included in the preliminary identification of management measures, described in Section 6.3. The school engagement also presented an opportunity to extend the reach of the community consultation material, however unfortunately did not result in receiving many more questionnaires. An excerpt from the Gundagai High School newsletter describing the study is included overleaf, which at the very least may have made more residents aware the study was being undertaken.

YEAR 9 SCIENCE/GEOGRAPHY COLLABORATION

Recently, as part of their geography studies Year 9 students were greeted with guest presenter Catherine Goonan from WMA Water, who presented information about causes of floods, flood analysis techniques and flood mitigation measures. Catherine is conducting a project looking into methods of managing floods in our area. As students form part of our community, G-CRC and WMA water are keen to include the students' ideas about appropriate flood mitigation measures into the project.

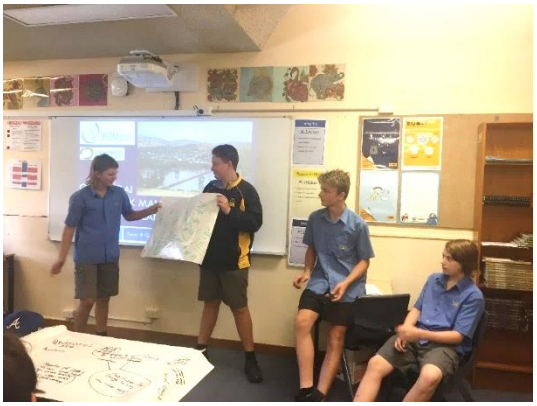
Catherine will return later in the year to present the projects findings to the students as part of their science studies on Local Systems. As part of our school community, if you would like to have your say on managing flood risk in Gundagai please use this link: https://www.surveymonkey.com/r/gundagai

Ms Allison Appleby
Head Teacher Science

157 Hanley St GUNDAGAI Ph: 02 6944 1233 Email: gundagai-h.school@det.nsw.edu.au

Excerpt 1 An article from the Gundagai High School Newsletter (23rd March 2018) describing the flood engagment session with Year 9 students and inviting parents to participate in the community consultation.

Plate 1 Flood Engagement Lesson with Year 9 Geography classes at Gundagai High School



4.3. Public Exhibition

At the Ordinary Meeting of Council held on Tuesday 30th October, 2018, Council resolved to place the draft Gundagai FRMS&P on Public Exhibition for 28 days. The report was made available online via Council's *Have Your Say* website from the 1st to the 29th November 2018. No submissions were received during the Public Exhibition period.

5. CURRENT FLOODPLAIN RISK MANAGEMENT

5.1. Planning and Policy Review

5.1.1. National and State Planning Context

It is important to understand the national and state legislation that overarches appropriate local legislation to ensure proposed floodplain risk management measures are in keeping with both state and local statutory requirements. The national and state legislation instruments that influence or align with planning in relation to flood risk at the local government level have been listed below and are described in more detail in Appendix C:

- National Provisions – Building Code of Australia
- State Provisions:
    - NSW Environmental Planning and Assessment Act 1979 and Ministerial Direction 4.3;
    - NSW Flood Prone Land Policy;
    - Planning Circular PS 07-003;
    - Section 10.7 planning certificates (discussed in Section 5.1.2.4 below);
    - State Environmental Planning Policy (Exempt and Complying Development Codes (2008));
    - General Housing Code; and
    - Rural Housing Code.

5.1.2. Local Planning Provisions

Appropriate planning restrictions and ensuring development is compatible with flood risk can significantly reduce flood damages. Environmental Planning Instruments (EPIs) such as Local Environmental Plans (LEPs) guide land use and development by zoning all land, identifying appropriate land uses allowed in each zone. Development in appropriate zones is then managed through other planning standards such as Development Control Plans (DCPs) which can contain flood related development controls. Section 10.7 (formerly Section 149) Planning Certificates inform a property owner if such controls are required for development on their property. These three instruments are described below.

5.1.2.1. Local Environmental Plan

LEPs are an integral part of the NSW planning system. In 2006, the NSW Government initiated the Standard Instrument LEP program and produced a new standard format to which all LEPs should conform. An LEP is a legal document prepared by Council and approved by the State Government to regulate land use and development. In regards to flooding, LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. The Gundagai LEP 2011 was prepared under the Standard Instrument LEP program. The Gundagai LEP clause (Clause 6.4) relating to flooding has been provided overleaf.

Gundagai LEP 2011: Clause 6.4 Flood Planning

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

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

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:
- *(a) is compatible with the flood hazard of the land, and*
- *(b) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
- *(c) incorporates appropriate measures to manage risk to life from flood, and*
- *(d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
- *(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

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

(5) In this clause:
flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.3 metre freeboard.

5.1.2.2. Flood Planning Area

It is noted that at the time of writing Council did not have a Flood Planning Area map for Gundagai, as the necessary flood information had not been available. A Flood Planning Area map has been developed as part of this study, described further in Section 6.6.4.

5.1.2.3. Development Control Plans

Development Control Plans (DCPs) are used by Councils to regulate development on flood prone land. There is currently no DCP applicable to Gundagai. At the time of writing, Cootamundra – Gundagai Regional Council had noted that drafting the DCP for the merged Councils was planned for 2019 to formalise the flood related development guidance currently provided to developers (such as suggested minimum floor levels or height of internal power points, for example). Council staff noted that while there was limited development in the Gundagai region, it would be beneficial to formalise requirements relating to flooding for clarity for both the proponent and Council assessor.

Suggestions for possible types of flood related development controls are provided in Section 6.6.6 that Council may consider for inclusion in the revised DCP.

5.1.2.4. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the restrictions on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) planning certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

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

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

3. *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property.

Cootamundra – Gundagai Regional Council does not currently include flood information on Section 10.7 Planning Certificates, as until recently, flood information has not been available. With completion of the Flood Study (Reference 5) and this Floodplain Risk Management Study, up to date flood information will be available for Council to include on Section 10.7 Planning Certificates. Suggestions for types of additional information to include on Section 10.7 (5) Planning Certificates are provided in Section 6.6.5.

5.2. Current Local Flood Management Practices

Interviews with local business owners and residents confirmed that the SES and Council manages flooding in Gundagai very effectively. This is thought to be due to a combination of available warning time, available resources, the fact that relatively few properties are directly affected by flooding, and the involvement and leadership of experienced SES and Council staff.

The local Gundagai SES and Council provides coordination and assistance to residents and business owners during flood events in Gundagai. Individual businesses do not tend to have their own flood plans, but defer to the SES for instruction in the lead up to or during a flood. This process is considered and reviewed as part of the floodplain risk management options assessed in Section 6.

The Gundagai Flood Intelligence Guide is one of the key tools used by both parties, and contains information regarding the infrastructure affected when the Murrumbidgee River reaches particular gauge heights. This study will take the opportunity to amalgamate the Council and SES versions of the Guide to ensure both parties have consistent information, and where possible use modelled design flood behaviour to confirm the intelligence.

The Gundagai Flood Intelligence Guide has been developed and subsequently verified by real flood events. However, there is a lack of detail about flood impacts in larger events, that is, events rarer than the 2012 event, which reached 10.9 m at the Gundagai gauge and was the largest event since 1974. To improve the level of detail and confidence in the Flood Intelligence Guide above this gauge height, results from the recently completed Gundagai Flood Study (Reference 5) have been examined to identify any roads that may be overtopped or properties that are affected, and to provide an indication of the gauge height at which affectation is likely to occur.

The resulting augmented Gundagai Flood Intelligence Guide is provided to Council and the SES as an electronic spreadsheet. When using the Flood Intelligence Guide, it is important to acknowledge that it is only a guide, and that real floods can behave differently to modelled events due to a range of factors.

The following sections describe specific actions that are undertaken in preparation for a flood event in Gundagai, including preparing commercial properties that are at risk, organising road closures and protecting the Gundagai River Camping & Caravan Park.

5.2.1. Commercial Premises on Sheridan Street

Commercial premises along Sheridan Lane are subject to inundation from Morleys Creek when the Murrumbidgee River is in flood. Water initially backs up via a pipe from Morleys Creek and fills the pit at the rear Mitre 10 carpark (corner Byron Street and Sheridan Lane). Staff typically sandbag the pit to delay ingress of floodwater into the carpark area. Subsequently, the banks of Morleys Creek are breached and floodwater enters the basement level of Mitre 10 when the Murrumbidgee River reaches 8.80 m at the Gundagai gauge. Staff prepare by raising as much floor and low-level shelved stock higher up, and relocating stock via truck to alternative premises.

The Gundagai District Services Club, Bidgee Banks Golf Clubhouse, and Woolworths are also subject to inundation from Morleys Creek, and were affected in the 2012 event. The Golf Clubhouse building is located south of Sheridan Lane directly beside Morleys Creek, and has storage of stock and golf carts on the ground floor. Stock and carts require relocation in the event of a flood. Photo 1 to Photo 4 overleaf show high water marks and inundation during the March 2012 event.

Photo 1 High water mark at the rear of the Bidgee Banks Golf Clubhouse (10.9 m at the gauge, March 2012) (Photo WMAwater, 2018)

Photo 2 High water mark at the rear of the Bidgee Banks Golf Clubhouse (Mar 2012) (Photo WMAwater, 2018)

Photo 3 Services Club, March 2012 (Photo J Lico)

Photo 4 Entry to Bidgee Banks Golf Course, Morleys Ck crossing, March 2012 (Photo J Lico)

5.2.2. Road Closures

Access between the Gundagai City Centre and South Gundagai is typically via the Otway Street causeway and Yarri Bridge (Homer Street to Middleton Drive). Both are affected by flooding from Morleys Creek. The Otway Street causeway is overtopped in frequent events (gauge height as low as 3.6 m), and is closed when the Murrumbidgee River reaches 4.60 m on the Gundagai Gauge (according to the SES Flood Intelligence Guide). The Otway Street causeway is first affected by water backing up along Morleys Creek from the Murrumbidgee River, and secondarily by water flowing through Morleys Creek from the east. During flood events, Morleys Creek crossings are monitored by SES staff (in person), who alert Council staff when the road has been, or will shortly be, overtopped. Council staff then close and lock gates on Otway Street near Sheridan Lane (Photo 7). Yarri Bridge is overtopped at approximately Gauge 7.20 m (Photo 8) The gauge height at which Yarri Bridge is closed is not documented separately in the SES Flood Intelligence Guide.

Photo 5 Otway Street causeway - before gates were installed, March 2012 (Photo J Lico)

Photo 6 Otway Street looking towards Sheridan Lane, March 2012 (Photo J Lico)

Photo 7 Otway Street Causeway (1 August 2017)

Photo 8 Yarri Bridge (4 March 2012)

Photos from @Gundagai Floods twitter and http://www.abc.net.au/news/2012-03-04/the-murrumbidgee-river-floods-in-gundagai/3867242

Table 11 shows the estimated overtopping level at the Gundagai gauge for various structures due to Murrumbidgee River flooding, based on results from the Flood Study (Reference 5).

Table 11: Estimated Structure Overtopping Level (m) at the Gundagai Gauge

Name	Overtopping Level (m)
Prince Alfred Bridge	15.9
Historic Railway	16.8
Yarri Bridge	7.6
Landon St Bridge	7.6
Byron Street Foot Bridge	7.6
Otway Street Foot Bridge	6.5
Otway Street Causeway	4.6
Golf Course Foot Bridge	7.6
Nangus Road Bridge	11.3
Sheridan Lane Causeway	7.2
Sheridan Street Bridge	11.3

5.2.3. Gundagai River Camping & Caravan Park

The Gundagai River Camping and Caravan Park is located on the right bank of the Murrumbidgee River between the historic Prince Alfred and Railway bridges, on the Gundagai Common off Middleton Drive. The caravan park has 41 sites, powered and unpowered, with amenities, laundry facilities, potable water and wash-up/ BBQ facilities. There are also four cabins on site.

The caravan park's response to flooding is coordinated by the SES, and there is no officially documented 'flood emergency plan' specifically for the caravan park. Water begins to enter the park when the Murrumbidgee River reaches 7.9 m at the gauge, and a predicted peak flood level of 8.50 m at the gauge triggers a full evacuation order (as noted on the SES Flood Intelligence Guide). When a flood warning is received it is communicated directly to campers, and caravan owners are required to keep their caravan hooked to their vehicle in preparation for evacuation. Cabins are easily disconnected from power, water and sewer, and a tractor is brought in to tow cabins to the Middleton Drive Bridge. Assistance is provided by Council and the SES and the general community. Even if not inundated, the Caravan Park is effectively closed when flooding from Morleys Creek cuts access to Middleton Drive as campers cannot reach the site.

Photo 9 Cabins are towed to Middleton Drive Bridge on 1st of March, 2012

5.2.4. Vulnerable and Critical Facilities

Vulnerable facilities are those in which occupants are likely to require experience difficulties evacuating either due to age or infirmity. Vulnerable facilities may include child care centres, preschools, schools, hospitals and aged care facilities. At the time of writing, there were no vulnerable facilities noted to be located within the PMF extent, as many facilities are situated up the hill north of Sheridan Street. However, many of these facilities would normally be accessed via Sheridan Street, which is restricted by flooding during events of around a 5% AEP level.

Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. Critical facilities in a town might include fire, ambulance and police stations, hospitals, water and electricity supply installations, interstate highways, bus stations and chemical plants. The Gundagai Sewage Treatment Plant is located within the floodway, and at the time of writing was slated to be upgraded and designed to be operational in flood events up to and including the 0.2% AEP event. The STP is discussed in Section 3.3. The Gundagai Water Treatment Plant (WTP) has also been identified as potentially being flood prone. It is located on the southern bank of the Murrumbidgee River just upstream of the Middleton Drive bridge. There are no other critical facilities noted within the PMF extent.

6. FLOODPLAIN RISK MANAGEMENT MEASURES

6.1. Categories of Available Measures

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

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

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

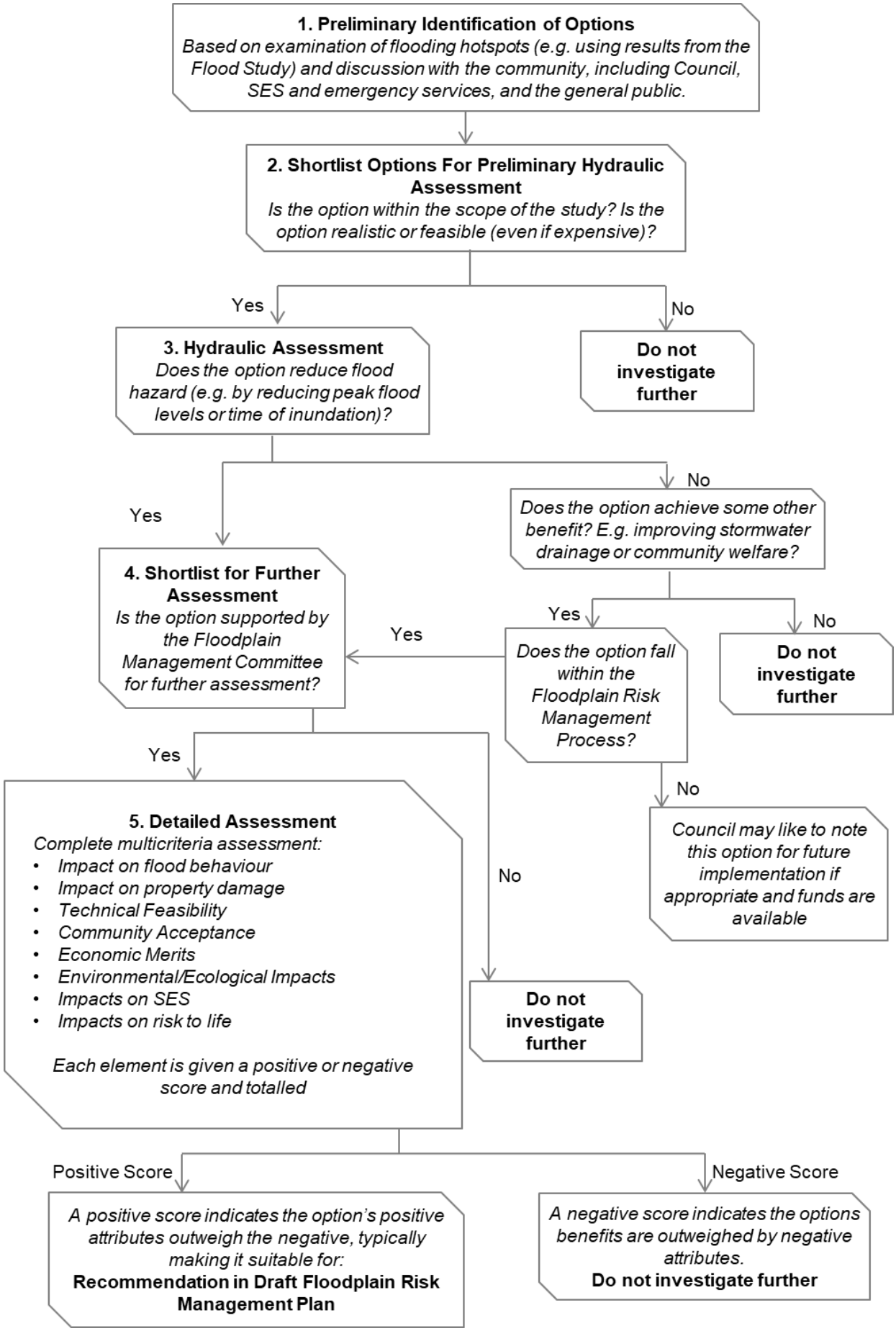
Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

This study assesses options from each category.

6.2. Assessment Methodology

The Gundagai Floodplain Risk Management Study assessed a range of potential options for the management of flooding. The assessment process started with identifying options that may be effective in mitigating flood risk. Suggestions for options were gathered from the community via the initial consultation period (see Section 3.6), as well as discussions with Council, Emergency Services and the examination of available flood modelling and identified hotspots (Reference 5). Options were then shortlisted for hydraulic assessment, and if effective, proceeded to detailed assessment and multicriteria analysis. Options that are scored positively in the multicriteria analysis are typically included in the Floodplain Risk Management Plan for implementation. The assessment process is illustrated in Diagram 3.

Diagram 3 Flood Mitigation Assessment Methodology



6.3. Preliminary Option Identification

Options investigated in the Floodplain Risk Management Study are identified through three main methods: consideration of improving “flooding hotspots” using modelled flood results (i.e. areas of significant depth, velocity or hazard), inspection of property affectation via the property damages assessment, and via discussions with the local community.

Suggestions for potential flood management measures were sought from residents, Council staff and emergency service staff and volunteers via face to face and phone interviews, classroom visits with Year 9 students and a newsletter and questionnaire publicised in the Council newsletter. Community members provided valuable insight into problematic flooding hotspots, and offered a range of suggestions of possible solutions. The inclusion of community suggestions in the subsequent option assessment is critical to identifying useful and effective flood risk mitigation options, as well as engendering a sense of ownership of the Floodplain Risk Management Study in the community.

6.4. Options not investigated further

6.4.1. Gundagai Commons Flood Storage

During the initial consultation period and high school flood workshop, students from Gundagai High School (GHS) suggested a basin excavated in the Gundagai Commons might assist in the reduction of peak flood levels. Given the scale of flooding in the Murrumbidgee River, a basin would have to be of significant proportions to have any substantial impact. The environmental impacts, capital costs, technical difficulties and public safety concerns render this option unfeasible and further investigation is not warranted.

6.4.2. Dredging Local Waterways

Another suggestion coming out of the high school workshop was to widen and deepen the Murrumbidgee River and Morleys Creek with the aim of increasing conveyance and reducing peak flood levels. As described above, the scale of flooding in this region means that substantial earthworks or dredging would be required to make even a minor impact on flood behaviour. Such works would be cost prohibitive and potentially environmentally devastating, and are therefore not appropriate for further investigation. It is also likely that major works on either waterway would not be supported by the local community due to potential impacts on the amenity of Morleys Creek and the Murrumbidgee River.

6.4.3. Modification of major dam operations

Options regarding major dams (in particular Blowering Dam and Burrinjuck Dam) are beyond the scope of the investigation. Furthermore, flood mitigation, which relies on the maintenance of airspace in a dam, is in direct conflict with the primary purpose of these dams, which are designed to store water to supply to downstream towns and irrigators. In addition, Reference 5 notes that Burrinjuck Dam already provides significant flood attenuation even when near-full (for example in

the 2012 flood event, in which Burrinjuck Dam effectively eliminated the first peak of the event and significantly attenuate flows for the second (larger) peak.

6.5. Response Modification Measures

The measures described in this section relate to how the Gundagai community responds to flood emergencies. Options are either designed to improve emergency management procedures, or to improve community flood awareness and preparedness and recovery.

6.5.1. Option RM01: Gundagai Flood Intelligence Improvements

RM01 Overview

☑ It is recommended that the Gundagai Flood Intelligence documents be consolidated to ensure consistency between SES and Council (RM01A), enhanced to include flood information available from the modelling and analysis undertaken in this Study (RM01B), and reviewed and updated following future flood events (RM01C).

Flood Intelligence Guides relate a particular river level (usually in local gauge terms) to action(s), or consequence(s) triggered at that level, for example road closures or evacuation orders. As discussed in Section 5.2, the Gundagai SES and Council rely on flood intelligence documents to effectively manage flood risk. Discussions with the Floodplain Management Committee have identified two key areas in which Gundagai's current flood intelligence documents can be improved. These are described below:

6.5.1.1. RM01A: Consolidation of flood intelligence documents

The Floodplain Management Committee expressed concern that the Council and SES held different versions of the Flood Intelligence Guide, and there may be gaps or conflicting gauge levels attributed to the same action. Work has been undertaken in this Floodplain Risk Management Study to review and consolidate flood intelligence spreadsheets held by Council and the Gundagai SES staff. The review found that the Council and SES Flood Intelligence Guides were near identical, with one additional entry found in the Council's version. An amalgamated version is provided with this Study with additional information and validation provided as described below.

6.5.1.2. RM01B: Addition of modelled flood information to flood intelligence guide

The SES and Council flood intelligence documents have been verified and improved by staff during recent flood events, however the largest events that have contributed to this intelligence were the 2012 event (10.9 at the Gundagai gauge), and before that, the 1974 event (11 m at the gauge). As a result, verified flood intelligence above 11 m at the gauge is limited. Furthermore, intelligence currently focuses on actions related to riverine flooding from the Murrumbidgee River, and does not contain details on the impacts of overland flooding during local rain events within the Jones Creek catchment.

Flood modelling results produced in this study and Reference 5 have therefore been used to:

- Verify and supplement existing intelligence entries (below 11 m at the gauge);
- Extend intelligence to cover rarer events (i.e. above 11 m at the Gundagai gauge);
- Add design flood levels (e.g. 1% AEP) and historic events to the intelligence guide for reference;
- Addition of “Major”, “Moderate” and “Minor” classifications as per the Local Flood Plan; and
- Add key consequences of overland flow due to local rainfall in the Jones Creek catchment.

As local rainfall events can occur independently of Murrumbidgee River levels, it is not appropriate to link actions relating to overland flow to gauge levels. Instead, flood intelligence for local overland flow is related to rainfall characteristics, and is based on analysis that underpins the overland flow flood model (Reference 5). Jones Creek catchment flood intelligence is provided on a separate spreadsheet tab that can be referred to when local rain is forecast. This data should be adopted as a general guideline rather than a definitive action plan as the modelled flood behaviour represents a limited number, size and temporal pattern of storms compared to rainfall patterns that could realistically occur.

Furthermore, it should be noted that the design flood model results have an element of uncertainty associated with each entry, and provided gauge heights should be taken as a guide only. For this reason all flood intelligence entries based on modelled data should be confirmed in real flood events as the opportunity to do so arises. Modelled flood behaviour may differ from real flood behaviour for a number of reasons, including:

- Variability of rainfall patterns;
- Antecedent catchment conditions;
- Range across which each “design event” could reasonably occur; and
- Local variations in flood behaviour, for example due to culvert blockage or local surge from trucks driving through floodwaters etc.

Nevertheless, the addition of modelled consequences at particular gauge heights is valuable to understand the likely sequence of events. The amalgamated and extended flood intelligence guide will be provided to Council and SES as a spreadsheet. This document is recommended to be a “living guide”, (see Post Flood Evaluation in Section 6.5.1.3) and should be updated following each flood event as new information becomes available, especially if changes in typical flood behaviour are noticed, as occurred in the 2012 event. Further to this, details of major developments, such as the new sewage treatment plant should be incorporated into the flood intelligence guide, to ensure that flood operation thresholds are well understood by Council staff. Additionally, the level at which the town power would be disconnected is critical to note in the intelligence, as it affects the function of other critical utilities (such as the water treatment plant).

It is essential to note actions and consequences with as much clarity as possible, and not to rely too heavily on local knowledge. In larger events SES personnel from other regions may be assisting with operations, and will need to be able to accurately interpret intelligence guides with limited local knowledge or familiarity.

6.5.1.3. RM01C: Post Flood Evaluation and Data Collection

It is acknowledged that flood events can be chaotic, and there is unlikely to be the opportunity to record important information during the event itself. However, capturing the lessons learnt during a flood is invaluable to improving the management of subsequent flood events. Therefore, immediately following flood events of any magnitude, it is recommended that a Flood Intelligence Collection and Review is undertaken in Gundagai. The purpose of this review would be to:

- Identify any gaps or shortcomings of flood-related action plans or intelligence guides;
- Collect data including flood marks, community experience, damage to property;
- Keep track of which roads were overtopped (and when, or at what gauge height);
- Identify what worked well and opportunities for improvement in flood response actions;
- Any further items deemed relevant at the time.

Note that this list is not exhaustive and should be developed further by Council in collaboration with the SES. All emergency response documents (including Local Flood Plans and Flood Intelligence Guides) should be updated as or validated necessary to reflect findings of the review to ensure they contain the most up to date information available.

6.5.2. Option RM02: Improve Flood Emergency Management Operations

RM02 Overview

☑ It is recommended the following works are undertaken to improve flood emergency management operations in Gundagai:

- Improve access to Gundagai Gauge Boards (RM02A);
- Install water level sensor at the Otway Street Causeway (RM02B); and
- Update the Gundagai Local Flood Plan using information from this Study (RM02C)

6.5.2.1. RM02A: Access to Gundagai Gauge Boards

Description

The 'Murrumbidgee at Gundagai Gauge' (410004) is located on the south bank of the Murrumbidgee River adjacent to the Gundagai Water Treatment Facility and just east (upstream) of the Middleton Drive bridge. The gauge is electronically read every 15 minutes, with readings uploaded to the WaterNSW Real Time Data portal. Council has noted that if the electronic gauge stops working, which has been known to happen during a flood event, Council and/or SES staff go to the gauge boards to take manual readings. Council and SES staff have noted a number of hazards associated with manual readings that impact on safety and efficiency during flood events. These hazards include:

- Difficult access along the embankment (steep slope, slippery surface due to pine needles, especially in wet weather);
- Visual obstructions and trip hazards due to trees and roots;
- Lack of lighting at the site.

Given the limited number of SES personnel, and Gundagai's reliance on them during flood events, an accident at the gauge boards would significantly disrupt normal flood operations, potentially having severe consequences

Recommendation

A number of relatively simple works could be undertaken to significantly improve the safety of Council and SES personnel during manual gauge readings. These improvements would also assist in reducing the time taken to complete the reading and potentially improve the efficiency of SES operations. The following works are recommended:

- Undertake routine maintenance to trim branches that obstruct the clear view of the gauge boards;
- If possible, remove the tree growing between the 12 m and 11 m marker (see Photo 10) to remove the visual obstruction to lower markers, in line with Council's vegetation management standard operating procedures;
- Install non-slip stairs down the embankment, especially between the 9 m and 12 m markers to improve all-weather access during flood events; and
- Install sensor-operated security lighting at the building adjacent to the gauge board.

Photo 10 Murrumbidgee at Gundagai Gauge (410004)

6.5.2.2. RM02B: Install water level sensor at the Otway Street causeway

Description

As described in Section 5.2.2, the causeway through Morleys Creek at Otway Street is overtopped when the Murrumbidgee River reaches around 4.6 m at the gauge. In the event of an anticipated flood, SES personnel patrol the Otway Street area to make constant visual inspections of the water level in Morleys Creek. Once the causeway is overtopped, the SES staff alert Council, who then close the gates on Otway Street (on the northern side of the creek) and put up road closure signs on the southern side. Patrolling the area (often through the night) places a burden on SES personnel, whose efforts could be better placed either resting or assisting with operations elsewhere.

A wireless water level sensor (such as a DipStik or equivalent) at the Otway Street causeway is recommended to be installed to record water levels and send text message alerts to the appointed agency (likely to be SES and Council), minimising the need for SES personnel to undertake constant visual inspections. This would allow SES staff to be available to respond to other issues or call outs during the flood event. Considerations regarding the use of telemetered water level sensors may include for example:

- Cost of initial purchase and installation and ongoing service and maintenance fees;
- Potential failure of the sensor (e.g. due to being impacted by debris);
- Inaccurate reading of water level (e.g. due to local obstructions in the creek bed);
- Suitable placement of the sensor; and
- Potential damage to the sensor and solar panel for unrelated reasons (e.g. vandalism);
- Identification of the agency responsible for funding, installation and ongoing maintenance.

A cost effective alternative may be to forego the text messaging alert functionality, and install a water level sensor fitted with flashing lights or siren. Significant savings may come from not using a telemetered system which would have ongoing service fees, whilst still reducing the need for SES personnel to be on the ground to continuously inspect the water level. The flashing lights and/or siren would also assist to warn motorists if they arrive before the road has been closed, and should be included even if a telemetered option is pursued. Consideration could also be given to installation of a manually closed boom gate to simplify the road closure, and remove the need for Council staff to retrieve and set up road closure signs.

Recommendation

It is recommended that a detailed assessment of available products is undertaken to identify the preferred product, and determine how it would be funded, used and maintained. If appropriate, it is recommended that the selected product is installed at an appropriate location beside the Otway Street causeway.

6.5.2.3. RM02C: Gundagai Local Flood Plan Update

Description

The Gundagai Local Flood Plan is issued under the authority of the State Emergency and Rescue Management Act 1989 and the State Emergency Service Act 1989. It was accepted by the

Murrumbidgee SES Region Controller and the Gundagai Local Emergency Management Committee. The plan covers the town of Gundagai and the villages of Nangus, Coolac, Tumblong and Muttama, and describes preparedness measures, the conduct of response operations, evacuations, and the coordination of immediate recovery measures for all levels of flooding within the plan area.

Recommendation

It is recommended that the Local Flood Plan is updated to be consistent with the recently completed Flood Study (Reference 5), and updated flood intelligence documents (see Section 6.5.1). Design events reach the following gauge heights at the current Murrumbidgee River at Gundagai Gauge (Station No. 410004):

- 0.2 EY – 9.12 m
- 10% AEP – 10.08 m
- 5% AEP – 10.8 m
- 2% AEP – 11.52 m
- 1% AEP – 11.93 m
- 0.5% AEP – 12.33 m
- 0.2% AEP – 12.96 m
- PMF – 19.84 m

Further to updating referenced design flood levels, it is recommended that the Local Flood Plan is reviewed to ensure all evacuation locations and responsible agencies are up to date, with current contact details available for each. Recommendations pertaining specifically to evacuation management are provided in Section 6.5.4.2

6.5.3. Option RM03: Improve Flood Warning Systems

RM03 Overview

☑ It is recommended that the current flood warning systems in Gundagai are improved in the following ways:

- Investigate installing a water level sensor and signage at Muttama Road near Muttama Creek (RM03A); and
- Improve the ways in which flood warnings are shared with residents and business owners in Gundagai (RM03B).

The Bureau of Meteorology (BoM) provides Flood Warning Services to Gundagai via the Flood Watch notifications. A Flood Watch is a notification of the potential for a flood to occur as a result of a developing weather situation either locally or further upstream, and consists of short, generalised statements about the developing weather including forecast rainfall totals, description of catchment conditions and indications of streams at risk. As specified in the Gundagai Local Flood Plan (Reference 15), the BoM will attempt to estimate the magnitude of likely flooding in terms of adopted flood classifications. Continued cooperation between the SES and BoM is supported by this FRMS. The Gundagai Floodplain Management Committee identified two areas for improvement regarding flood warnings in Gundagai. These are described as follows:

6.5.3.1. RM03A: Installation of water level sensors and signage on Muttama Road at Muttama Creek

Muttama Road near Muttama Creek, approximately 35 km north of Gundagai, is a known location where water overtops the road and accidents commonly occur. While this site is outside of the Gundagai FRMS Study Area, local SES personnel are frequently called to this location to assist motorists who have driven into the floodwater and gotten stuck or swept off the road. A water level sensor with flashing lights (such as DipStik or similar) and additional signage (such as a depth gauge) would assist in warning motorists that there is water over the road and that it is not safe to enter. Reducing the number of accidents at this location would improve community safety, and lead to reduced demand on SES personnel during flood operations.

A water level sensor with telemetered alerts (e.g. DipStik) would have the added benefit of providing additional information to the SES and Council about the flows coming down Muttama Creek. However, as there is already a gauge on Muttama Creek at Berthong, upstream of Cootamundra, this would be a secondary benefit rather than the primary purpose for installing the sensor.

6.5.3.2. RM03B: Improve dissemination of flood warnings to the community

Description

The Gundagai SES is the agency responsible for disseminating flood warnings (from BoM) to the community. The relatively small number of SES personnel however means that this task can become quite onerous when residents or business owners call them directly for information. A centralised point of contact would relieve the SES of this task and provide consistent messages to the community.

The Local Flood Plan (Reference 15) notes that the Gundagai Flood Warning Association provides information directly to members. During the Floodplain Management Committee meetings and initial consultation interviews it was noted that membership was limited (potentially due to residents not being aware, or put off by the membership fee), and the association was only active during flood events. However, there is potential for the association to become a valuable conduit for communication between the SES and the community, reducing the burden on the SES and ensuring consistent messages are given to all members.

Recommendation

It is recommended that the functionality of the volunteer-run Gundagai Flood Warning Association (GFWA) be enhanced to support the SES and deliver warnings to the broader community. Possible improvements may include:

- Assess running costs and consider offering free membership to all residents in Gundagai and the broader floodplain;
- Ensure business owners in flood prone areas are members of the GFWA, potentially as a condition of DA approval for new developments;
- Host annual events to increase community flood awareness (see Section 6.5.4) and provide opportunities for fundraising to cover operational costs;
- Work closely with the SES and Council as an active agency during flood events;

- Be a point of contact for residents, and refer queries to other services as necessary (to reduce number of calls direct to SES personnel);

To complete these tasks successfully, organisers of the Gundagai Flood Warning Association may benefit from training sessions with the SES and Council to confirm their roles and responsibilities during flood events, and ensure they are supported to deliver the required service. Volunteer community groups such as this may be eligible for grants or funding via a range of state and federal sources, potentially including the “Stronger Communities Program” or “Volunteer Grants” program to help offset the proposed elimination of membership fees.

As a first step, it is recommended that Council and the SES meet with the current president and secretary of the association to discuss opportunities for collaboration and improvement moving forward, identify potential challenges, and brainstorm solutions together.

6.5.4. Option RM04: Improve Evacuation Management

RM04 Overview

☑ It is recommended the following works are undertaken to improve flood evacuation management operations in Gundagai:

- Improve access to the Gundagai Showground by raising low points in O.I. Bell Drive (RM04A); and
- General improvements to evacuation procedures, including confirming appropriate locations, responsibilities of assisting agencies, and key trigger levels as part of the Local Flood Plan Update (RM04B).

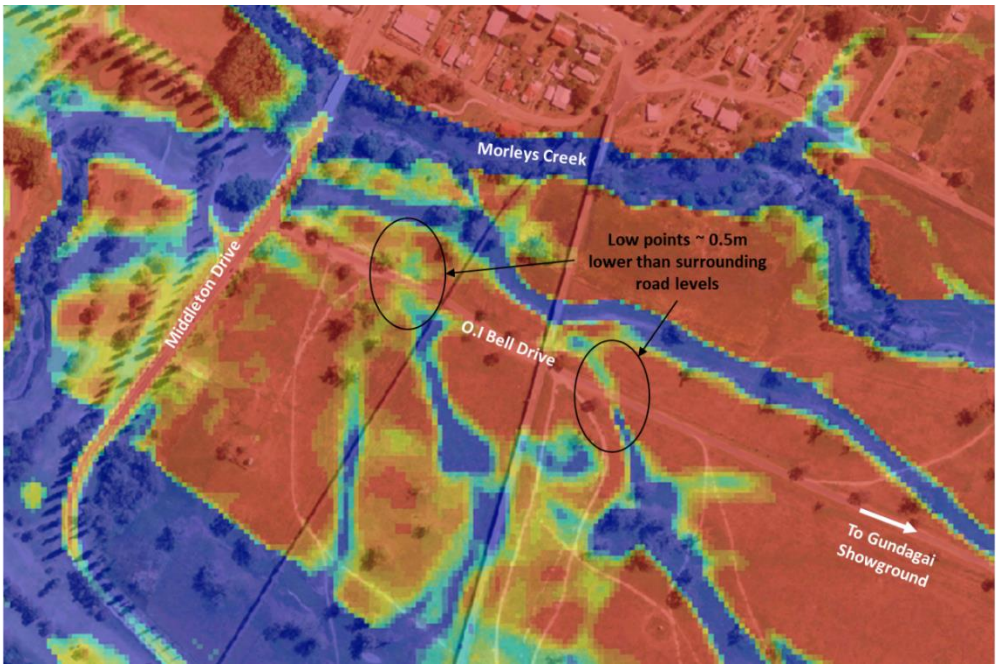
6.5.4.1. RM04A: Access to Gundagai Showground via O.I. Bell Drive

Description

The Gundagai Showground and Racetrack is located between Morleys Creek and the Murrumbidgee River in the Gundagai Commons, with access via O.I. Bell Drive only. The Showground hosts several popular community events throughout the year, including the rodeo, several horse racing events, and ongoing activities associated with the Gundagai Pony Club. At any given time up to 20 horses are stabled at the Showground, with a small number of staff and horse trainers residing onsite. Major events, such as the Snake Gully Cup, can attract over 4000 people to the site.

There are two low points on O.I. Bell Drive in which road levels are approximately 0.5 m lower than surrounding road levels (determined by inspecting the Digital Elevation Model – shown in Diagram 4 and confirmed by a site visit in July 2018 guided by SES personnel). At these points flood runners overtop the road and restrict access between the Showground and Middleton Drive. This occurs when the Murrumbidgee River reaches about 7.6 m at the gauge. These low points form the control for evacuation requirements from the Showground. Furthermore, power must be disconnected by the SES at the Showground before this low point is overtopped and O.I Bell Drive becomes unsafe to cross.

Diagram 4 Digital Elevation Model (ground levels based on LiDAR) showing low points in O.I. Bell Drive



Recommendation

To increase the time available to safely access and evacuate the Showground, it is recommended that the low points in O.I. Bell Drive are raised to tie in with existing levels, and appropriately sized culverts installed beneath the road at the two locations. The flood models developed in the Flood Study do not simulate a small enough event (i.e. more frequently than an 0.2 EY event) to be able to accurately size the culvert or quantify the benefits in terms of extended evacuation time. In lieu of modelled results, it is recommended that the installed culvert aims to replicate existing levels as to maintain flow path connectivity and avoid causing increased flood levels on either side of the road. For reference, the peak flow across each of the low points is estimated to be 0.1 m^3/s in the 0.2 EY event.

6.5.4.2. RM04B: General Evacuation Management Improvements

Description

The Gundagai Local Flood Plan describes evacuation management practices, responsible agencies, and locations of evacuation centres in Gundagai. Whilst relatively few residential properties are affected by riverine flooding, many commercial premises are required to be evacuated in frequent events. As described in Section 5.2.3, the Gundagai River Camping and Caravan Park is typically the first facility to be evacuated, followed by commercial premises on Sheridan Lane.

In rarer events in which residential properties are threatened, there are a number of properties identified as potential evacuation centres. The following are located outside of the PMF extent, though access to the centres may be restricted due to inundation on Sheridan Street:

- Gundagai Community Health Centre at the Gundagai District Hospital
- South Gundagai Primary School, Luke Street, Gundagai

- Anglican Church Hall, Punch Street, Gundagai
- St. Patricks Hall, Homer Street, Gundagai

The Gundagai LFP also notes the "Gundagai Neighbourhood Centre, Punch Street, Gundagai" as a potential evacuation centre. The address of this facility should be confirmed, as there is currently a "Gundagai Neighbourhood Centre" on Sheridan Street, which would difficult to access due to flood affectation in events as frequent as a 5% AEP event. This facility therefore may not be a suitable choice for evacuation centre.

In these rarer events it is possible that power lines are threated, in which case power would be disconnected by the provider. If power is off for a prolonged period the town water supplies may be affected. The Local Flood Plan notes that this may result in *"secondary evacuation of North Gundagai to Yass, and South Gundagai to Tumut because of potential health problems."*

Recommendation

The success of evacuations, whether locally or to other towns, would be greatly improved by increasing the community's awareness of their flood risk, and what they need to do to prepare themselves and their properties for an evacuation. Section 6.5.5 discusses several strategies that could contribute to improving flood awareness in Gundagai.

Further to this, the Local Flood Plan references several evacuation locations and names a number of agencies (such as Department of Community Services (DOCS), Cootamundra Office) as playing a crucial role in managing evacuation centres. It is recommended that this role is confirmed and references to DOCS are replaced with the Department of Family and Community Services (FACS), if appropriate. If not, the responsible agency should be confirmed and Local Flood Plan updated accordingly.

6.5.5. Option RM05: Community Flood Awareness

RM05 Overview

☑ It is recommended that Council establishes a flood education program to improve flood awareness within the Gundagai Community. A range of potential strategies for engaging with the community are provided in this section.

Description

Flood awareness is a vital component of flood risk management for people residing and working in the floodplain. Community members play a key role in the overall floodplain risk management practices, especially by preparing themselves and their property for a flood event. In Gundagai, business owners in particular need to respond in relatively frequent flood events, as many are located in close proximity to Morleys Creek along Sheridan Lane and Sheridan Street.

As described in Section 5.2, business owners and residents are generally reliant on the SES to provide instruction and assistance if evacuation is required. While this is expected to remain the case in future flood events, the burden on the SES would be reduced significantly if business owners (and staff) had a better understanding of their flood risk, and were able to self-manage their own preparations and evacuations, with oversight from the SES. This would become even

more important in larger flood events, where other areas of Gundagai, or villages further afield, may become vulnerable and place additional demands on SES resources.

Recommendations

To improve the flood awareness of the Gundagai community, it is recommended that Council implements a flood education program as part of the Floodplain Risk Management Plan, with a focus on aspects of personal safety and flood preparedness (including evacuation planning). Some strategies that should be considered for inclusion in the program are provided below, and could be tailored to suit Council's needs.

- **Distribute "Flooding in Gundagai" Fridge Magnet to all dwellings and businesses**
  - Provide gauge levels of key local road closures;
  - Information on historic flood levels;
  - Emergency contact phone numbers;
  - A preliminary design is provided Image 1.

- **Site specific flood emergency management plans for commercial properties:**
  - Ensure staff are trained in how (and when) to prepare for a flood, for example;
    - Relocate stock to higher shelves or upstairs;
    - Install temporary flood proofing measures; and
    - Know the critical trigger levels for their property and neighbouring properties.
  - Host day courses for training – perhaps run by Council with the SES; and
  - Encourage membership of the Gundagai Flood Awareness Association, or make compulsory via DA approvals process for new developments.

- **Host an annual "Sheridan Street Flood Prep" event:**
  - Discuss and coordinate flood preparations with staff and neighbouring businesses if assistance is needed;
  - Get to know the SES personnel and Council staff before an actual flood event;
  - Acknowledge anniversary(ies) of past flood events – perhaps host the "Flood Prep Event" to coincide with a significant anniversary;
  - If appropriate, encourage businesses on Sheridan Street and Sheridan Lane to practise installing flood proofing measures (see Option PM03, Section 6.6.3) to identify and resolve any issues that may be found.

- **Distribute (existing) SES FloodSafe materials to residents and businesses:**
  - Provide information on what to do before, during and after a flood event;
  - Locations of evacuation centres within Gundagai and further afield if necessary;
  - Dangers of not responding to evacuation orders and becoming isolated;
  - Dangers of driving through floodwaters.

- **School Projects on Flooding and Flood Safety**
  - Improve local knowledge of flooding in Gundagai;

- Incorporate messages about not playing or driving in floodwaters into appropriate lessons;
- Host 'flood awareness" days including visits from the SES, invitation to join the Gundagai Flood Warning Association, and run flood safety activities with students;
- Engage with local Aboriginal representatives and share the story of the two Wiradjuri men, Yarri and Jacky Jacky, who used bark canoes to rescue 68 people in the flood of 1852;

School engagement is an excellent means of informing the younger generation about flooding, and can lead to infiltration of flood awareness to parents.

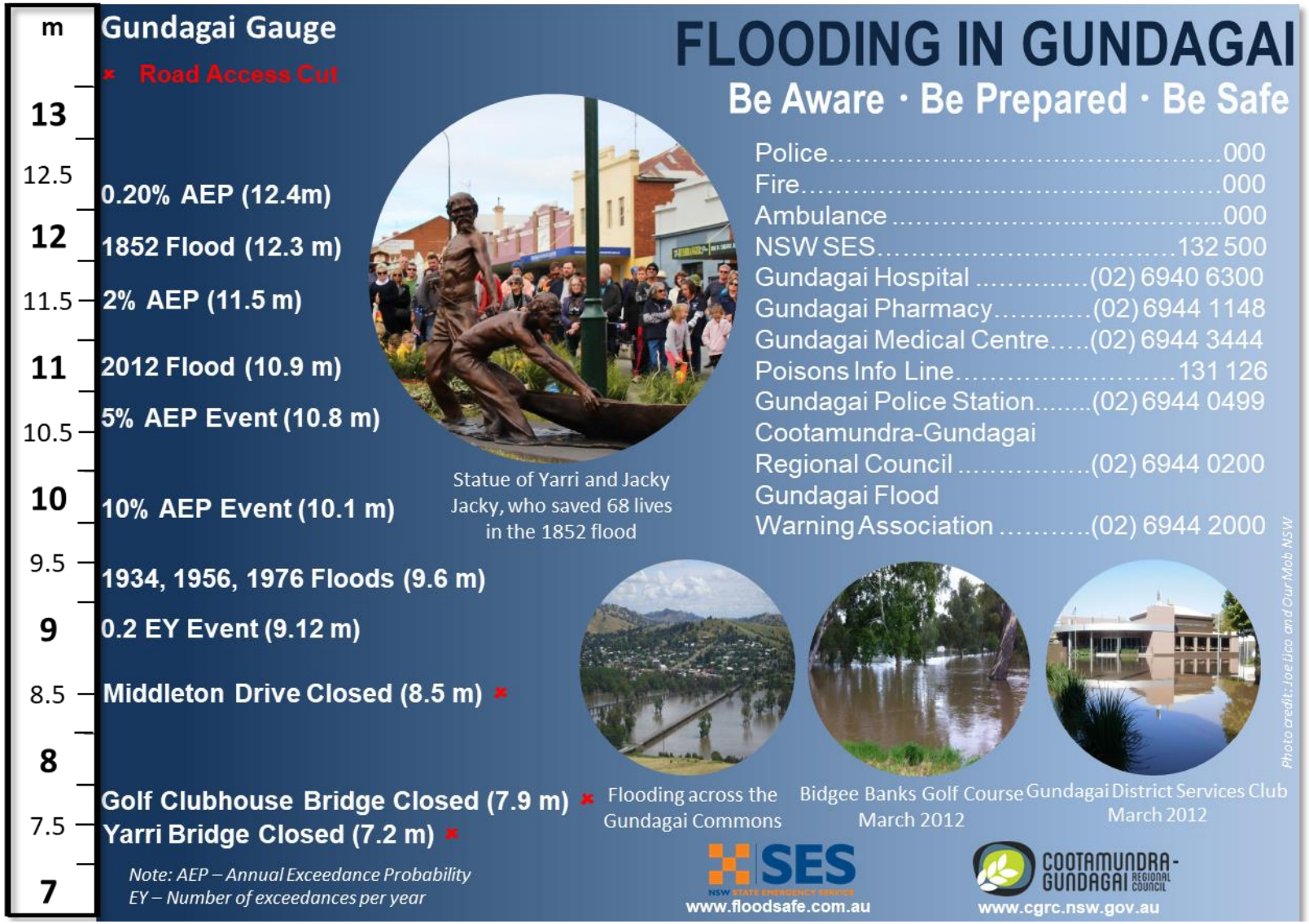
- **Advertise and discuss the above via other media outlets:**
  - Council newsletter;
  - Local newspapers.

- **Include property – specific flood information on Section 10.7 Planning Certificates**
  - Refer to Section 6.6.5 (Option PM05) for discussion and information.

Recommendation

It is recommended that Council implements a Flood Awareness Program to improve the community's understanding of their flood risk, and how to prepare themselves and their properties for a flood. The program would utilise the above listed strategies and be delivered in collaboration with the SES, Gundagai Flood Warning Association, and other schools and community groups as appropriate.

Image 1 Preliminary design for the "Flooding in Gundagai" information fridge magnet



6.6. Property Modification Measures

Property modification measures aim to reduce flood risk to existing properties and future developments. Voluntary house raising and flood proofing can be implemented to reduce damage to existing properties, while voluntary purchase schemes can be implemented to remove dwellings from areas of high flood hazard, thereby reducing the number of residents at risk and potentially improving flood conveyance. Flood risk to future developments can be managed via planning controls which regulate where and how various types of developments are constructed. The key tools Council uses to regulate development are the Local Environmental Plan and Development Control Plan. This section discusses each of these types of measures and assesses their suitability for implementation in Gundagai.

6.6.1. Option PM01: Voluntary House Raising

PM01 Overview

☑ It is recommended that Council undertakes a feasibility study to investigate implementing a Voluntary House Raising Scheme in Gundagai to reduce residential property damages and minimise the stress and costs associated with water entering dwellings.

Option Description

Voluntary house raising (VHR) seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the minimum Flood Planning Level (FPL). This results in a reduction in the frequency of household disruption and associated trauma and anxiety, however other external flood risks remain. VHR schemes are eligible for state government funding based on criteria set out in the *NSW OEH Guidelines for Voluntary House Raising Schemes* (Reference 13). According to these guidelines, VHR is generally excluded in floodways (as defined in Section 3.4.1), is limited to low hazard areas (see Section 3.4.2), and applies only to houses constructed before 1986. House raising is most suitable for non-brick single storey buildings on piers, and is typically not feasible for slab-on-ground constructions. However, advancements in construction techniques and other alternatives may make house raising a viable option for slab-on-ground constructions.

Suitability in Gundagai

Outputs from the Gundagai flood damages assessment (See Section 3.5 and Appendix C) have been used to identify residential properties that are a) located outside of the floodway (as defined in Section 3.4.1) and b) are inundated over floor in events up to and including the 1% AEP event. In total, 26 dwellings were found to meet these criteria. The dwellings are generally either located along Sheridan Lane or Brungle Road (subject to riverine affectation), or along Punch Street, West Street and Otway Street, and subject to flooding associated with the Jones Creek catchment. A number of these dwellings have been confirmed to be constructed on piers, however confirmation of the construction type of all dwellings would be needed if the option were to progress.

Economic Assessment

The maximum potential economic benefits of VHR in Gundagai have been estimated by assuming that all 26 dwellings are raised to the FPL, that is, the 1% AEP level plus 0.5 m freeboard (refer to freeboard assessment presented in Appendix E), then recalculating the residential flood damages. The “benefits” accounted for in this economic assessment are limited to the reduction in property damages, and do not consider the intangible benefits (reduction in stress, anxiety or loss of sentimental possessions etc.) that would result from the significant reduction in frequency of inundation. In reality, it is unlikely that all 26 of these dwellings would be of suitable construction to be raised (i.e. slab on ground constructions would generally not be considered feasible). However, to gain a picture of the upper limit of benefits, all identified dwellings have been included at this stage.

The assessment showed that VHR would result in a reduction in the total residential Annual Average Damages (AAD) from $483,950 to $180,860 (i.e. 63%), and in residential AAD per property from $2,251 to $841 per dwelling.

A high level estimate for the cost of a VHR program in Gundagai has been prepared to complete the cost-benefit analysis. The cost estimate assumes construction costs in the order of $60,000 per property, plus ancillary costs of around $36,000 per property to account for grant application and project management, detailed survey and design, consultation between Council and property owners, and interim accommodation and furniture removal if required. Note that for the purpose of this cost estimate, the same cost has been applied to each property regardless of the height the dwelling would need to be raised to meet the FPL. The cost-benefit analysis resulted in a benefit cost ratio (BCR) of 1.78, indicating the option would be economically viable. A summary of the economic assessment is provided in Table 12.

Table 12 Option PM01 - Economic Assessment (assumes 26 dwellings raised to FPL)

Option:	PM01
Capital Cost:	$2,512,200
% Reduction in AAD:	63%
NPV of Benefits (over a 50 yr period):	$4,474,340
BC Ratio:	1.78

Option PM01A: VHR in the Jones Creek Floodway

As described above, VHR is not generally permitted in floodways. However, parts of the Jones Creek floodway are classified as being in the lower hazard categories (H1-H3), indicating that, despite being a ‘floodway’, there may be scope for considering VHR for frequently affected properties. An additional 12 dwellings have been identified, and a second economic assessment has been undertaken. The results are presented in Table 13 below. If these additional properties were included in the Scheme, the AAD (residential only) per property would drop from $2,251 to $617, indicating the high economic benefits available through the scheme.

Table 13 Option PM01A - Economic Assessment (assumes 38 dwellings raised to FPL)

Option:	PM01A
Capital Cost:	$3,660,600
% Reduction in AAD:	73%
NPV of Benefits (over a 50 year period):	$5,187,576
BC Ratio:	1.42

Summary

Given the significant economic merits of VHR, this option is recommended to be progressed. A detailed feasibility study is recommended to be undertaken to:

- Confirm the eligibility of identified dwellings;
- Assess the technical feasibility of raising the eligible dwellings;
- Rank each property to prioritise those with the highest hazard; and
- Consult with each homeowner to determine willingness to participate in the scheme.

It is recommended that the feasibility study also investigate Voluntary Purchase. This scheme is described in the subsequent section.

If, following the feasibility study, the VHR scheme did not proceed, development controls would act to reduce flood risk to these properties in the long term as redevelopment would require floor levels to be raised to the FPL. While this would ultimately have a similar outcome to VHR, it would take significantly longer to achieve as house raising would be contingent on residents' appetite to rebuild, and properties would be subject to risk from floods occurring in the interim.

It is noted that a significant number of *commercial* premises are also located in low hazard areas and are affected over-floor in frequent events. However, commercial properties are not eligible for VHR. As an alternative, it is likely that these commercial properties would benefit from flood proofing to the FPL. Flood proofing is considered in Option PM03, discussed in Section 6.6.3.

The details of properties included in this high level assessment will be provided to Council. This information is confidential and will not be released to the public as part of this FRMS as further investigation is required prior to progressing any VHR scheme in Gundagai.

6.6.2. Option PM02: Voluntary Purchase

PM02 Overview

☑ A Voluntary Purchase Scheme is recommended for further investigation as part of the Feasibility Study into Voluntary House Raising for Gundagai (Option PM01)

Option Description

Voluntary Purchase (VP) Schemes are a long-term option to remove residential properties from areas of high flood hazard. Voluntary purchase (VP) is recognised as an effective floodplain risk management measure for existing properties in areas where:

- There are highly hazardous flood conditions 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 its removal may contribute to a floodway clearance program that aims to reduce significant impacts of flood behaviour elsewhere in the floodplain by improving the conveyance of the floodway; or
- Purchase of a property enables other flood mitigation works to be implemented (e.g. channel improvements or levee construction).

In the NSW OEH *Guidelines for Voluntary Purchase Schemes* (Reference 14), eligibility criteria notes that VP will be considered only where no other feasible flood risk management options are available to address the risk to life at the property (5.2), and, that subsidised funding is generally only available for residential properties and not commercial and industrial properties (5.3). Once a dwelling is purchased it would be demolished, and a restriction placed upon the lot to prevent future residential or commercial development.

Reference 14 sets out the way in which a VP scheme should be undertaken and how properties should be valued. Valuations are to assume there are no flood related development constraints applied to the property. The aim of this is to allow those who take up voluntary purchase to be able to buy a similar property in a location not subject to flood risk, acknowledging that flood risk and subsequent flood related constraints may have an impact on property value.

Suitability in Gundagai

Outputs from the Gundagai flood damages assessment (See Section 3.5 and Appendix C) have been used to identify residential properties that are located within the enveloped Jones Creek and Murrumbidgee River 1% AEP floodway (as defined in Section 3.4.1). In total, 22 dwellings were found to meet these criteria. One dwelling (on Brungle Road) is located within the Murrumbidgee River floodway, while the remainder of the properties are located immediately adjacent to Jones Creek around Punch Street and Sheridan Street.

As described in Section 6.6.1, parts of the Jones Creek floodway is zoned as H1-H3, and only two dwellings are located with areas categorised as H4-H6. This indicates that the benefits of removing residents from 'high hazard' areas to reduce risk to life would be limited. As an alternative, it may be possible to consider dwellings in low hazard areas of the Jones Creek floodway for VHR rather than VP. 12 properties have been identified as being located in low hazard floodway areas, and have been included in the assessment of Option PM01A.

Summary

The above analysis has found that there is a limited number of dwellings that would be considered eligible for VP, indicating that a VP scheme would not significantly reduce AAD nor reduce risk to life of occupants. However, it is recommended that the feasibility study for Voluntary House Raising in Gundagai (Option PM01) be expanded to include consideration of the properties identified for Voluntary Purchase.

6.6.3. Option PM03: Flood Proofing Measures for Commercial Properties

PM03 Overview

☑ Commercial property damages in Gundagai (mainly on Sheridan Street and Sheridan Lane) would be significantly reduced if flood proofing measures were implemented to prevent ingress of water, or improve recovery following flood events. Additional benefits would include a reduction in the amount of preparations required, and hence a reduced burden on business owners, their staff, and the SES who currently provide assistance.

Option Description

Flood proofing measures have been assessed as a method to reduce commercial property damages in Gundagai. Flood proofing is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building, and aims to minimise damages and/or reduce recovery times through use of water resistant materials, locating electricals above the FPL, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building, and is typically best incorporated into a structure at the construction phase, though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered. Flood proofing may be a preferable alternative to more expensive and technically challenging measures such as levees or temporary flood barriers, discussed in Section 6.7.4.

Suitability in Gundagai

A review of the flood damages assessment has identified 18 commercial premises (generally on Sheridan Street and Sheridan Lane) subject to over-floor flooding in events up to and including the 1% AEP event. Consultation at the beginning of the study confirmed that flooding in 2012 caused closures of a number of shops and facilities, and incurred damage and clean-up costs. It is noted though that the 2012 event was approximately a 5% AEP event, and that a 1% AEP event would be over a metre higher and cause significantly higher damages. The number of commercial properties at risk indicates that further investigation of flood proofing is warranted.

Given the warning time available in Gundagai, it is expected that dry flood proofing measures such as doorframe-mounted barriers could be deployed effectively. This would significantly reduce damage to internal fittings and stock, clean-up costs, and the cost of days of business lost when flood waters have receded. Site specific dry flood proofing measures could be expected to have the following benefits:

- Can be implemented by the individual business owner (with little or no SES assistance);
- Reduce or eliminate need for sandbagging;
- Reduce property damages;
- Allow premises to reopen as soon as safe access is restored;
- Reduction of days of lost business during recovery period;

- Increased continuity of work (and hence wages) for employees of affected businesses; and
- Improved social amenity of being able to access and use key facilities and shops.

Access to community facilities, shops and pubs or Services Clubs are key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event.

Economic Assessment

The potential economic benefits of flood proofing commercial in Gundagai have been estimated by assuming that 18 commercial properties are dry proofed up to the FPL, that is, the 1% AEP level plus 0.5 m freeboard, then recalculating the commercial flood damages. The "benefits" considered in this economic assessment are limited to the reduction in property damages only, and do not consider other tangible benefits (reduction in number of days of business lost, loss of income to employees) nor intangible benefits (e.g. reduction in stress and anxiety, improved community amenity) that would result from the reduction in internal damages. If the identified commercial premises were each dry proofed to the FPL, the commercial AAD would be reduced from $312,800 to $52,100 (i.e. 68% reduction), or from $6,015 to $1,000 per commercial property.

It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks or stock yards). Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the recovery period.

Considerations for Option Implementation

Development controls can be used by Council to ensure new commercial developments (or redevelopment of existing buildings) are constructed with flood proofing technologies at entry points, or wet-proofed by using flood compatible materials that can be easily washed down. However it is more likely in Gundagai that existing premises will retrofit flood proofing products, as new development is limited. Further investigation is required to identify flood proofing products that are affordable, can be implemented in existing buildings, and meet aesthetic requirements of various businesses. There may be efficiencies in businesses using the same product where possible, though depending on construction type, sizing and visual amenity this may not be possible.

Site specific emergency management plans should be in place in all businesses, and annual staff training undertaken to ensure employees are aware of how and when to deploy the flood barrier. Any tools needed for the installation should be kept with the flood barrier.

It is recommended that annual training drills are held, where all affected businesses practise deploying their flood barriers. This would assist in keeping current staff trained, ironing out any challenges, and identifying any difficulties or obstacles. It is also important to know how long it takes to install the barrier, as this may affect the warning time different businesses need, and

where additional assistance may be needed. Annual drills could be coordinated by the SES and Council, and would contribute to improvement of the community's flood awareness (described further in Option RM05, Section 6.5.5).

Summary

Commercial properties along Sheridan Street and Sheridan Lane are among the worst affected properties in Gundagai, and commercial damages across Gundagai currently constitute 39% of the total AAD. Reduction of internal flood damages to these properties would yield significant benefits to the community in terms of property damage, reduced clean-up costs, swifter recovery from floods and greater community amenity. This option is therefore recommended for implementation via the Floodplain Risk Management Plan.

6.6.4. Option PM04: Revision of Flood Planning Level and Flood Planning Area

PM04 Overview

It is recommended that the Gundagai LEP be amended to use the following definition:

***"flood planning level** means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other freeboard as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual."*

☑

The Flood Planning Levels for Gundagai are recommended to be adopted as follows:

- Mainstream flooding (Jones Creek and Murrumbidgee River): 1% AEP level + 0.5 m freeboard;
- Overland Inundation (due to local runoff): 1% AEP level + 0.3 m freeboard.

The corresponding Flood Planning Area map produced in this Study is recommended for adoption.

6.6.4.1. Flood Planning Level (FPL)

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (Reference 2) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a design flood event and a freeboard. The FPL for planning purposes is generally the height at which new (or redeveloped) residential building floor levels should be built to minimise frequency of inundation and associated damage. It may also refer to the height to which flood proofing should be applied to reduce damages to commercial properties.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- 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 that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding; and
- Duty of care.

As a guide, Table 14 has been reproduced from the NSW Floodplain Development Manual (Reference 2) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life. The data indicates that there is a 50% chance of a 100 year Annual Recurrence Interval (ARI) (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 non-tangible 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 200 Year ARI (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 more vulnerable development.

Table 14: Likelihood of given design events occurring in a period of 70 years

Likelihood of Occurrence in Any Year (ARI)	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
20	97	86
50	75	41
100	50	16
200	30	5

6.6.4.2. Freeboard Selection

A freeboard ranging from 0.3 – 0.5 metres is commonly adopted in determining the FPL. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in flowpath vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
    - Local flood behaviour (due to local obstructions);
    - Wave action (e.g. wind generated waves or waves from vehicles);
    - Culvert blockage; and
    - Climate change (affecting both rainfall and ocean levels).

A freeboard assessment is presented in Appendix E to assess the appropriate freeboard for mainstream flooding in Gundagai due to Jones Creek and Murrumbidgee River flooding. The assessment considers impacts on modelled flood behaviour due to the above factors. The assessment concludes that at a minimum, a freeboard of 0.5 m is appropriate for the mainstream Flood Planning Level in Gundagai. As discussed in 6.6.4.3, the Flood Planning Area (FPA) for the Gundagai Study Area distinguishes between overland and mainstream flooding, as they are associated with different levels of risk. In areas subject only to overland flow, the addition of 0.5 m freeboard to the 1% AEP level would put the FPL well above the PMF level. For this reason, for properties in the FPA that are subject to only overland flooding, Council should use a 0.3 m freeboard to determine the FPL.

Recommendation
It is recommended that a planning proposal be lodged to change LEP definition of the FPL from:

***"flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.3 metre freeboard"*

to:

***"flood planning level** means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other freeboard as determined by any floodplain risk management plan adopted by the Council in accordance with the Floodplain Development Manual."*

6.6.4.3. Flood Planning Area (FPA)

The FPL, and other flood related development controls, is applied to properties within the Flood Planning Area (FPA). The FPA is typically the land at or below the flood planning level. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. It is also important to define the FPA on criteria defined in the NSW Floodplain Development Manual (Reference 2). At the time of

writing, Gundagai did not have a Flood Planning Area map. The FPA map has been produced as an output of this Study, developed through the below approach and is presented in Figure 19.

Gundagai is subject to two types of flooding, mainstream and overland. The separation of flooding into mainstream and overland flow acknowledges that mainstream flood levels will increase significantly in events rarer than the 1% AEP, while overland flooding is often not significantly different between the 1% AEP and the PMF. Whilst for mainstream flooding the FPA can be defined simply as the 1% AEP event plus freeboard (typically 0.5 m), such a method is sometimes not appropriate for areas subject to overland flow flooding which often do not reach the depths that could occur from mainstream flooding and additionally, where depths do not tend to increase significantly for rarer events and flooding duration may be less than 15 minutes.

The following approach has been undertaken to determine the FPA in Gundagai:

1. Delineate the 1% AEP flood extent into mainstream and overland flood extents. Mainstream flooding occurs where water surcharges a natural watercourse (i.e. Jones Creek and the Murrumbidgee River), while overland flooding occurs where water flows over the ground towards a watercourse of channel.
2. Using the mainstream flood extents and levels, a freeboard of 0.5 m was added to the flood level and the resulting level was extended laterally on either side of the channel or creek, to intersect with the ground (using topographic data). This approximates the extent of a flood that is 0.5 m higher than the 1% AEP flood, and forms the boundary of the mainstream FPA.
3. Using the overland flood extent, depths of less than 150 mm were removed from the flood extent to remove insignificant flowpaths. Cadastral lots were then selected if 10% or more of the lot was inundated;
4. The FPA was then defined as all properties in (2) and (3), shown on Figure 19.

Recommendation

It is recommended that an additional definition be inserted in the LEP to define the Flood Planning Area as it relates to the Flood Planning Level, consistent with definitions in the Floodplain Development Manual (Reference 2). A map indicating the Flood Planning Area is recommended to be adopted by Council, however is not required to be contained within the LEP. The Flood Planning Area may be updated following future Floodplain Risk Management Studies in the LGA, and it is useful to be able to update the Flood Planning Area map without going through the planning proposal process (to amend the LEP) each time a study is completed.

6.6.5. Option PM05: Inclusion of Flood Related Information on Section 10.7(2) and (5) Planning Certificates

PM05 Overview

☑ It is recommended that Council uses outputs from this Study to provide flood information on Section 10.7 (2) and (5) Planning Certificates to improve the flood awareness of property owners.

Option Description

Further to the description in Section 5.1.2.4 and in Appendix D, Section 10.7 (formerly Section 149) planning certificates are issued in accordance with the Environmental Planning & Assessment Act 1979. They contain information on how a parcel of land may be used and the development restrictions that apply. Generally a Section 10.7 planning certificate will be requested when a property is to be redeveloped or sold as the Conveyancing Act 1919 (Sale of Land) Regulation 2010 requires that the certificate be attached to the contract of sale for the land.

The contents of the Section 10.7(2) planning certificate are regulated by the Environmental Planning and Assessment Regulation 2000, Schedule 4. In particular, part 7A denotes the information relating to flooding required to be provided.

Section 10.7(2) and (5) planning certificates contain the information prescribed in Schedule 4 and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property. This more sophisticated level of data and mapping from this study and Reference 5 will assist in the dissemination of accurate information to the community. A GIS based map can be used by Council to provide useful information to a property owner.

Suitability in Gundagai

Until recently, Council has not had flood information to provide to residents. The completion of the Flood Study (Reference 5) however means that high resolution information for a range of flood events and metrics including peak flood depths, levels, velocity, hydraulic hazard and hydraulic categorisation, can be used by Council staff, provided to residents, and used to inform appropriate development.

The following items are recommended to be incorporated into Section 10.7 planning certificates provided by Council:

- Whether the land is within the FPA and flood related development controls apply (10.7(2) and (5));
- Identification of flooding mechanism (mainstream, overland, or both);
- Design flood levels/depths specific to the property for the 5% AEP, 1% AEP and PMF events (10.7(5));
- Percentages of lots affected by the FPA if not 100% (10.7(5)); and
- Flood hazard and description of H1-H6 classification (10.7(5)).

It is important that the information presented in the planning certificate is clear, because although flood controls only apply to land in the FPA, flood risk exists to the PMF. Land outside of the FPA therefore can still flood during rare events and the community can be made aware of this via notes on the Section 10.7 (2) and (5) planning certificate.

Summary

Outputs from the modelling developed in the Flood Study are provided to Council, and can be used to improve the information provided to residents. Benefits of this include improved flood awareness for residents (which can help greatly during flood events), and assist in ensuring development is compatible with the flood risk of the property. This option is therefore recommended for implementation.

6.6.6. Option PM06: Inclusion of Flood Related Development Controls in Development Control Plan

PM06 Overview

☑ It is recommended that Council includes flood related development controls in the Cootamundra- Gundagai Development Control Plan to support the objectives of Clause 6.4 of Gundagai LEP 2011

Option Description

A development control plan provides detailed planning and design guidelines to support the planning controls in the Local Environment Plan (LEP). Appropriate planning controls that ensure that development is compatible with flood risk can significantly reduce structural failure, material damages, loss of life, resident isolation and rescue hazards. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding.

At the time of writing, a Development Control Plan (DCP) for Gundagai did not exist. Aside from providing some informal guidance on floor levels or the height of power outlets, Council did not have formal controls to apply to new developments or the redevelopment of existing buildings. With the recent amalgamation of the Cootamundra and Gundagai LGAs, Council is intending to draft a new DCP to cover both towns (and other villages within the LGA). This provides an opportunity to draft flood related development controls that can be applied in Gundagai.

Discussion

Flood related development controls in the Cootamundra – Gundagai DCP should be drafted to support the following objectives of Clause 6.4 the Gundagai LEP 2011, which are developed under the Environmental Planning and Assessment Act:

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

Suggestions for potential controls to address the above objectives are provided below:

Controls to minimise the flood risk to life and property associated with the use of land:

- Regulate development in “low risk areas”, i.e. between the FPA and PMF (note this is implemented in the LEP);
- Prepare and implement site specific flood emergency management plans for commercial properties;
- Provide flood information to residents via Section 10.7 Planning Certificates (see Section 6.6.5)

allow development on land that is compatible with the land’s flood hazard, taking into account projected changes as a result of climate change

- Ensure appropriate building siting, design and construction using flood compatible materials; and
- Imposing minimum floor level or flood proofing requirements appropriate to the type of development via the Flood Planning Level.

avoid significant adverse impacts on flood behaviour and the environment

- Requiring new developments to demonstrate off-site flood impacts will not be caused by the development.

It is recommended that Council engage a specialist planning consultant to prepare advice/ content for the development of Council’s Comprehensive DCP. The DCP should be prepared to be applicable to all flood prone land within the LGA, rather than only specific to Gundagai to provide a consistent approach for development with the LGA.

Summary

It is recommended that Council takes the opportunity when drafting the Cootamundra – Gundagai DCP to include flood related development controls that support the objectives of Clause 6.4 of Gundagai LEP 2011. These controls regulate development with a view to reduce risk to life of building occupants, reduce flood risk to a development itself, and control flood impacts on existing properties and the wider floodplain.

6.7. Flood Modification Measures

6.7.1. Introduction

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale.

Flood impact maps have been produced to display the effect that the various mitigation works would have on flood behaviour. These maps display the difference in peak flood level between a design flood event and the same event with the mitigation works implemented. Impacts maps are presented in Volume 2, Appendix F.

6.7.2. Drainage Modifications

Modification of existing drainage systems through the installation of new or larger drainage channels or culverts can increase conveyance and help to reduce upstream peak flood levels, or reduce the duration of inundation. Drainage network modifications can also be used to divert flows from one area to another.

6.7.2.1. Option FM01 – Channel underneath Sheahan Bridge

FM01 Overview

☒ This option investigated excavating a channel beneath Sheahan Bridge to assist in the drainage of flooding on the eastern side of the southern abutment. However, the investigation showed that such a channel would initially backwater and result in Ferry Street being inundated some 5 hours earlier. Furthermore, the option did not reduce property damages, and is not recommended to be progressed.

Option Description

The construction of the Sheahan Bridge southern abutment was identified in the Flood Study (Reference 5) as causing an increase to peak flood levels at the Gundagai Gauge. A review of the catchment topography before and after bridge construction, undertaken as part of the Flood Study, suggests that the abutment obstructs natural flood runners (which had historically flowed unimpeded across the floodplain) to an extent likely to cause adverse flood impacts upstream, particularly in frequent flood events (the 0.2 EY event for example). Options FM01 and FM02 were modelled with the aim of reducing flood levels and ponding upstream of the southern abutment.

The aim of Option FM01 is to restore connectivity of a major runner on the eastern and western sides of the southern bridge abutment to simulate natural flow conditions and reduce ponding on the eastern side of the southern abutment. The option was modelled by excavating a 4.5 m deep channel with a 15 m bed width, and average total width of 40 m, resulting in a total excavation volume of 19,250 m^3. The channel was tested in both the 0.2 EY (given the observation of obstruction in frequent flood events) and 1% AEP to determine any potentially negative effects

during a rarer flood event. It is noted that any excavated material must be deposited outside the floodplain to ensure no obstruction is formed in the floodplain.

Modelled Impacts

The peak flood level impacts of Option FM01 in the 0.2 EY and 1% AEP events are shown on Figure F1 and Figure F2. Figure F1 shows that in the 0.2 EY event, the new section of channel would significantly reduce flood levels along Ferry Street in the vicinity of the Sheahan Bridge (greater than 1 m in parts), and increase flood levels downstream of the proposed channel (south-west of the southern bridge abutment, upstream of the Murrumbidgee River) by up to 0.04 m. Flood level reductions within the Murrumbidgee River itself (up to 0.05 m) are also present up to 4 km upstream and 1 km downstream. There are no dwellings on the Southern Commons, and so the minor localised increases in flood levels would not affect property damages.

Figure F2 shows that in the 1% AEP event, the new channel would increase flood levels downstream by up to 0.05 m and decrease flood levels up to 0.1 m along Ferry Street. Flood level reductions within the Murrumbidgee River (up to 0.05 m) are also present up to 1 km upstream and downstream of the works. As there are no dwellings on the Southern Commons downstream of the southern abutment, the minor flood level increases noted do not affect property damages.

A flood runner comes off the left bank of the Murrumbidgee River approximately 1.8 km downstream of Sheahan Bridge. This flood runner becomes active in events as frequent as the 0.2 EY event, and conveys water to the east and north, around and subsequently through Lot 7019 DP1029003, and back upstream across the Southern Commons towards Sheahan Bridge. The southern abutment of Sheahan Bridge currently obstructs this flood runner. The proposed channel allows this flow to be conveyed towards properties on Ferry Street, and although it does not increase the peak flood level that occurs in this area, it would cause the area to flood earlier than it currently would, reducing preparation or evacuation time.

Discussion of Other Concerns and Considerations

The construction of a 40 m wide, 4.5 m deep channel through the middle of the floodplain is a significant excavation, likely to have high capital costs associated with the earthworks and haulage (as spoil must be deposited outside the floodplain). Ongoing maintenance requirements are expected to be minimal as the channel is likely to be as per the existing surrounding area, perhaps with native grass seeding to help manage erosion. From an environmental standpoint, while the option aims at re-connecting a historically blocked flood runner, the manner in which it does so (by cutting a path underneath the bridge to circumvent the bridge abutment) is not natural and complications could arise as a result.

The Gundagai Southern Common is Crown Land currently managed by the Gundagai Common Trust. Council has noted a good relationship with the Trust and that approvals for works on the Common are likely to be attainable. Liaison with RMS may be required as the channel excavation is proposed to be adjacent to the bridge abutment. Public safety should also be considered, as the channel would create an area of higher hazard (increasing from H1 to H5 as shown in Diagram 1 and Diagram 2), with peak depths of 2.5 m in the 0.2 EY, with velocities of up to 1 m/s. Parts of the channel beside properties (i.e. on the eastern side of the bridge) should be fenced.

Furthermore, opening up this channel results in Ferry Street being overtopped 5 hours earlier, with flood waters reaching properties near the corner of Mount Street and Ridge Street 3 hours earlier, without any reduction in duration of inundation. This option would significantly reduce evacuation time without a notable benefit to peak flood depths around properties.

Diagram 5 Existing Hazard - 0.2 EY Event

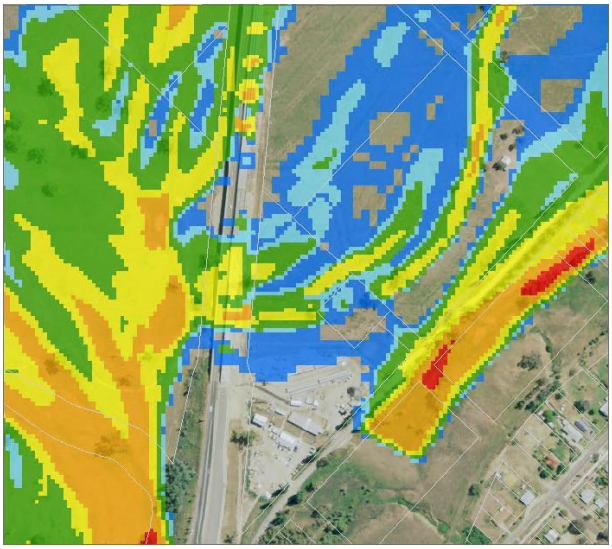
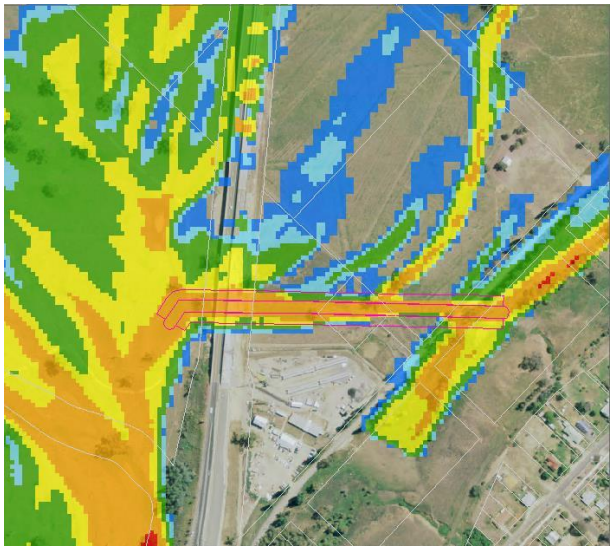
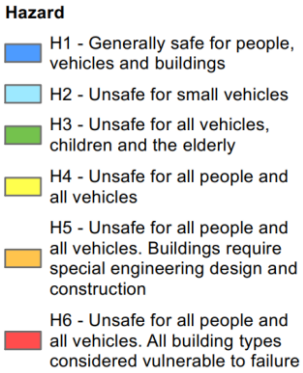


Diagram 6 FM01 Hazard - 0.2 EY Event





Economic Assessment

The potential economic benefits of Option FM01 have been estimated by assessing the residential flood damages in the existing case (i.e. no channel), and with the channel in place. The “benefits” accounted for in this economic assessment are limited to the reduction in property damages, and do not consider the intangible benefits (reduction in stress, anxiety or loss of sentimental possessions etc.) that would result from the reduction in frequency of inundation. The assessment showed that FM01 would result in a negligible reduction in the residential Annual Average Damages (AAD), of $12.

A high level estimate for the cost of constructing FM01 has been prepared to complete the cost-benefit analysis. The cost estimate assumes construction costs in the order of $330,000 for the excavation of 19,250 m^3 plus compaction and surface treatment (e.g. topsoil seeding), plus ancillary costs of around $125,000 to account for grant application and project management, detailed survey and design, consultation between Council and the Gundagai Common Trust. The

cost-benefit analysis resulted in a benefit cost ratio (BCR) of 0, indicating the option would not be economically viable. A summary of the economic assessment is provided in Table 12.

Table 15 Option FM01 - Economic Assessment

Option:	FM01
Capital Cost:	$545,800
% Reduction in AAD:	0%
NPV of Benefits (over a 50 yr period):	$180
BC Ratio:	0

Evaluation

A channel across the floodplain beneath Sheahan Bridge was suggested by the Floodplain Management Committee, as it was expected to assist in drainage of the Ferry Street area and potentially have broader benefits across the floodplain. However, the hydraulic assessment of such a channel demonstrated that the channel would backflow initially and cause earlier inundation of properties and roads around Ferry Street and Mount Street. While peak flood levels were slightly reduced, reductions weren't significant enough to reduce property damages materially, resulting in a BCR of 0. This option is therefore not recommended to be progressed.

6.7.2.2. Option FM02 – Culverts through southern Sheahan Bridge Abutment

FM02 Overview

☒ This option considered installing culverts through the southern abutment of Sheahan Bridge to improve flood drainage from the Ferry Street area. The assessment showed that the resulting benefits were limited and that the construction through the abutment would likely not be supported by Roads and Maritime Services. This option is not recommended for further investigation.

Option Description

During the assessment of Option FM01 it was observed that a raised embankment running perpendicular to the southern Sheahan Bridge abutment caused a significant pooling of floodwaters upstream of the abutment itself (particularly in more frequent events), although this bank was overtopped in rarer events and the Sheahan Bridge abutment itself acted as an obstruction to flow in these cases. Option FM02 was modelled with the aim of allowing flow to travel through both the Sheahan Bridge abutment and the raised embankment in order to allow pooled water on the eastern side of the bridge to flow across to the western side and join its original flow path.

Option FM02 was modelled by constructing two sets of culverts: one set to divert flow through the raised embankment to the abutment and one set to divert flow through the abutment itself to the flow path on the other side. The quantity and size of each set of culverts was informed by the topography of the embankment/abutment as well as the amount of flow present. Culvert information for each set is included in Table 16 below. Option FM02 was tested for both the 0.2 EY and 1% AEP events.

Table 16 Modelled Culvert Information Option FM02

Location	Modelled Culvert Details
Raised Embankment	4 x 2.0 m x 1.5 m box culverts
Southern Abutment	4 x 4.0 m x 4.0 m box culverts

Modelled Impacts

The flood level impacts of Option FM02 in the 0.2 EY and 1% AEP events are shown on Figure F3 and Figure F4. Figure F3 shows that in the 0.2 EY event, the channel construction will decrease flood levels along and west of Ferry Street in the vicinity of the bridge as well as some parts of the Murrumbidgee River (up to 0.05 m with larger decreases in isolated areas). A localised increase in flood levels of up to 0.04 m is noted directly downstream of the proposed culvert (south-west of the bridge abutment). The culvert through the raised embankment will also create newly flooded areas upstream of the abutment as flow from the north east is directed into this area by the new culverts.

Figure F4 shows that in the 1% AEP event, installation of the box culverts will decrease flood levels between the embankment and the abutment downstream of the proposed channel by 0.5 m and decrease flood levels up to 0.02 m along Ferry Street. There is no increase in peak flood levels associated with this option in the 1% AEP event. It is also noted that lots along Ferry Street are largely vacant, with the exception of a couple of sheds.

Note that the same initial backwatering effect caused by Option FM01 (described in Section 6.7.2.1) would occur as a result of the culvert installation, in which the Ferry Street area would be inundated earlier than it currently is in a 0.2EY event. However, the benefit of the culvert is that this area, which is also inundated from the Murrumbidgee River, improves the drainage and reduces peak flood levels in the area.

Discussion of Other Concerns and Considerations

The main drawback of Option FM02 is that it requires tunnelling through the bridge abutment. Such construction is likely to not be supported by RMS, or if so, would necessarily involve careful considerations of the structural implications of such work, and is hence likely to be a costly exercise. Culverts would need to bear the weight of the abutment and road deck above them, and thus the cost of materials and installation are likely to be prohibitive. Given the limited benefit to properties nearby, the cost - benefit ratio for the option may be too low to justify its implementation.

Evaluation

Mitigation Option FM02 showed widespread peak flood level reductions in the more frequent 0.2 EY event but less impact in the larger 1% AEP event. The results suggest that while the option does help to promote the flow of stagnating water and a return to natural flow conditions in smaller events, the large amount of flow present in rarer events cannot be so easily transferred by a series of pipes in the set-up suggested in this option. The economic and construction concerns mean that this option in its current form is not recommended for further investigation.

6.7.2.3. Option FM10 – Install flap valve on Culvert at Gundagai McDonalds

FM10 Overview

☑ It is recommended that a flap valve is installed at the western end of the pipe that drains the McDonald's carpark through the Hume Highway embankment. The flap valve would prevent ingress of water into the swale beside the carpark when water levels in the Murrumbidgee River are elevated, preventing inundation of the sewage pump station.

Option Description

The Gundagai McDonalds is located at the corner of Mount Street and South Street in South Gundagai, with the Hume Highway along the western site boundary. A 450 mm diameter pipe through the highway embankment is designed to drain local runoff from the south western corner of the McDonalds carpark through the Hume Highway embankment and into the Southern Commons (refer to Diagram 7). When the water level in the Murrumbidgee River reaches approximately 10 m at the Gundagai Gauge, water backflows through the pipe from the Murrumbidgee River, and inundates the sewage pump station (SPS) located adjacent to South Street. The SES and/or Council are typically called out to block the culvert or contain the inundation and protect the SPS.

Diagram 7 Location of existing pipe and required flap valve (Option FM10)

Recommendation

A flap valve on the western end of the pipe would provide a cost effective solution to this problem. Flap valves cover the pipe opening and are hinged at the top. As a default, the flap acts to close

the pipe, but can be pushed open when flow (from the carpark) runs through the pipe. The flap valve is pushed shut when the water level on the outside (Murrumbidgee River side) is above the pipe invert. Flap valves are often used in tidal systems or on stormwater drainage pipes through levee banks. The installation of a flap valve would reduce demand on the SES and Council staff (when there may be other issues to react to), and prevent inundation of the sewage pump station. The required flap valve is estimated to cost less than $3,000, and would be the Council's responsibility to fund and install.

6.7.3. Road Modification Measures

DESCRIPTION

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. Increasing hydraulic conveyance through modification of these structures can lead to a decrease in flood levels upstream of a structure. Generally the most effective method of increasing hydraulic conveyance is to increase a structure's cross-sectional area perpendicular to the flow direction. This is often done by lengthening a bridge, raising a deck level, increasing the size of a culvert or reducing the structure's crest height.

6.7.3.1. Option FM03 – Otway Street Bridge

FM03 Overview

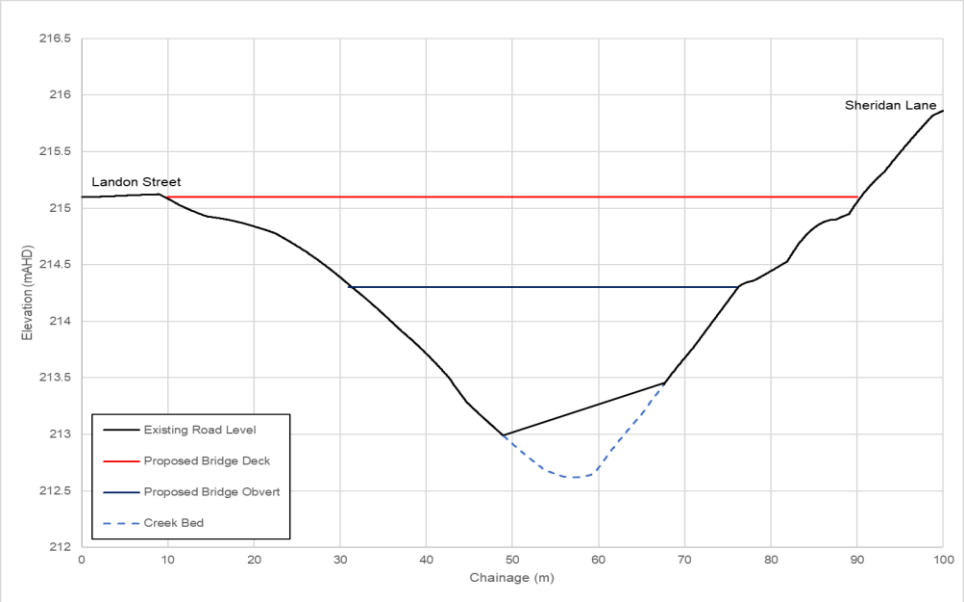
☒ A bridge to replace the Otway Street causeway is not considered to be justified while there are alternate access routes to South Gundagai (e.g. via Yarri Bridge and the Hume Highway). Furthermore, the Otway Street causeway is currently used by the SES in flood operations as a boat ramp, and its replacement with a bridge would remove this functionality. This option is not recommended to be investigated further.

Option Description

As described in Section 5.2.2, the Otway Street Causeway through Morleys Creek is low-level creek crossing overtopped in relatively frequent events. Once overtopped, access to South Gundagai and Anzac Park to the south is restricted, and although there are alternate routes available (e.g. Yarri Bridge, Hume Highway), residents interviewed during the community consultation period noted it is a nuisance and inconvenience. A review of flood conditions and catchment topography, as well as current causeway design suggested that a replacement of the causeway with a bridge may be able to provide an improvement to flood access conditions and reduce the frequency with which Council staff need to close the road. It is noted however that the floodplain to the south of Morleys Creek (including the sports ground) is inundated from the 0.2 EY event, and as such the benefit of raising the Morleys Creek crossing will be limited.

Option FM03 was modelled by raising the underside of the Otway Street causeway by approximately 1 m and raising the road deck to the same level as the surrounding roads. An approximate modelling schematic is included as Diagram 8 below. Option FM03 was tested for the 0.2 EY event.

Diagram 8: Approximate Design Schematic for Otway Street Bridge



Modelled Impacts

The flood level impacts of Option FM03 in the 0.2 EY event are shown on Figure F5. The figure shows that in the 0.2 EY event, the bridge does not have a material impact on flood behaviour. With the implementation of the proposed option, the Otway Street bridge would be overtopped at 7.8 m at the Gundagai Gauge, compared to 6.5 m currently.

Discussion of Other Concerns and Considerations

Construction of Option FM03 is likely to have a high cost relative to its flood mitigation effect, and installation of the bridge structure is likely to temporarily produce some minor social disruption during construction. Environmental considerations will need to be factored into the construction methodology as the option would involve removal of the existing concrete pavement and culvert, and the construction of a bridge with a higher road deck and obvert. Increasing the obvert and the flow area underneath the structure may help to improve stream flow in local rain events and promote a healthier creek system. As previously mentioned, the option does have some community support and it is possible that the raising of the road deck may provide better access to the sports grounds when water levels in Morleys Creek are slightly elevated.

SES staff have noted that the Otway Street causeway is used as a boat ramp to launch the SES dinghy during flood operations, and that raising the road deck would affect this functionality. As described in 5.2.2, there is a demand on SES personnel to monitor the causeway during flood events to alert Council to close the road gates. While it is noted that raising the road entirely would reduce this burden, this outcome could also be achieved via installation of a water level sensor, which has been noted to be preferred by SES and Council. This option is discussed in Section 6.5.2.2.

Evaluation

Upgrading the Otway Street causeway does not provide benefit in terms of flood impacts, however it would reduce the incidence of overtopping and the frequency at which Council would need to implement a road closure, and extend the time access remains available during flood events. The

option would have the social benefits of improved access to South Gundagai and Anzac Park, though it is noted that alternative access routes to South Gundagai are available via Homer Street/Yarri Bridge. The Floodplain Management Committee has noted that a preferred alternative to this option would be to install a water level sensor at the Otway Street causeway, (discussed in Section 6.5.2.2), and to not pursue raising the road deck further in this Study.

6.7.3.2. Option FM04 – Lower Middleton Drive

FM04 Overview

☒ The Floodplain Management Committee noted that parts of Middleton Drive had been built up over time, and may be acting as an obstruction within the floodplain. Modelling has confirmed that the impact of the road is localised, and does not affect any properties. This option is not recommended to be progressed further.

Option Description

Two options have been identified at Middleton Drive; Option FM04, which involves lowering a portion of the road, and Option FM05, described in the subsequent section, which involves increasing culvert capacity beneath the road.

The gradual raising of the Middleton Drive road surface over time was identified in the Flood Study (Reference 5) as having created an impedance to the natural northern Gundagai floodplain (known locally as the 'Gundagai Commons'). The lowering of part of Middleton Drive was therefore suggested as a potential flood mitigation option, with the aim of removing blockage and re-establishing part of the natural flow path. The road is proposed to be lowered by around 300 mm for the extent shown on Figure F6. Option FM04 was assessed for impacts in the 5% and 1% AEP events.

Modelled Impacts

Option FM04 was modelled by lowering a section of the DEM to represent regrading the road to the surrounding natural surface level. The flood level impacts of Option FM04 in the 5% AEP and 1% AEP events are shown on Figure F6 and Figure F7 respectively. Figure F6 indicates that in the 5% AEP event, lowering this section of Middleton Drive will decrease flood levels up to 0.1 m along the lowered section of road and up to 0.05 m for a small region upstream. Figure F7 shows that in the 1% AEP event, lowering Middleton Drive will decrease flood levels up to 0.1 m along the lowered section of road and up to 0.05 m for a small region upstream. These reductions do not extend to any residential or commercial buildings. The inverse of these impacts can be used to infer the impacts caused by the gradual raising of Middleton Road over time.

Discussion of Other Concerns and Considerations

The lowering of an existing road is likely to have economic and social costs. Economic costs stem from works involved in the excavation, regrading and resurfacing the section of road to match the surrounding landscape. Social impacts include the temporary disruption of the road closure, and the potential evacuation risks in the construction period (during which only the Hume Highway would be available to cross the Murrumbidgee River.) Post-construction, the newly lowered

section of road would be liable to more frequent overtopping potentially reducing road access between North and South Gundagai and possibly increasing maintenance requirements.

Evaluation

Given the lack of positive flood level impacts outside of a localised area upstream of the road lowering and the likely economic costs and social disruptions, Option FM04 is not recommended for further assessment.

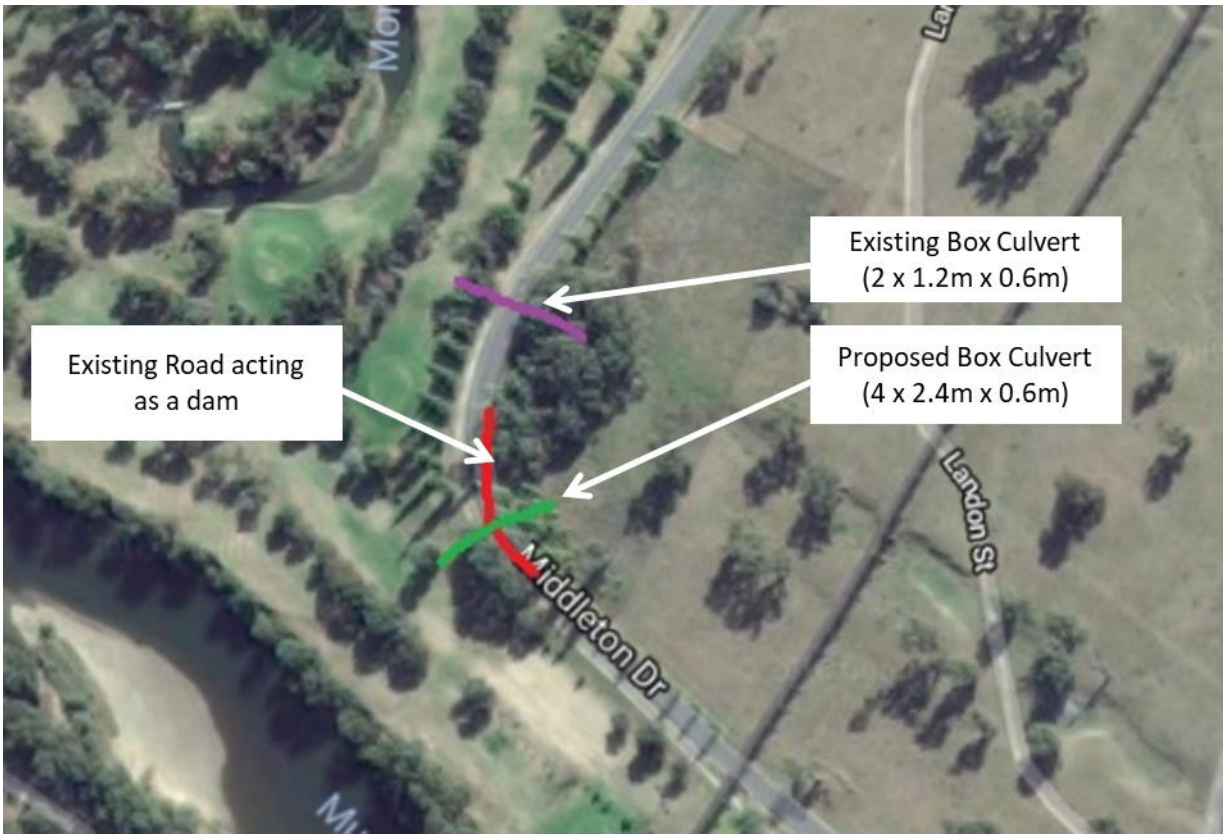
6.7.3.3. Option FM05 – Install Additional Culvert Underneath Middleton Drive

FM05 Overview

☒ An option to increase the culvert capacity at the corner of Middleton Drive has been assessed and found to be ineffective in reducing peak flood levels or delaying the time at which Middleton Drive would be overtopped. This option is not recommended to be progressed.

Option Description

The bend in Middleton Drive near the Murrumbidgee River is observed to act as a dam in small flood events, and an existing box culvert (2 x 1.2 m x 0.6 m) is noted to be insufficient to convey the flood. The lowering of elevated road levels at the bend has been tested in Option FM04, described above.



As an alternative to lowering Middleton Drive, the installation of a new culvert under the raised section of Middleton Drive was proposed as a potential flood mitigation option. Option FM05 was

proposed with the aim of allowing flow to travel through the raised section of Middleton Drive to reduce the amount of water damming behind the embankment.

Option FM05 included 4 x 0.6 x 2.4 m box culverts through the raised curved section of Middleton Drive running parallel to the Murrumbidgee River. Option FM05 was tested for its impact on flood behaviour for the 0.2 EY and 10% AEP events.

Modelled Impacts

The flood level impacts of Option FM05 in the 0.2 EY and 10% AEP events are shown on Figure F8 and Figure F9 respectively. The figures show that in the 0.2 EY and 10% AEP events the proposed culvert does not have material impact on flood behaviour. Examination of modelling files showed that the proposed culvert also had no impact on the time at which Middleton Drive is cut in either event.

Discussion of Other Concerns and Considerations

Installation of the culverts would likely have high economic cost for limited flood mitigation benefits. Economic costs stem from works involved in the excavation of a section of the road, installation of the culverts and resurfacing of the section. Social impacts stem from the temporary disruption caused and the potential evacuation risks in the construction period (during which only the Hume Highway would be available to cross the Murrumbidgee River.)

The proposed culvert arrangement of 4 x 2.4 m x 0.6 m box culverts is a large drainage system that could be considered a “best-case-scenario” for the proposed location. In reality, it is possible that physical or economic limitations would mean that a system of this size could not be installed at the site in question.

Evaluation

Given the lack of positive flood level impacts and the significant economic costs involved with such large culverts, Option FM05 is not recommended for further assessment.

6.7.3.4. Option FM06 – West Sheridan Lane Causeway Upgrade

FM06 Overview

☒ An option to replace the steep causeway at the western end of Sheridan Lane with a bridge is not recommended to be progressed as it would be likely to cause upstream impacts within Jones Creek. Improving access to the site west of this causeway is not a priority for flood risk management in Gundagai.

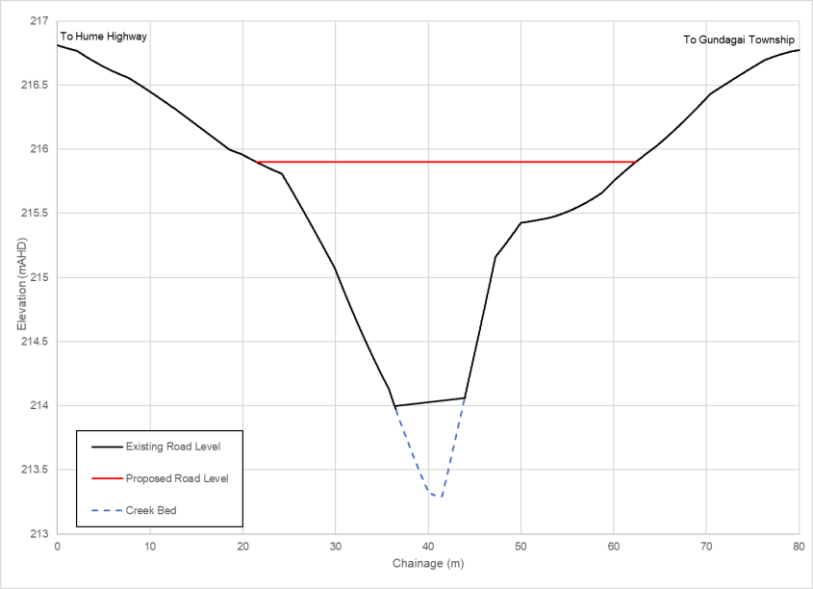
Option Description

There is a portion of flood free land bounded by the south-bound onramp to the Hume Highway and the 1% AEP extent, west of Jones Creek. Access to this site is currently via a causeway from Sheridan Lane across Jones Creek. The causeway and surrounding sloping land is overtopped in events as frequent as the 0.2 EY event. It was identified during community consultation that the flood – free land may be appropriate for the construction of storage warehouses or similar commercial activities. It is likely that such construction would require improved access across

Jones Creek. Option FM06 was therefore modelled with the aim of providing improved access to this lot.

Option FM06 was modelled by raising the underside of the West Sheridan Lane Street causeway by approximately 2 m and raising the road deck to the same level as the surrounding road – representing a bridge structure rather than a causeway, as the cross-sectional area beneath the road deck is open to allow flow. An approximate modelling schematic is included as Diagram 9 below. Given the flood affectation in minor flood events, there is little benefit in providing access in events greater than the 0.2 EY event, and so larger events were not assessed.

Diagram 9: Approximate Design Schematic for West Sheridan Lane Causeway



Modelled Impacts

Murrumbidgee River Flooding

The flood level impacts of Option FM06 in the 0.2 EY mainstream event are shown on Figure F10A. The figure shows that in the 0.2 EY event, the new bridge structure has negligible flood level impacts outside of a small (0.015 m) flood level increase in Morleys Creek upstream of the Otway Street causeway.

Jones Creek Flooding

The option was assessed separately for overland flooding in the Jones Creek catchment. The impacts in the 0.2 EY overland event are shown in Figure F10B, and indicate that the raised road deck will increase flood levels (up to 0.13 m) in a small section of Jones Creek upstream of the proposed development.

Discussion of Other Concerns and Considerations

Option FM06 does not provide material flood risk mitigation benefits to properties or access routes, and is not likely to have a BCR of greater than 1. Additionally, construction in an area directly crossing the creek may have some environmental impact, although replacing the road deck with a bridge and removing the paved causeway may help to improve stream flow in local rainfall events and promote a healthier creek system. The option does have some community support,

but the benefit (of flood free access in more frequent flood events) is limited to one site rather than the broader community.

It is noted that the causeway makes up part of a cycleway/walking path around the town, and at present cyclists are required to dismount and walk their bikes down and up the steep dip. While a bridge structure may improve the amenity to cyclists, it may also attract residents to the bridge during flood events where they would be in an area of high flood hazard.

Evaluation
Given the lack of beneficial flood impacts, the likely costs of construction, and considerations for public safety, Option FM06 is not recommended for further assessment.

6.7.4. Levees and Temporary Flood Barriers

DESCRIPTION
Levees are barriers between the watercourse and developed areas that prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or steel sheet piles where there is limited space or other constraints. Flood gates, flap valves and pumps are often associated with levees to prevent floodwaters backing up through the drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee. These types of infrastructure are vital for the effectiveness of a levee. Temporary flood barriers have the same ingress prevention purpose on a shorter-term scale and can include demountable defences, wall systems and sandbagging deployed before the onset of flooding.

The crest height of a levee is set at a level that equals the height of the design flood event for which it is designed to protect against, plus an allowance for freeboard. The freeboard allows for: settlement of the structure overtime, variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind. A preliminary freeboard of 0.5 m has been assumed for the options discussed below, however the appropriateness of this freeboard allowance would need to be confirmed via a detailed freeboard assessment if the option were to progress. Levees would also be typically constructed with a spillway with a lesser amount of freeboard. A spillway is a lower portion of the levee which allows for controlled overtopping of the levee to minimise the damage to the structure in floods larger than the design level of protection. As the subsequent section is a preliminary assessment only, no spillway has been included in the modelled options.

6.7.4.1. Option FM07 – Sheridan Lane Levee

FM07 Overview

☒ A levee between Morleys Creek and Sheridan Lane has been investigated with the aim of reducing flood damages to residential and commercial premises along Sheridan Lane and Sheridan Street. Modelling has shown limited benefits, and the cost of the levee is unlikely to be justified by the low number of properties protected. Furthermore, a levee in this location would significantly reduce the amenity of Morleys Creek for the local community. This option is not recommended to be progressed. Instead, a range of response and property modification options are proposed to better help businesses prepare for and recover from flooding in Sections 6.5 and 6.6.

Option Description

Commercial premises along Sheridan Lane are subject to inundation from Morleys Creek flooding, and were affected during the 2012 event (10.9 m at the Gundagai Gauge). The construction of a levee along Sheridan Lane running parallel to Morleys Creek has been suggested as a method to reduce inundation of these properties in frequent flood events. Although a levee did not have widespread community support, this FRMS provides the opportunity to assess the hydraulic impacts that may be caused by a levee in this area. The high level assessment is described below.

Option FM07 was modelled by raising the existing ground level along the south side of Sheridan Lane to a crest height equal to the 5% AEP level plus freeboard, equalling an average height of 1.2 m - 1.5 m above ground level. West of West Street, the levee dog-legs and heads northwards to Punch Street. The 5% AEP level was selected as it was the design event (10.8 m at the Gundagai Gauge) that most closely represented the 2012 event. Option FM07 was tested for impacts on flood behaviour in the 5% and 1% AEP event. Note that for this preliminary assessment a spillway has not been included in the modelled levee alignment.

Modelled Impacts

Murrumbidgee River Flooding

The flood level impacts of Option FM07 in the 5% and 1% AEP events are shown on Figure F11A and Figure F12A. Figure F11A indicates that in the 5% AEP event the levee acts to exclude floodwaters from properties inside the levee along the northern side of Sheridan Lane, without having a significant impact on flood levels on the 'wet' side of the levee. In the 1% AEP, the levee would be overtopped and properties inside the levee would be inundated as they would without the levee. Peak flood levels inside the levee along Sheridan Lane between Homer Street and Byron Street would be reduced slightly (up to 0.05 m), while peak flood levels outside the levee would remain largely unchanged, with some minor localised increases of up to 0.05 m east of Homer Street.

Note that this high level assessment has not captured the possible change in other elements of flood behaviour such as rate of rise in the Gundagai Commons, or the duration of inundation for properties inside the levee during an event in which the levee is overtopped.

Jones Creek Flooding

The option was assessed separately for overland flooding in the Jones Creek catchment. The flood level impacts in the 5% AEP and 1% AEP overland events are shown on Figure F11B and Figure F12B. Figure F11B indicates that in the 5% AEP event the levee would cause widespread increases to flood levels (up to 0.5 m) and newly flooded areas along the length of Sheridan Lane from Jones Creek to Middleton Drive. Figure F12B indicates similar flood level increases for the 1% AEP event. Flood level and extent increases in both events occur due to the obstruction of overland flow (which would otherwise drain to Morleys Creek) by the proposed levee. It is likely that the installation of levee gates or flood flaps would reduce the impact of the levee on overland flow flooding, although these items have not been included in preliminary mitigation option modelling.

Discussion of Other Concerns and Considerations

Aside from peak flood level impacts, there are a number of factors to consider regarding the use of levees as a flood mitigation option. These include, for example:

- Space constraints and easement availability;
- Capital costs and ongoing maintenance requirements;
- Economic merits – limited number of beneficiaries of the levee would likely result in a low BC ratio;
- Obstruction to internal drainage in local rain events (see Jones Creek modelled flood impacts above);
- Delayed drainage following flood events in which the levee is overtopped;
- Additional demand on Council to close levee pipe gates in the event of a riverine flood, and cost to maintain pipes and gates for the life of the levee;
- Potential for catastrophic failure;
- Visual amenity and access to Morleys Creek;
- Limited community support;
- Community flood education required to ensure business owners, especially, know their residual flood risk – and understand that a levee is not a ‘cure all’ for flooding.

The construction of a levee along Sheridan Lane does not have widespread community support; although business owners understand the potential flood benefits, they consider that Council and the SES currently manage flood awareness and evacuation well during flood events. A levee running the full length of Sheridan Lane and along Jones Creek is also likely to have a significant upfront cost, ongoing maintenance commitments and internal drainage issues. In rarer flood events, Option FM07 may also cause evacuation problems for areas to the south or increased flood level impacts in other areas of the township (although these have not been investigated as yet).

Evaluation

In a 5% AEP Murrumbidgee River flood event, Option FM07 would provide significant reductions in flood affectation in properties along Sheridan Lane and roads including Sheridan Lane, Sheridan Street, and cross streets between West Street and Homer Street. However, the option would have a number of challenges in terms of easement restrictions, high capital costs, ongoing

maintenance requirements, creek amenity and potential evacuation implications. Additionally, the levee would cause a major obstruction to local runoff draining to Morleys Creek. This is shown in the preliminary overland flow flood impact figures which indicate that the levee would cause widespread flood level increases and newly flooded previously unaffected areas. Business owners interviewed in the community consultation period indicated that they were already able to manage the flood risk effectively and were well supported by Council and SES. It is considered that improving the existing flood response practices would be a better approach than constructing a levee along Sheridan Lane. This option is not recommended for further investigation.

6.7.4.2. Option FM08 – Temporary Flood Barriers

FM08 Overview

☒ Temporary flood barriers have been investigated as an alternative to a permanent levee, with the aim of reducing flood damages to commercial premises. There are many complications associated with using temporary flood barriers in Gundagai, including deciding which premises to protect, when to set up the barriers (and close businesses) and whose responsibility the setup and storage of materials should be. This option is not considered suitable in Gundagai. As an alternative, flood proofing for individual commercial premises is recommended. This option (PM03) is described in Section 6.6.3.

Option Description

As discussed in Option FM07 and Section 5.2.1, commercial premises along Sheridan Lane are subject to inundation from Morleys Creek when water levels in the Murrumbidgee River reach 10.4 m at the Gundagai gauge. The construction of temporary flood barriers around specific properties (those which have experienced heavier affectation historically) was suggested as a method to reduce inundation (and hence flood damages) of specific properties in frequent flood events without the associated costs, restriction to creek access and visual impacts of a full scale levee.

Option FM08 was modelled to enclose the blocks bounded by:

- West Street, Sheridan Street, Otway Street and Sheridan Lane (currently occupied by commercial premises including the Gabriel Motel, Woolworths and the Gundagai District Services Club); and
- Lot 45/ DP1140037 at the corner of Byron Street and Sheridan Lane (currently occupied by the Mitre 10 hardware store).

The temporary levee is modelled to have a level of protection of 5% AEP, with 0.5 m freeboard. This equates to approximately 1.2 m above the existing natural surface. Option FM08 was tested for the 5% AEP event.

Modelled Impacts

The flood level impacts of Option FM08 in the 5% AEP event are shown on Figure F13. The figure shows that in the 5% AEP event, the barriers will remove flood affectation from the enclosed blocks altogether, whilst having negligible impact on flood levels upstream.

Discussion of Other Concerns and Considerations

Temporary flood barriers have been utilised in a number of recent Australian flood events (e.g. Rockhampton, April 2017), and their popularity is growing internationally. For temporary barriers to be successful, it is vital that the agency responsible for coordinating the barrier setup is defined and trained appropriately prior to a flood event. Resourcing (in terms of time and people required) should be considered, as this will inform the amount of warning time necessary. There may be social issues tied to the selection of which areas to protect. Funding avenues for the use of temporary flood barriers for the protection of commercial premises would need to be further investigated, and financial contributions from the benefitted businesses may need to be considered.

Evaluation

Temporary flood barriers would provide significant reduction in flood risk to the enclosed properties and could reduce property damages to those protected properties. However, the option is not without its complications, and careful consideration would need to be given to the social equity of selecting which properties to enclose, the responsibility and liability of equipment storage, operation and pack up, and the logistics of using the barriers safely and effectively during a flood event. The Gundagai Floodplain Management Committee resolved to not pursue this option further, but rather to look into temporary flood proofing techniques that could be deployed on an individual property basis for affected commercial premises in the Sheridan Street area. This option is documented as PM03 and is discussed in Section 6.6.3.

6.7.5. Channel Modifications

DESCRIPTION

Channel modification can include a range of measures from increasing the size, shape or materials of a channel to altering the natural surrounds via dredging, lining (or naturalising lined channels), or other vegetation management practices. Channel modifications can help to reduce peak upstream flood levels by improving conveyance, although such measures may also increase flood levels in adjacent or downstream locations.

6.7.5.1. Option FM09 – Vegetation Management

FM09 Overview

☑ It is recommended that Council continues its ongoing vegetation management activities to ensure the density of riparian vegetation does not increase unchecked and impact on flood behaviour.

Option Description

Vegetation management refers to the planning and implementation of the activities involved in managing native and exotic plant species within a particular area. Activities may include removal of weeds or debris, thinning of shrub layers or targeting a particularly problematic noxious plant species. In a flooding context, vegetation management may aim to improve flood behaviour, however in a broader context it may bring about a range of ecological values, for example the improvement of habitats for native fauna or bushfire hazard reduction. While there are many benefits available, the current legislative context imposes a number of constraints on vegetation management, especially in riparian areas. Council currently undertakes routine maintenance and minor works to manage vegetation in riparian areas.

Vegetation density can be represented in flood modelling using the hydraulic roughness parameter known as 'Manning's n'. The 'n' value is determined by a number of factors that affect the resistance of channels and floodplains, including but not limited to the presence of vegetation. Option FM09 has been assessed to determine how flood levels might be affected if normal vegetation management were neglected, and the banks of the Murrumbidgee River and Morleys Creek were allowed to become densely vegetated. The scenario was simulated by significantly increasing the applied Manning's 'n' to represent increased channel roughness in the locations shown on Figure F14. This scenario (FM09) was tested for the 5% and 1% AEP events to assess the likely impacts of dense vegetation in a relatively frequent and rare flood event.

Modelled Impacts

The flood level impacts of Option FM09 in the 5% and 1% AEP events are shown on Figure F14 and Figure F15. Both figures show that vegetation build-up in the modelled sections would lead to a widespread increase in flood levels (up to 0.1 m) for more than 10 km upstream of Gundagai. It should be noted that the modelled increase in vegetation density is quite exaggerated (the Manning's 'n' for large areas of channel banks is increased to 'n' > 0.1, compared to current assumptions of n = 0.03 or lower). Plate 2 indicates two examples of vegetation considered to be represented by a Manning's 'n' of 0.1 and have been taken from the *Murrumbidgee River Wagga Wagga Riparian Vegetation Management Plan* prepared as part of the Revised Murrumbidgee River at Wagga Wagga Floodplain Risk Management Study (Reference 16).


Plate 2 Examples of vegetation considered to be represented by a hydraulic roughness of Manning's 'n' = 0.1

Other Concerns and Considerations

Morleys Creek is typically well maintained by the local community and the Bidgee Banks Golf Course for amenity to fishermen and golfers. Local land care groups may be eligible for funding to support its role in maintaining the amenity of Morleys Creek. It is therefore unlikely that Morleys Creek would become overgrown to the extent modelled in Scenario FM09. However, the aim of Option FM09 is to demonstrate the need for and importance of regular vegetation management. Incorrect or improper vegetation clearing may also have significant environmental impacts such as bank erosion or removal of native species. It is noted that in the months (or years) following a flood event additional effort may be required to manage debris and new saplings or exotics that sprout from seeds deposited on river banks during the flood.

Evaluation

It is recommended that Council continue its current ongoing riparian maintenance schedule, with additional efforts made following flood events.

7. MULTI CRITERIA MATRIX ASSESSMENT

7.1. Introduction

The Floodplain Development Manual (Reference 2) recommends the use of multi-criteria assessment matrices when assessing flood risk mitigation measures. A multi-criteria matrix (MCA) provides a method by which options can be assessed against a range of criteria, and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCA will not give a definitive 'right' answer, but will provide a tool to debate the relative merits of each option.

7.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criteria: Flood Behaviour, Economic, Social and Environmental. Scores for each criterion are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further.

Table 17 Multicriteria Assessment Scoring System

	Criteria	Metric	Score -3	-2	-1	0	1	2	3
Economic	Economic Merits	*Comparison of the economic benefits against the capital and ongoing costs*	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Technical & Implementation Complexity	*Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe*	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome easily	No constraints or uncertainties	No construction requirements
	Staging of Works	*Ability to stage proposed works*	NA	NA	NA	Works cannot be staged	Some minor components of the works may be staged	Some major components of the works may be staged	NA
Social	Impact on Emergency Services	*Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).*	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Emergency Access	*Flood depths and duration changes for critical transport routes*	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities[1]	*Disruption to critical facilities*	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	*No. of properties flooded over floor. Across all events*	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
	Impact on flood hazard	*Change in hazard classification*	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	*Change in community flood awareness, preparedness and response*	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	*Closure of or restricted access to community facilities (including recreation)*	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-5 days	No Change to acess but facilities disrupted for 0-2 days	No Change	Reduces duration of access disruption or facility disruption by 0-2 days	Reduces duration of access disruptioin or facility disruption by 3-5 days	Prevents disruption of access or facility altogether
	Community and stakeholder support	*Level of agreement (expressed via formal submissions and informal discussions)*	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
Environmental	Impacts on Flora & Fauna (inc. street trees)	*Impacts or benefits to flora/fauna*	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	*Impacts to heritage items*	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
	Acid Sulfate Soils and Contaminated Land	*Disruption of PASS and/or Disruption of Contaminated Land*		Any works within Class 1 or 2 ASS area or Excavation >1m within Class 3 ASS area or Excavation >1m within Class 4 ASS area	Surface works within Class 2 ASS area or Excavation <1m or surface works within Class 3 ASS area or Excavation <2m or surface works within Class 4 ASS area	Works not within areas identified as PASS or contaminated land	NA	NA	NA
Other Aspects	Financial Feasibility and Funding Availability	*Capital and ongoing costs and funding sources available*	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies and projects or measures (such as environmental)	*Level of compatibility*	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

[1] Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

7.3. Results

Table 18 Multi Criteria Assessment Results

		Economic			Social								Environmental			Other Aspects			
ID	Option	Economic Merits	Technical & Implementation Complexity	Staging of Works	Impact on Emergency Services	Emergency Access	Impact on critical and/or vulnerable facilities1	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and stakeholder support	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Acid Sulfate Soils and Contaminated Land	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	Total Score	Overall Rank
PM03	Flood Proofing Measures for Commercial Properties	3	1	2	3	0	0	3	0	3	2	3	0	0	0	-1	2	21	**1**
RM02	Improve Flood Emergency Management Operations	NA	1	2	3	0	0	0	0	2	0	3	0	0	0	2	2	15	**=2**
PM05	S10.7 Planning Certificates	NA	NA	NA	0	0	3	3	0	3	0	3	0	0	0	0	3	15	**=2**
RM01	Voluntary House Raising	2	-2	3	2	0	0	3	0	2	2	1	0	0	0	2	0	15	**=2**
FM10	Install flap valve on Culvert at Gundagai McDonalds	2	2	2	2	0	0	1	1	0	0	2	-1	0	0	2	0	13	**=3**
RM05	Gundagai Flood Intelligence Improvements	NA	3	2	0	0	0	0	0	2	0	3	0	0	0	1	2	13	**=3**
PM06	Community Flood Awareness	NA	2	2	0	0	0	0	0	3	0	2	0	0	0	2	2	13	**=3**
PM01	Inclusion of Flood Related Development Controls in DCP	NA	NA	NA	0	0	3	3	0	3	0	1	0	0	0	0	3	13	**=3**
RM04	Improve Evacuation Management	NA	-1	2	2	2	1	1	1	0	1	2	0	0	0	-1	1	11	**=4**
PM04	Revision of FPL and FPA	NA	NA	NA	0	0	3	3	0	1	0	1	0	0	0	0	3	11	**=4**
RM03	Improve Flood Warning Systems	NA	1	1	1	0	0	0	0	2	0	1	0	0	0	1	1	8	**5**
FM09	Vegetation Management	NA	1	2	0	0	0	0	0	0	0	0	2	0	0	-1	3	7	**6**
PM02	Voluntary Purchase	-2	1	2	1	0	0	1	0	0	0	-3	0	0	0	1	0	1	**7**
FM08	Temporary Flood Barriers	1	-1	1	-1	-1	-1	0	0	0	0	0	0	0	0	1	0	-1	**8**
FM06	West Sheridan Lane Causeway Upgrade	-1	-2	2	0	0	-1	-1	-1	0	-1	1	-1	0	0	1	1	-3	**9**
FM05	Install Culvert Underneath Middleton Drive	-2	-3	2	-1	0	0	0	0	0	-3	0	0	0	0	1	2	-4	**10**
FM01	Channel underneath Sheahan Bridge	-3	-1	2	-2	-2	0	0	-2	0	0	1	-1	0	0	2	0	-6	**11**
FM07	Sheridan Lane Levee	-3	-2	2	-1	-1	-1	2	1	0	-1	1	-1	0	0	-3	0	-7	**12**
FM04	Lower Middleton Drive	-3	-2	2	-1	-1	0	0	0	0	-3	0	0	0	0	-2	2	-8	**13**
FM02	Culverts through southern Sheahan Bridge Abutment	-3	-3	1	-2	-2	0	0	-2	0	0	1	-1	0	0	2	0	-9	**14**
FM03	Otway Street Bridge	-3	-2	2	-3	2	0	0	0	0	-3	-3	-2	0	0	-2	2	-12	**15**
	Option is recommended in Draft Floodplain Risk Management Plan																		

7.4. Discussion

The results of the multicriteria assessment are provided in Table 18, with each of the assessed management options scored against the range of criteria. It is important to note that the approach undertaken does not provide an absolute “right” answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis, which stakeholders can then use to make a decision.

For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison. Options highlighted in blue have positive scores, indicating that the benefits of the option outweigh negative aspects. These options have been recommended for inclusion in the Floodplain Risk Management Plan (See Section 8).

The highest ranking option is PM03: Flood Proofing Measures for Commercial Properties. This option’s high score is a result of its relatively low capital cost, compared to the significant reduction in Annual Average Damages it would provide to commercial premises, especially on Sheridan Lane and Sheridan Street. One aspect of the option is for individual businesses to purchase and use temporary flood barriers. There are many products available, and are an inexpensive way to prevent ingress of floodwaters, thereby preventing loss of stock, damage to fittings, and significantly reduce the recovery period following the flood. This option is described in detail in Section 6.6.3.

Conversely, options with negative scores are not recommended for further investigation. These options have been discarded at various stages of the investigation due to a range of factors, including being ineffective in reducing flood risk, having high costs compared to the tangible benefits available, or being impractical to implement. These options are unlikely to warrant further investigation as part of future Floodplain Risk Management Studies and Plans.

8. FLOODPLAIN RISK MANAGEMENT PLAN

8.1. Introduction

The Gundagai Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (Reference 2). The Plan:

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

8.2. Recommended Floodplain Risk Management Measures

An investigation of possible management measures was undertaken to assess the effectiveness of each option against a range of criteria. The assessment criteria included how the option affected property damages, community flood awareness, impact on the SES, and economic merits, and a range of other factors described in Section 7.1.

The following options were found to be effective in reducing flood risk across a range of criteria, and have been recommended for implementation. Each measure has been prioritised based on its ability to reduce flood risk in Gundagai, and how readily it can be implemented (and funded, if necessary). The recommended measures are as follows (in no particular order within each priority group).

8.2.1. High Priority Actions

Options that are highly effective in reducing flood risk, scored highly in the Multi Criteria Assessment (Section 7.3) have been allocated a high priority in the Floodplain Risk Management Plan. Further to these, options with relatively little cost that can be implemented readily are also allocated a high priority. The high priority actions are as follows:

- Install flap valve (to prevent backflow) through the McDonalds carpark culvert through the Hume Highway embankment (FM10).
- Amalgamate and improve SES and Council flood intelligence guides (RM01A & RM01B);
- Improve safe access to the Murrumbidgee River at Gundagai Gauge (RM02A);
- Update the Local Flood Plan (RM02C);
- Improve dissemination of flood warnings to the community (RM03B);
- Raise low points in O.I. Bell Drive to improve access to the Gundagai Showgrounds (RM04A);
- Implement a Community Flood Education program (RM05);
- Undertake a feasibility study to investigate Voluntary House Raising and Voluntary Purchase Scheme for Gundagai (PM01);
- Investigate flood proofing measures for commercial properties (PM03);

- Adopt Flood Planning Level of 1% AEP + 0.5 m, and associated Flood Planning Area (PM04); and
- Include flood related information on Section 10.7(2) and (5) Planning Certificates (PM05).

8.2.2. Medium Priority Actions

- Include flood related development controls in the (future) Cootamundra – Gundagai Development Control Plan (PM06);
- Install a water level sensor at the Otway Street causeway (RM02B);
- Install water level sensor and signage at Muttama Road near Muttama Creek (RM03A);

8.2.3. Low Priority Actions

- Complete post flood evaluation and review of flood intelligence guides and management practices (RM01C);
- General evacuation management improvements (RM04B); and
- Continue routine vegetation management activities (FM09).

The Floodplain Risk Management Plan is provided in Table 19.

Table 19 Floodplain Risk Management Plan (Part 1 of 2)

Response Modification Measures										
Option ID	**Option**		**Description**	**Benefits**	**Concerns**	**Responsibility**	**Funding**	**Cost**	**B/C Ratio**	**Priority**
RM01	Improve Gundagai Flood Intelligence	RM01A: Consolidation of flood intelligence documents	Amalgamate SES and Council Gundagai Flood Intelligence documents for consistency	Consistent and detailed documents regarding same actions of work for Council and SES.	Clarity regarding roles and responsibilities is essential.	SES and Council	SES and Council	Minimal	N/A	High
		RM01B: Addition of modelled flood information to flood intelligence guide	Provide additional detail from flood modelling, including design flood levels and consequences for events greater than 11 m at the gauge.	Increase understanding of flood behaviour in events greater than have been experienced first hand.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled results.					High
		RM01C: Post Flood Evaluation	A Flood Intelligence Collection and Review is to be undertaken immediately following flood events.	Improve management of subsequent flood events.	Other recovery actions may be prioritised immediately after a flood, when it is most effective to review the intelligence guide.					Low
RM02	Improve Flood Emergency Management Operations	RM02A: Access to Gundagai Gauge Boards	Improving operations reagrding gauge readings, during emergency flood events.	Improved safety for SES personnel and Council staff when taking manual gauge readings, especially during wet weather.	None.	Council	N/A	<$10 k	N/A	High
		RM02B: Install water level sensor at the Otway St causeway	Add new wireless water level sensor at Otway St causeway	Reduces the need for SES personnel to undertake constant visual inspections at the area.	Potential target for vandalism, sensor may stop working during a flood event. Ongoing telemetry costs may be prohibitive.	Council	May be eligible for OEH funding	TBD (varies depending on product)	N/A	Medium
		RM02C: Gundagai Local Flood Plan Update	Review of the Local Flood Plan to update relevent details.	Information from this study can be used to update documented operations and update design flood levels.	Regular reviews required to ensure contact details and roles/ responsibilities are current.	SES	N/A	Minimal - In house	N/A	High
RM03	Improve Flood Warning Systems	RM03A: Installation of water level sensor on Muttama Road at Muttama Creek.	Investigate installing an additional water level system at Muttama Rd near Muttama Creek.	Improved warning for motorists, and potential reduction in number of incidences of motorists driving through floodwater. Reduced demand on SES to attend accidents.	Potential target for vandalism, sensor may stop working during a flood event. Ongoing telemetry costs may be prohibitive.	SES/Council	May be eligible for OEH funding	TBD (varies depending on product)	N/A	Medium
		RM03B: Improve dissemination of flood warnings to the community	Improve the procedures in which flood warnings are shared with residents and business owners.	Improved flood awarness to residents and business owners.	Information may be ignored or forgotten by residents.	SES, Council and GFWA	N/A	Minimal	N/A	High
RM04	Improve Evacuation Management	RM04A: Access to Gundagai Showground via O.I Bell Drive	Improve access to the showground by raising low points on O.I. Bell Drive	Increased time available for safe evacuation.	Costs of installing and maintaining new culverts.	Council	May be eligible for OEH funding	<$10k	N/A	High
		RM04B: General Evacuation Management Improvements	Improvements to evacuation procedures and ensuring necessary elements of the Local Flood Plan are updated.	Improved community awareness of flooding and how best to prepare in a flood event.	Information may be ignored or forgotten by residents.	SES and Council	N/A	Minimal	N/A	Low
RM05	Improve Community Flood Awarness		Council to implement a flood education program to improve flood awarness in Gundagai.	Improved community awareness of flooding and how best to prepare in a flood event, and reduced burden on SES for assistance.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council	N/A	N/A	N/A	High

Table 19 Floodplain Risk Management Plan (Part 2 of 2)

Option ID	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	B/C Ratio	Priority
Property Modification Measures									
PM01	Voluntary House Raising and Voluntary Purchase Feasibility Study	Feasibility study to investigate the suitability of a voluntary house raising scheme to reduce property damages to dwellings in low flood hazard areas of Gundagai.	Reduction in frequency of over-floor inundation of dwellings in low hazard areas, and associated cost savings and reduction in stress/trauma/ cleanup requirements.	Not all eligible dwellings may be suitable to raise and may require alternative approaches. VHR schemes take time and residents may be impatient, or unwilling to participate.	Council	Eligible for OEH funding	$50k	~1.4	High
PM03	Flood Proofing Measures for Commercial Properties	Implement temporary flood barriers, or wet proofing measures, to commercial premises in flood affected areas (e.g. Sheridan Lane and Sheridan Street)	Significantly reduce commercial property damages, and associated stress and trauma. Reduce burden on the SES to help businesses prepare for floods, and decrease recovery times following	Staff to be regularly trained in the installation of temporary flood proofing measures. Implementation of measures at the time of construction may be considered onerous by developers.	Individual business owners	N/A	TBD (varies depending on product)	>>1	High
PM04	Revision of Flood Planning Level and Flood Planning Area	Council to adopt a Flood Planning Level of 1% AEP + 0.5 m freeboard in areas affected by mainstream flooding, and 0.3m freeboard in overland flow	The higher FPL will improve the level of protection for new developments, while the FPA will provide clear guidance on the properties subject to flood related	A planning proposal is required to amend the LEP and implement the new FPL and FPA. Some residents may oppose the higher FPL as it may be considered more	Council	N/A	Minimal	N/A	High
PM05	Inclusion of Flood Related Information on Section 10.7(2) and (5) Planning Certificates	Council to provide flood information from the Gundagai Flood Study to property owners via planning certificates.	Improve the flood awareness of property owners in Gundagai, and ensure flood related development controls are applied where necessary.	Provision of data may be considered onerous for Council staff.	Council	N/A	Minimal	N/A	High
PM06	Inclusion of Flood Related Development Controls in Development Control Plan	When the new Cootamundra - Gundagai DCP is drafted it is recommended that flood related development controls are included. Engagement of a specialist planning consultant to provide advice and guidance is recommended.	Objectives of the Gundagai LEP (Clause 6.3) to be supported by the appropriate application of flood related development controls.	Development controls may be considered onerous by developers.	Council	N/A	Estimated at $30k for specialist planning consultant	N/A	Medium
Flood Modification Measures									
FM10	Install flap valve on Gundagai McDonalds carpark culvert	A flap valve is to be installed at the western end of the culvert that drains the McDonalds carpark through the Hume Highway embankment.	Prevent backflow of the culvert during flood events, reducing flood risk to the carpark and the burden on the SES/Council to respond to inundation.	Minor cost to purchase and install valve, inclusion in routine maintenance schedule to ensure proper function.	Council	N/A	<$3k	N/A	High
FM09	Vegetation Management	Continue routine riparian vegetation management.	Ensure density of vegetation in riparian areas does not increase and affect flood levels in Gundagai.	Vegetation management must be done in line with NSW bidiversity legislation.	Council	N/A	As per existing schedule	N/A	Low

9. REFERENCES

Pilgrim DH (Editor in Chief)

1. **Australian Rainfall and Runoff – A Guide to Flood Estimation**
Institution of Engineers, Australia, 1987.

NSW Government

2. **Floodplain Development Manual**
2005

Commissioner For Sustainability And The Environment

3. **State of the Environment Report – Gundagai Land Degradation**
ACT Government, 2004

Cootamundra – Gundagai Regional Council

4. **Morley's Creek Rehabilitation Rivercare Award Application Form**
Landcare Murrumbidgee and Murrumbidgee Catchment Management Authority, 2007

WMAwater

5. **Gundagai Flood Study**
Cootamundra – Gundagai Regional Council, March 2018

Hydrology Section, NSW State Government

6. **Murrumbidgee River at Gundagai: Flood Frequency Studies (Ref 78/13149)**
November 1980.

WMAwater

7 **Murrumbidgee River Flooding - Data Collection - March 2012 – Draft Report**
NSW SES.

WMAwater

8 **Murrumbidgee River Flooding - Flood Data Collection - December 2010**
NSW SES, February 2011.

Australian Institue for Disaster Resilience

9. **Technical Flood Risk Management Guideline: Flood Hazard**
Second edition, 2012

Department of Environment and Climate Change

10. **Floodplain Risk Management Guideline – Residential Flood Damages**
NSW State Government, October 2007

Howells, L., McLuckie, D., Collings, G. and Lawson, N.

11. **Defining the Floodway – Can One Size Fit All?**
Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes

February 2003
Thomas C, Golaszewski R, Honour W

12. **Refinement of Procedures for Determining Floodway Extent**
Floodplain Management Authorities of NSW 50th Annual Conference

13. NSW Office of Environment and Heritage
Floodplain Management Program
Guidelines for voluntary house raising schemes
February 2013

14. NSW Office of Environment and Heritage
Floodplain Management Program
Guidelines for voluntary purchase schemes
February 2013

15. **Gundagai Local Flood Plan** – a Subplan of the Gundagai Local Disaster Plan (DISPLAN) July 2008.

WMAwater

16. **Revised Murrumbidgee River at Wagga Wagga Floodplain Risk Management Study and Plan**
Wagga Wagga City Council, March 2018

Appendix A

Appendix A: Glossary

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and

	typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain.

	continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage

Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models

The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach

The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the States rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding

Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures

Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge

The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to A water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Gundagai

Floodplain Risk Management Study & Plan

Council is currently undertaking a Floodplain Risk Management Study and Plan to investigate ways to manage flooding in Gundagai. This questionnaire gives you an opportunity to make suggestions or note key problem areas where flood risk could be reduced. Some examples of flood mitigation strategies are described below to help you complete this questionnaire.

DRAINS AND CHANNELS increase the rate at which water is removed from a flood affected area. These structures are often situated in existing flow paths and are generally earthen or concrete lined.

RETENTION BASINS are areas (such as playing fields) that store water and release it at a lower, more controlled rate to reduce downstream flood levels. Generally more suited to smaller, urban catchments.

LEVEES are used to exclude flood water from flood prone areas. Levees are often constructed from earth embankments, concrete walls or sheet piles.

CULVERTS AND BRIDGES allow water to flow under roads, train tracks or similar obstructions. It can often be beneficial to increase the conveyance capacity of existing culverts, or install new culverts to decrease upstream water levels, however the downstream impacts must also be taken into account.

VOLUNTARY HOUSE RAISING has been widely used throughout NSW to significantly reduce flooding of habitable floors particularly in lower flood hazard areas. Suitable houses are raised above the Flood Planning Level, to protect and reduce damages.

VOLUNTARY PURCHASE involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The floodplain is then reserved for a more appropriate land use.

FLOOD RESPONSE MEASURES
Include improvements to flood warning systems and alerts, road upgrades to improve local evacuation routes and community education and awareness programs. These options are best implemented in conjunction with the SES and local community groups.

SMART PLANNING POLICIES can help reduce risk to residents, existing and new developments across the wider floodplain. These can include improvements to the Local Environment Plan (LEP) and Development Control Plan (DCP).

Please complete and return this questionnaire to:

Cootamundra – Gundagai Regional Council

255 Sheridan Street,

Gundagai NSW 2722

DUE DATE: Wednesday 4th April

Please make sure all surveys are returned before this date or they may not be counted.

Alternatively, you can access an online version of this survey at:

https://www.surveymonkey.com/r/gundagai

If you have additional information you would like to make available for the Study or further comments, please attach them to your questionnaire response or alternatively email to the contacts on Page 4.

Gundagai
Floodplain Risk Management Study & Plan

COOTAMUNDRA-GUNDAGAI REGIONAL COUNCIL

Please complete this questionnaire and return to council. Please make sure all surveys are returned before Wednesday 4th April 2018 or they may not be counted.

1. Your Details

(Please note your contact details are optional, will be held confidential and will only be used to contact you for more information regarding this study)

Name:

Address:

Telephone:

Email:

2. How long have you lived in this area?

☐ Years ☐ Months

3. Can we contact you directly for more information?

☐ Yes ☐ No

If 'Yes', what method of contact would you prefer? e.g. telephone, Email etc.

4. Do you think something should be done to reduce flood risk in Gundagai due to the Murrumbidgee River and Jones Creek?

☐ Yes ☐ No ☐ Don't Know

5. Please describe the location/s where you think flood risk should be considered:

Please name nearest street and cross street and other useful information to identify the location of flood risk, and type of problem that occurs.

7. If eligible, would you be interested in a Voluntary Purchase scheme?

☐ Yes ☐ No

8. If eligible, would you be interested in a Voluntary House Raising scheme?

☐ Yes ☐ No

Please note that Questions 6. and 7. are only to obtain an indication of the level of community interest in these schemes. It does not mean your property is flood prone and/or appropriate for these options. Eligibility for VP and VHR are based on the severity of flood hazard. Please feel free to comment generally on VP and VHR schemes below.

9. Do you have any of your own ideas to reduce flood risk?

☐ Yes ☐ No

If 'Yes' can you please describe the location of where you think flood risk could be improved (please provide nearest crossroads or known landmarks). A number of pre defined options are presented on the next page that may help with your comments.

Gundagai
Floodplain Risk Management Study & Plan

As a local resident who may have witnessed flooding, you may have your own ideas about how to reduce flood risks. Which of the following management options would you prefer for Gundagai (1 = least preferred, 5 = most preferred)? See the front page for descriptions of the mitigation options.

10. Potential Options	Preference
Retarding or detention basins (these temporarily hold water and reduce peak flood flows) - Suggested location/other comments:	**1 2 3 4 5**
Improved flood flow paths such as channels and drains - Suggested location/other comments:	**1 2 3 4 5**
Culvert/bridge enlarging - Suggested location/other comments:.	**1 2 3 4 5**
Pit and pipe upgrades - Suggested location/other comments:	**1 2 3 4 5**
Levee banks or flood walls - Suggested location/other comments:	**1 2 3 4 5**
Strategic planning and flood related development controls - Suggested location/other comments:	**1 2 3 4 5**
Education of the community, providing greater awareness of potential hazards - Suggested location/other comments:	**1 2 3 4 5**
Flood forecasting, flood warnings, evacuation planning and emergency response measures - Suggested location/other comments:	**1 2 3 4 5**

Contacts

Ray Graham
Director of Engineering Services
rgraham@gundagai.nsw.gov.au

Cootamundra Gundagai Regional Council
PO Box 34, Gundagai NSW, 2722
Tel: 02 6944 0200

Catherine Goonan
Senior Engineer
gundagai@wmawater.com.au

WMAwater
Level 2, 160 Clarence Street
Sydney, NSW 2000
Tel: 02 9299 2855

Appendix C

APPENDIX C. FLOOD DAMAGES ASSESSMENT

PAGE

LIST OF FIGURES

C.1. BACKGROUND

C.1.1. Introduction

A flood damages assessment has been undertaken to determine the economic costs of flooding in Gundagai due to both the Murrumbidgee River, and overland flooding in the Jones Creek catchment. This appendix describes the factors that contribute to flood damages, and the methodology used to undertake the damages assessment for the Gundagai Floodplain Risk Management Study & Plan (FRMS&P).

The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (e.g sewage treatment plant) or flood borne debris;
- The types of development, assets and infrastructure affected and their building materials or construction type.

The quantification of flood damages is an important part of the floodplain risk management process and is typically focused on the direct, tangible damages (described below) relating to property development. Flood damages assessments typically do not capture other tangible or intangible damages. As a result, while the damages assessment is useful to get a “feel” for the magnitude of the flood problem, it is of limited value for absolute economic evaluation, or for determining overall viability of a mitigation option. The damages assessment however forms a useful basis of comparison to assess the relative economic merits of mitigation measures, in which their benefits (reduction in tangible property damages) are compared to the cost of implementation.

C.1.2. Flood Damage Categories

The Floodplain Development Manual (Reference 1) broadly categorises flood damages as either tangible or intangible.

Tangible Damages:

- Financial in nature and can be readily measured in monetary terms, and include:
    - Damage or loss caused by floodwaters wetting goods and possessions (direct damages); and
    - Loss of wages and extra outlays incurred during clean-up operations and in the post-flood recovery period (indirect damages)

Intangible Damages:

- Intangible damages are difficult, if not impossible to quantify in financial terms, and may include:

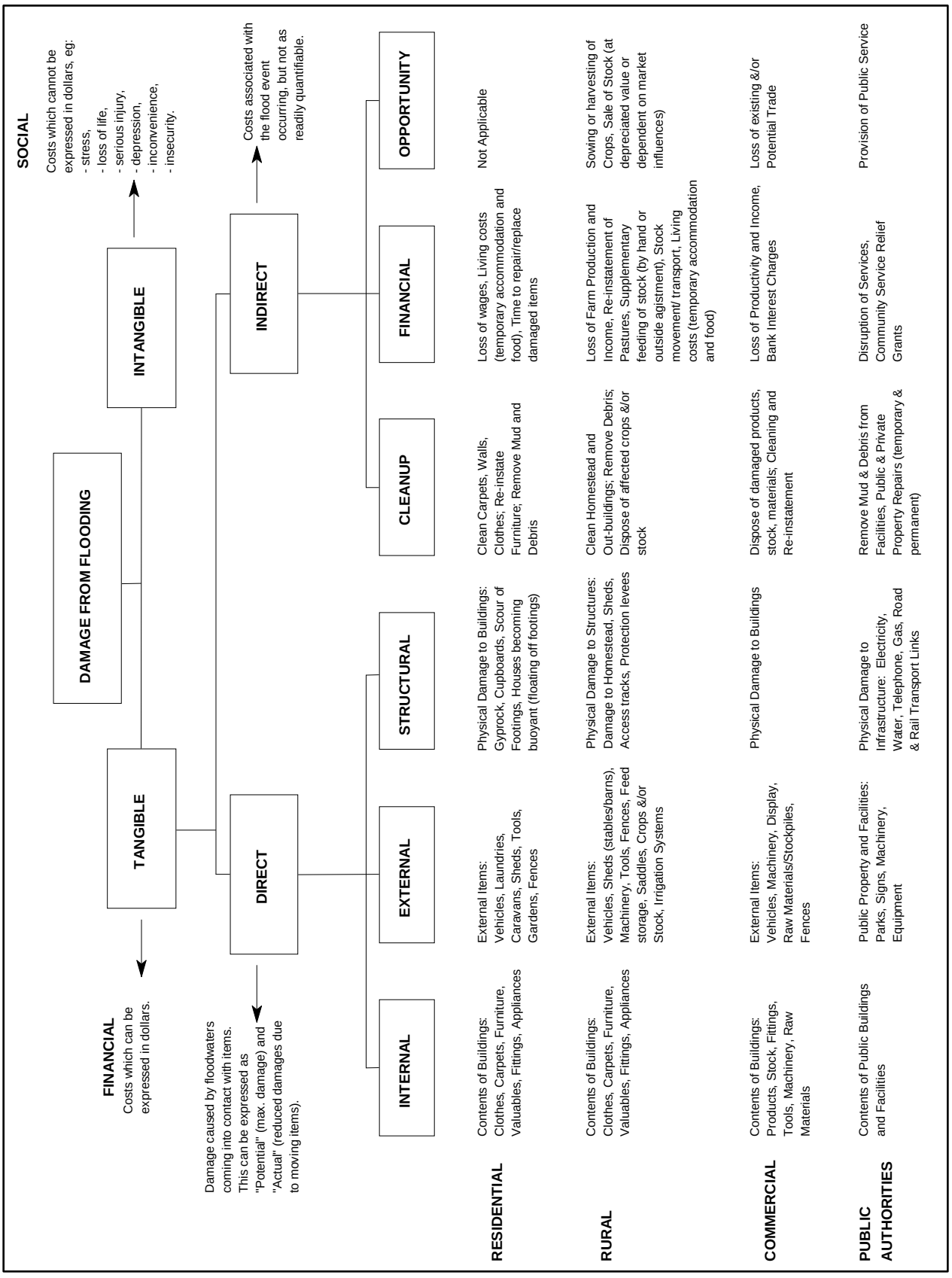
- increased levels of emotional stress and mental and physical illness caused by the flood episode;
- Sense of loss and despondency caused by the destruction of memorabilia (family photographs and documents) or loss of pets;
- Stress caused by additional (and at times quite large) financial outlays to replace flood damaged possessions; and
- Stress caused by family disruption – including for example temporary accommodation, attend different schools, increased distances or time to travel to work.

Tangible damages can be further classified as direct or indirect, presented in Diagram 1. Direct damages are those caused by floodwaters wetting goods and possessions, thereby either damaging them irreparably or reducing their value. Indirect damages are the additional financial losses caused by the flood, including for example:

- the extra cost of food and accommodation for evacuees;
- loss of wages by employees;
- loss of actual and prospective production or sales by flood-affected commercial and industrial establishments; and
- Opportunity cost to the public caused by the closure or limited operation of public facilities.

Intangible and indirect tangible damages are not considered in this damages assessment, however are evaluated for shortlisted flood risk mitigation options via a multi-criteria matrix assessment.

Diagram 1 Flood Damage Categories



C.2. QUANTIFICATION OF DAMAGES

C.2.1. Floor Level Data

To undertake the flood damages assessment, floor level data is required. Hydrographic and Cadastral Survey Pty Ltd were engaged in July 2014 to undertake a floor level survey for properties estimated to be located within the Murrumbidgee River 1% AEP flood extent. The survey included floor level data for 81 residential properties, 11 commercial premises (generally shops along Sheridan Street/ Sheridan Lane), 9 public facilities (such as the Gundagai District Services Club and Sports Club and a number of motels) and 1 industrial property.

For each property, the survey also captured the following descriptors:

- Estimate regarding whether the ground floor was habitable;
- Indication of house size (small, medium or large);
- Floor Construction (pier, slab or other);
- Wall construction (Brick, stone or rendered, clad, or mixed)
- Type (residential, commercial, industrial, public)
- Name and Nature of Use/Business (non-residential buildings only)

For properties outside this extent (but within the Murrumbidgee River PMF extent) and within the Jones Creek floodplain, detailed survey was not obtained due to the high incremental cost of obtaining these levels, and the limited value this data adds to the assessment. Instead, floor levels of the remaining 149 properties were estimated using visual inspection and available LiDAR data. The total number and type of properties included in the assessment (either surveyed or estimated) is provided in Table 1.

Table 1 Properties included in the damages assessment

Property Type	Total Count
Residential	199
Commercial	42
Industrial	1
Public	9
Total	**251**

One of the limitations associated with the floor level data is that the recorded level only represents the level that could be seen from the street frontage. It is acknowledged that properties may have different floor levels throughout the building, however these have not been captured.

C.2.2. Flood Levels and Depth of Flooding Calculations

The damages assessment is based on relating the depth of property inundation to a monetary amount. This section describes how the depth at each property is derived, while Section C.2.3 describes the process of determining financial losses.

Available floor levels, ground levels and peak flood levels were analysed to identify a representative depth for each property. Floor levels were adopted from the survey and estimation techniques described in Section C.2.1. For surveyed properties, ground levels were taken directly

from the survey. For estimated properties, a ground level was extracted from the digital elevation model (refer to Section 2.1 of the main report) at the same location as the floor level was estimated (usually at or close to the front door). The peak flood level for each design flood event was then extracted from the model results for the same location.

It is noted the approach is somewhat limited in that it does not necessarily account for variations in water level across a property. However, it is considered appropriate for the purpose of the damages assessment to provide a representation of damages across the study area rather than detailed damages for individual properties, to allow for the comparison of mitigation options.

C.2.3. Property Damage Analysis

The assessment is based on damage curves that relate the depth of flooding on a property to the potential tangible damage cost within the property. While it would be ideal to prepare damage curves for the individual catchment, damage data is generally not readily available and can be a costly exercise to obtain. To address this, NSW Office of Environment and Heritage (OEH) has carried out research and prepared a methodology (Reference 2) to develop damage curves based on state-wide historical data. The methodology is applicable for residential properties, and with some adjustment, can be applied to commercial or industrial properties.

C.2.3.1. Residential Damages

As described in Reference 2, a number of considerations are required to develop the residential damage curves, including, for example:

- Average value of contents;
- Contents damage repair limitation factor (on average damages are lower for short duration events compared to longer duration);
- Level of community flood awareness;
- Effective warning time (and ability of residents to relocate valuables);
- Typical table/bench height;
- External damage (to gardens, garages etc);
- Structural damage to the property;
- Clean up costs; and
- Additional costs during the recovery period, e.g. alternate accommodation.

These factors have not been assessed individually in this study, rather have contributed to the development of the OEH residential flood damage curve, which has been applied in this damage assessment. Chart 1 shows the components that make up a damage curve for a residential house (on a slab, or “low set”). The curves used for all residential property types are shown in Chart 2. The curves differentiate damages for dwellings with the lowest habitable floor close to ground level (e.g. on a slab), and “high set” which may refer to properties constructed on piers. Damages for two story dwellings are calculated separately, as some allowance is made for possessions to be stored on the second level. As shown in Chart 2, damages for lower flood depths are therefore lower in comparison to one-story dwellings, while there is a marked jump in damages when depths reach 2.5 m, as a result of inundation of the second story occurring.

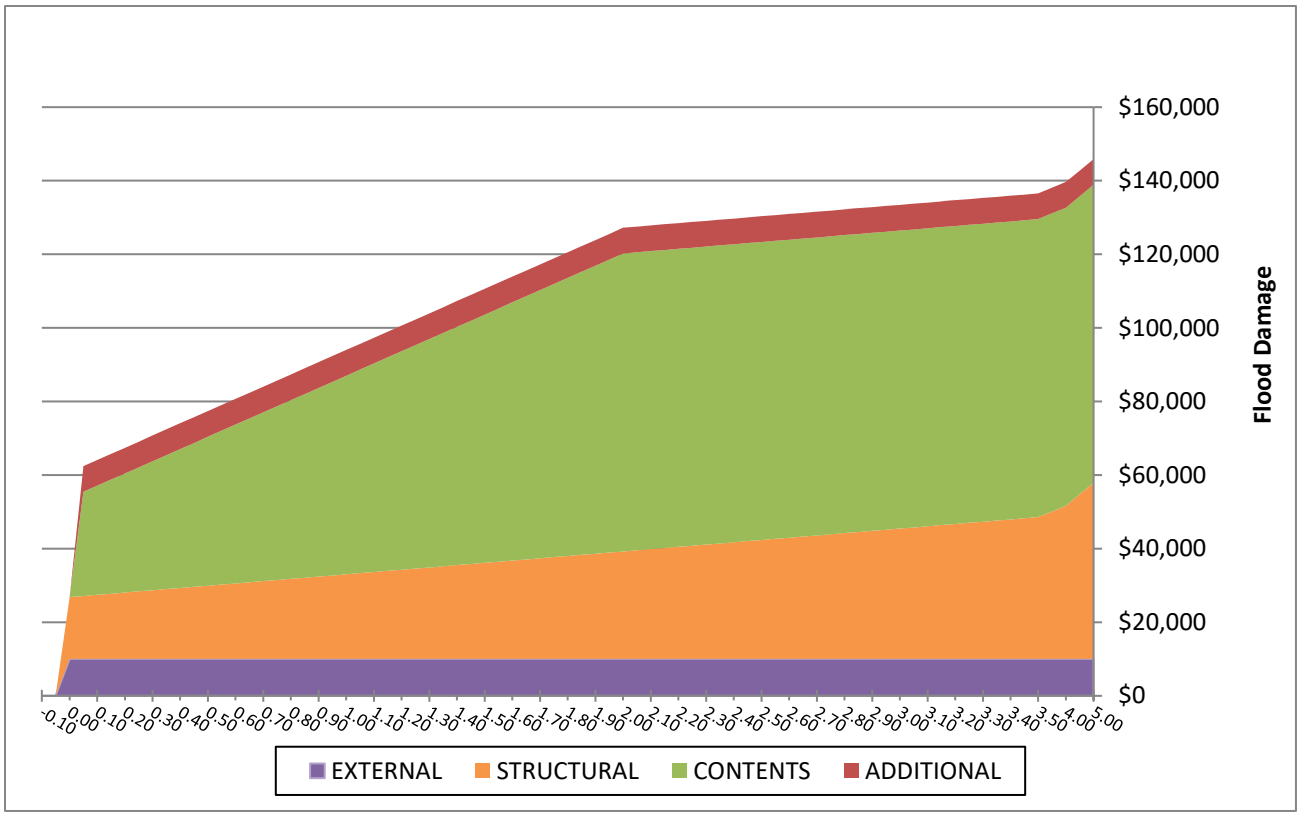


Chart 1 Residential Damage Curve (House on a slab)

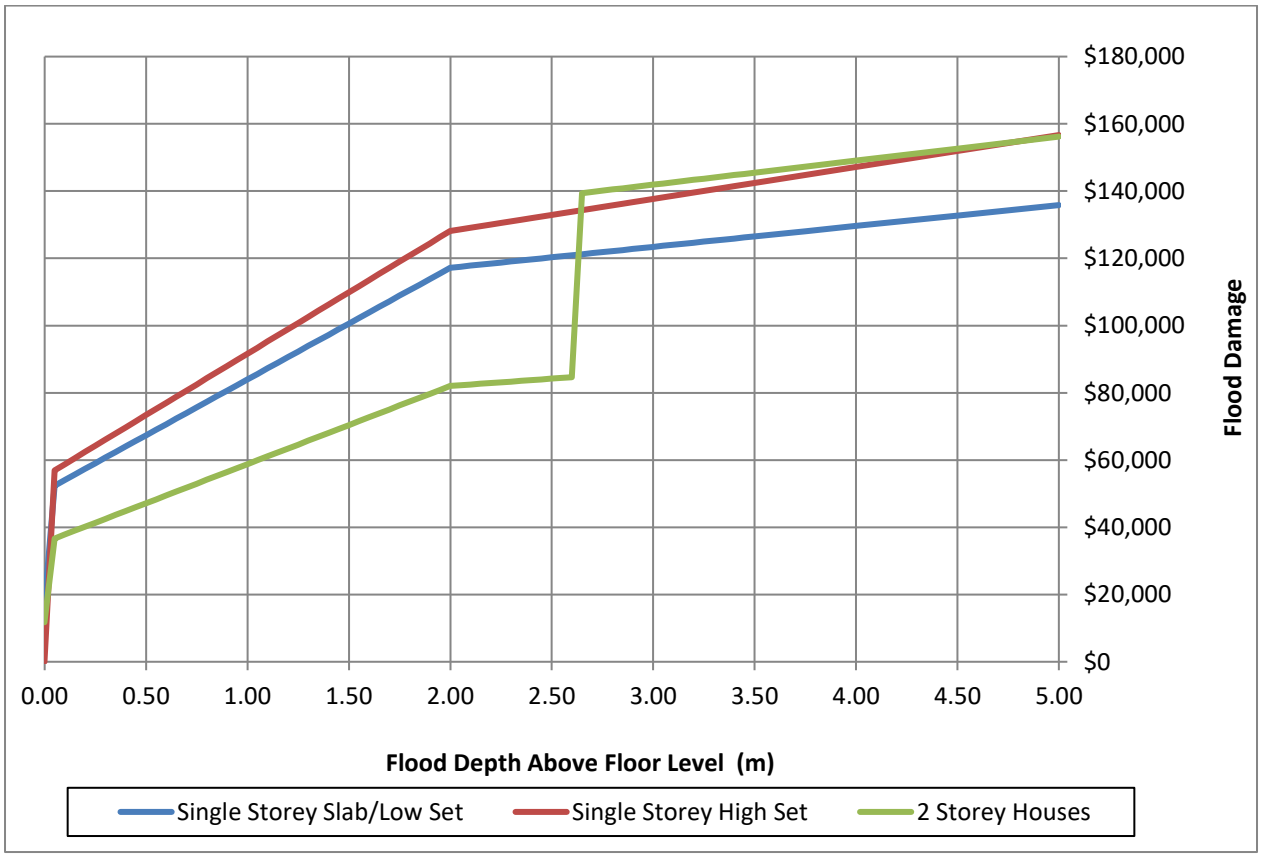
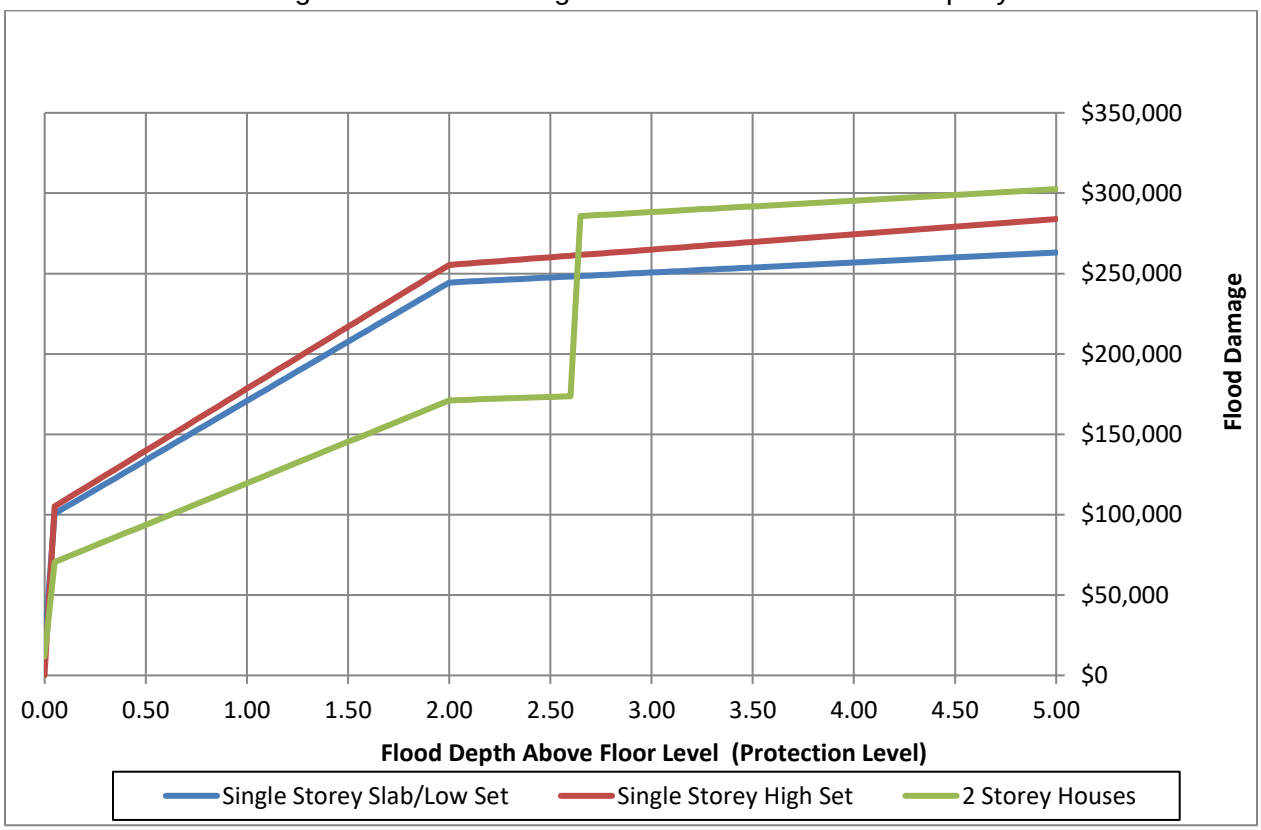


Chart 2 Residential Damage Curves

C.2.3.2. Commercial Damages

Commercial and industrial damages are typically higher than residential damages due to the potential value of stock and premises that may be damaged, and the ongoing losses of income as damages are repaired and days of business lost before operation can recommence. It is noted also that commercial damages can be highly variable and dependent on the nature of flooding, type of business, and any operational plans in place to minimise damage (e.g. relocation of stock). As a result it is difficult to make an estimate of total commercial damage. A method is adopted in which the residential damage curves are scaled up and applied to commercial properties. To adjust the residential curve for use in the commercial damages assessment, the average contents damages for a business was estimated to be $150,000 (compared to $60,000 for a dwelling).

Diagram 2 Flood Damages Curves – Commercial Property



C.2.4. Expressing Flood Damages

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This approach means that smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. For the calculation of AAD for Gundagai, the 0.2 EY event was the smallest (most frequent) flood event modelled. it was assumed that there are no flood damages incurred in events more frequent than the 0.2 EY flood event, as the riverine flood extent is largely confined to the main river channel, and that out-of-bank flow from Morleys Creek is unlikely to cause damage to properties aside from potentially some sporting amenities on the Gundagai Commons. Overland flooding in the Jones Creek catchment is also relatively minimal in this size event.

C.3. RESULTS

C.3.1. Overview

The damage assessment results presented in the main report (Section 3.5.2) are based on an 'envelope' of Jones Creek overland flooding and riverine flooding from the Murrumbidgee River. The envelope takes the higher of the two flood levels (that is, overland or riverine), at each model grid cell, and has been used to give an overview of the total flood damages that occur in Gundagai. However, it is useful to look at the two flooding mechanisms separately to understand the relative costs that are incurred by flooding in each system. As such, this appendix presents the flood damages due to each system separately.

C.3.2. Jones Creek Damages

The flood damages assessment results for Jones Creek are provided in Table 2 to Table 4 below. The results indicate that relatively frequent flood events, especially the 10% AEP and 0.2 EY events, constitute over a third of the residential average annual damages (AAD), and over half of the non-residential AAD. It is also notable that many more properties are subject to external inundation (e.g. through rear or front yards) than over floor inundation, indicating that flow is relatively shallow compared to the height of floor levels. This is typical of overland flow flood affectation driven by excess runoff from local rainfall.

Table 2 Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	41	10	$ 801,728	30	$ 19,554
10% AEP	47	16	$ 1,324,544	27	$ 28,182
5% AEP	53	17	$ 1,509,921	18	$ 28,489
2% AEP	58	18	$ 1,619,686	12	$ 27,926
1% AEP	63	24	$ 2,067,062	5	$ 32,811
0.2% AEP	74	40	$ 3,596,856	6	$ 48,606
PMF	122	95	$ 10,617,530	4	$ 87,029
Average Annual Damages (AAD)			**$ 399,611**		**$ 3,276**

Table 3 Non-Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	11	4	$ 453,606	31	$ 41,237
10% AEP	12	5	$ 722,125	27	$ 60,177
5% AEP	12	5	$ 729,661	16	$ 60,805
2% AEP	11	5	$ 729,136	10	$ 66,285
1% AEP	15	6	$ 933,317	4	$ 62,221
0.2% AEP	26	18	$ 3,495,236	8	$ 134,432
PMF	30	24	$ 5,833,581	4	$ 194,453
Average Annual Damages (AAD)			**$ 220,313**		**$ 7,344**

Table 4 Combined Residential and Non-Residential Flood Damages (Jones Creek)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	52	14	$ 1,255,333	30	$ 24,141
10% AEP	59	21	$ 2,046,669	27	$ 34,689
5% AEP	65	22	$ 2,239,582	17	$ 34,455
2% AEP	69	23	$ 2,348,822	11	$ 34,041
1% AEP	78	30	$ 3,000,379	4	$ 38,466
0.2% AEP	100	58	$ 7,092,092	7	$ 70,921
PMF	152	119	$ 16,451,111	4	$ 108,231
Average Annual Damages (AAD)			**$ 619,924**		**$ 4,078**

[1]*'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)*
[2]*'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.*

C.3.3. Murrumbidgee River Damages

This section presents the results of the flood damages assessment due *only* to riverine flooding from the Murrumbidgee River. These results assume no flooding is occurring in the Jones Creek local catchment concurrently.

Table 5 Residential Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	0	0	$ -	0	$ -
5% AEP	8	6	$ 422,948	10	$ 52,869
2% AEP	16	13	$ 1,109,773	22	$ 69,361
1% AEP	24	23	$ 2,125,039	15	$ 88,543
0.2% AEP	43	40	$ 4,748,502	26	$ 110,430
PMF	177	170	$ 23,380,104	27	$ 132,091
Average Annual Damages (AAD)			**$ 105,221**		**$ 594**

Table 6 Non- Residential Flood Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	2	1	$ 167,364	6	$ 83,682
5% AEP	7	5	$ 843,178	18	$ 120,454
2% AEP	12	11	$ 1,737,062	28	$ 144,755
1% AEP	16	15	$ 2,666,521	16	$ 166,658
0.2% AEP	20	20	$ 4,539,128	21	$ 226,956
PMF	51	51	$ 12,644,733	12	$ 247,936
Average Annual Damages (AAD)			**$ 140,274**		**$ 2,750**

Table 7 Combined Residential and Non-Residential Flood Damages (Murrumbidgee River)

Event	No. Properties Affected[1]	No. Flooded Above Floor Level[2]	Combined Damages	% Contribution to AAD	Ave. Damage Per Flood Affected Property
0.2 EY	0	0	$ -	0	$ -
10% AEP	2	1	$ 167,364	3	$ 83,682
5% AEP	15	11	$ 1,266,127	15	$ 84,408
2% AEP	28	24	$ 2,846,836	25	$ 101,673
1% AEP	40	38	$ 4,791,561	16	$ 119,789
0.2% AEP	63	60	$ 9,287,630	23	$ 147,423
PMF	228	221	$ 36,024,837	18	$ 158,004
Average Annual Damages (AAD)			**$ 245,495**		**$ 1,077**

[1]'No. Properties Affected': there is flooding above ground level within the property boundary (i.e. the lot)
[2]'No. Flooded above floor level': there is flooding above the surveyed or estimated floor level of the house.

C.3.4. Discussion of Results

C.3.4.1. Total Flood Damages

The total damages in each event for both overland and riverine flooding are shown in Chart 3 below. The chart displays how for very rare events the damages due to riverine flooding are far higher than for overland flooding. At the other end of the spectrum, in frequent events, such as the 10% AEP and 0.2 EY, the total damages due to overland flooding in the Jones Creek catchment are significantly higher than those due to riverine flooding. In the 0.2 EY and 10% AEP event, no residential properties are noted to be affected by riverine flooding. This is due to the floodplain being contained between Morleys Creek and the river channel itself, affecting only the (largely vacant) land between the two watercourses.

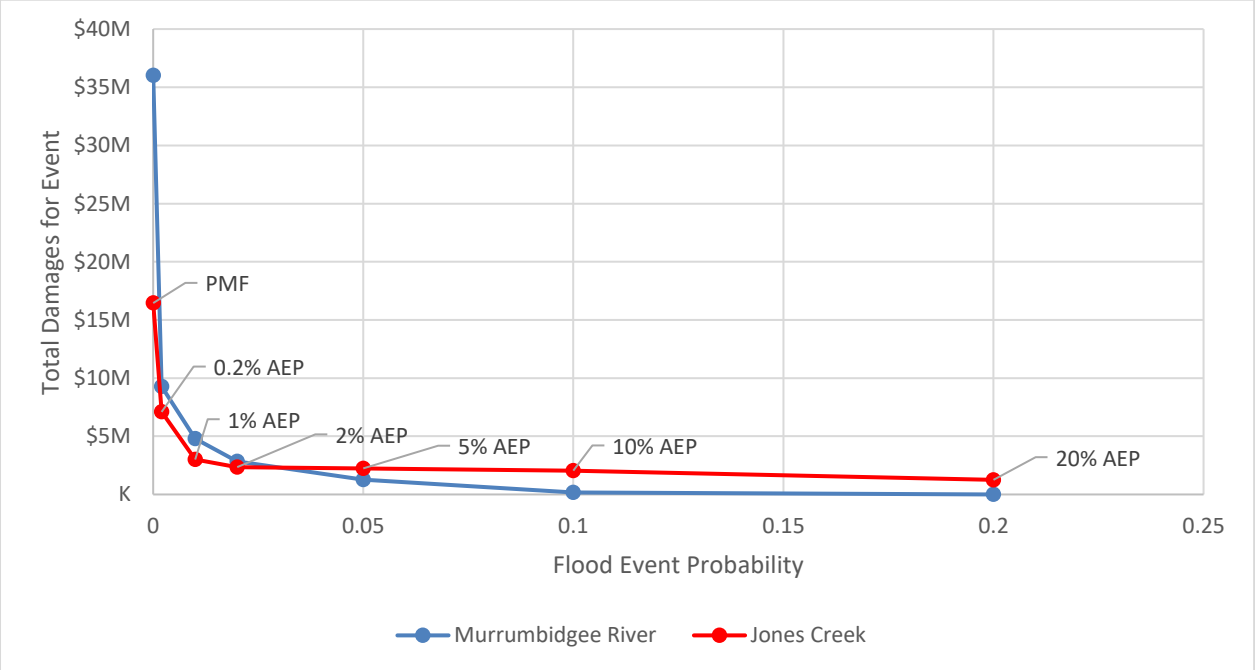


Chart 3 Total Flood Damages (Combined residential and non residential)

C.3.4.2. Annual Average Damages

The Annual Average Damages (AAD) for overland flooding and riverine flooding are identified in the previous results tables and summarised in Table 8 below.

Table 8 Average Annual Damages in Gundagai

	Jones Creek Catchment (Overland)	Murrumbidgee River (Riverine)
Residential	$399,600	$105,200
Non-Residential	$220,300	$140,300
Combined	**$619,900**	**$245,500**

As indicated in Chart 4, residential damages due to overland flooding in the Jones Creek catchment contribute the highest proportion to the Average Annual Damages, when looking at the two flooding mechanisms separately. This is a result of overland flow affecting properties in frequent events, whereas riverine flooding does not affect many properties until events around the 5% AEP level and greater.

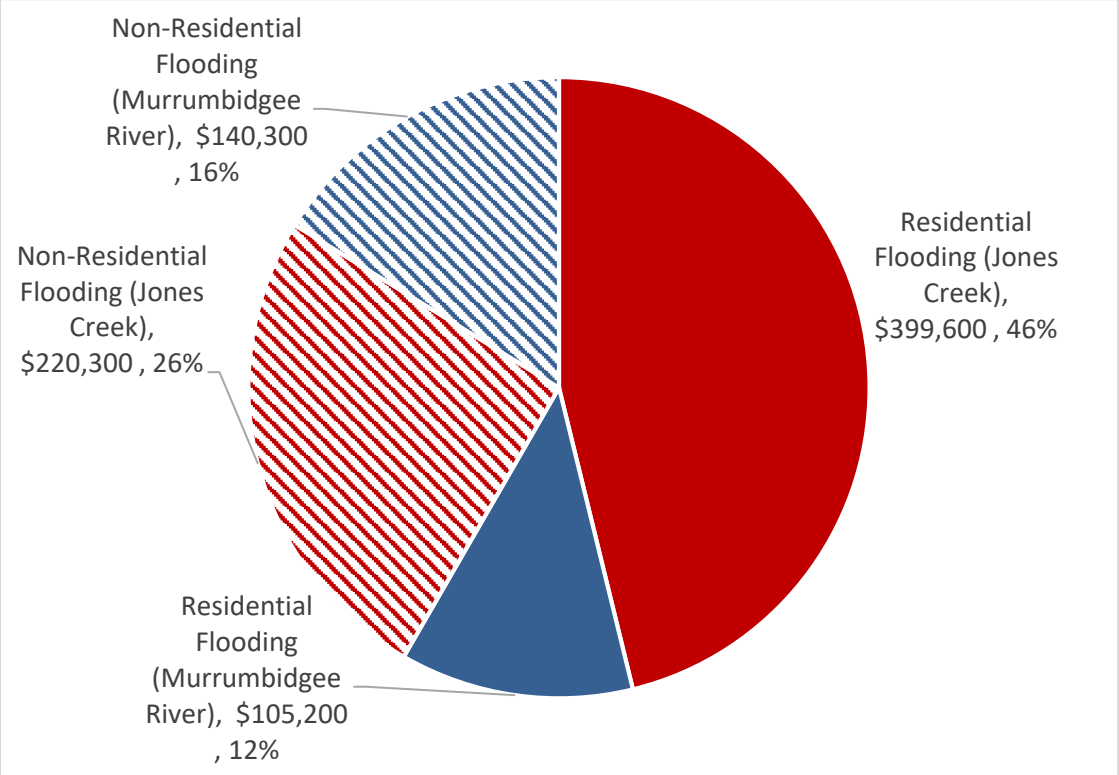


Chart 4 Average Annual Damages in Gundagai

Note: some properties are affected by both riverine and overland flooding. The analysis presented in this appendix assumes riverine and overland flooding do not occur concurrently, while the results presented in the main report reflect “enveloped” peak flood levels of both the Murrumbidgee River and Jones Creek local catchment.

C.3.4.3. Property Affectation

Another useful output from the flood damages assessment is the identification of the event in which a dwelling (or commercial premise) is first inundated above floor level. This information can be used to identify properties that are frequently affected internally and that may be eligible for Voluntary House Raising (see Appendix G), or to identify hotspots where other mitigation strategies should be targeted.

Figure C 1 shows the frequency of overfloor flood affectation due to Murrumbidgee River flooding, and the inset figure shows the same for overland flow in the Jones Creek catchment, assuming the two systems are not flooding concurrently. The coloured dots on each property indicate the event in which commercial (square icons) and residential properties (circular icons) are first affected over floor, thereby giving an indication of frequently affected properties. The results are consistent with the total damages results reported in Section C.3, showing that in the Jones Creek catchment a number of properties are affected by overland flow in the 0.2 EY and 10% AEP events that would not be affected by riverine flooding until a much rarer event. It is notable also that the majority of properties in the floodplain are not affected over floor until an event rarer than the 0.2 AEP event. This is a testament to sensible land use planning after the catastrophic flood of 1852, following which the town was relocated on higher ground.

C.4. INTANGIBLE FLOOD DAMAGES

The intangible damages associated with flooding are inherently more difficult to quantify than tangible damages. In addition to the direct and indirect tangible damages, additional costs/damages are experienced by residents affected by flooding, such as ongoing stress and anxiety, loss of life, injury etc. It is difficult to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to substantially greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that intangible damages are not overlooked when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur from Murrumbidgee River and Jones Creek floods in Gundagai is discussed below.

Isolation

Isolation (the ability to freely exit and enter a property, or escape a flooded area) during flood events will become a significant factor for rural residents. Often there is a high level of community support and spirit, which can to some extent negate the effects of isolation and can assist in a flood. Extended periods between floods can lead to some residents being unprepared for long periods of isolation, and highlights the need for community education between flood events. Isolation is also of significant concern if a medical emergency arises during a flood, or any other assistance is required by residents who may choose to ignore evacuation orders. Disconnection from utilities such as clean water, sewerage and power can exacerbate the risks of being isolated for extended periods. The relatively long warning time available in Gundagai goes some way to helping residents safely prepare and evacuate before becoming stranded, though it is acknowledged that not all residents will receive or heed warnings and isolation may still be an issue for both residents who elect to not evacuate and those who offer assistance to them during the flood.

Population Demographics

Analysis of the 2016 Census data indicates that there are some features of the population demographics of the community in Gundagai that may contribute to additional intangible damages, particularly community resilience. For example, the proportion of residents aged over 60 years is 27.0% compared to 16.2% for the whole of NSW. Elderly residents may have more difficulty evacuating or recovering from a flood event, however many of these residents are likely to have experienced at least one flood in Gundagai and may be better prepared for the challenges that come with a flood.

While some households in flood-liable communities enjoy high incomes, many people living in vulnerable communities are living on incomes that are significantly lower than the NSW average. For example, the median weekly income for households in Gundagai is $1,022 compared to $1,486 for NSW.

These age and income statistics indicate the possibility that flood-liable communities may be less able to adapt to change and less flood resilient therefore requiring local adaptation plans that acknowledge and respond to specific local challenges. Well-developed emergency

preparedness, response and recovery programs are especially important in providing assistance to vulnerable residents.

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, loss of work, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. In Gundagai, the majority of the population is situated outside the floodplain, and many residents would have experienced recent flood events in Gundagai (2010, 2012). However, a number of residents and business owners located within the floodplain (especially Sheridan Lane) may be affected by stress during and following a flood, and the importance of support during these times should not be underestimated.

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. Community safety during a flood can be impacted by several factors including:

- Availability of safe access routes;
- Willingness and ability of residents to obey evacuation orders;
- Effective warning time;
- The number of properties and access routes affected by high hazard flooding;
- The duration of inundation and potential for isolation;
- The proportion of aged residents living in flood affected properties.

Due to the difficulty quantifying these factors, and in the absence of a methodology to do so, intangible flood damages have not been included in the damages assessment described in this appendix. Analysis of intangible damages will instead be captured via a multi-criteria matrix assessment for each flood risk mitigation option investigated in this Study.

C.5. LIMITATIONS

Given the variability of flood behaviour and range of property and content values, the total likely damages in any given flood event is useful to get an indication of the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Nevertheless, damages estimates are appropriate to inform and compare the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

Aside from property damages, significant tangible costs can be expected for Gundagai that were not included in the flood damages assessment due to the lack of suitable data and established methodology. These costs include:

- inundation of properties for which floor level data were not obtained, such as rural/agricultural homesteads;
- loss of livestock and crops;
- other agricultural damages such as erosion of arable land and damage to equipment/fences;
- damage to public infrastructure such as roads, railways and power lines. Council noted combined damages costing around $17M to roads and related infrastructure following the 2010 and 2012 events;
- damage to public amenities such as toilets, parks and gardens, footpaths and cycleways; and
- costs of emergency management operations, such as helicopter rescue and evacuation centres.

As described in Section C.5, it is not possible to include intangible damages in this flood damages assessment. Such damages, including stress, risk to life and isolation, are incorporated into the mitigation option assessment through a multi-criteria matrix assessment.

APPENDIX C REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

2. Department of Environment and Climate Change
Floodplain Risk Management Guideline – Residential Flood Damages
NSW State Government, October 2007

FIGURE C1
PROPERTIES FIRST FLOODED OVER FLOOR

PROPERTY DAMAGES DUE TO MURRUMBIDGEE RIVER (RIVERINE) FLOODING

PROPERTY DAMAGES DUE TO JONES CREEK (OVERLAND) FLOODING

HUME HIGHWAY
JONES CREEK
MORLEYS CREEK
HOMER STREET
VIRGIL STREET
MURRUMBIDGEE RIVER
MOUNT STREET
COOKOOMOOROO GOCUP ROAD

Study Area
Commercial
Residential
First Flooded Floor
0.2 EY
10% AEP
5% AEP
2% AEP
1% AEP
0.2% AEP
PMF
Not Flooded

N

0 0.25 0.5 1 km

0 0.5 1 2 km

J:\Jobs\11\60541\Arc\ArcMap\FigureC1_FirstFlooded_Overfloor_JonesCk_Murrumbidgee.mxd

Appendix D

APPENDIX D. PLANNING AND POLICY REVIEW

PAGE

D.1. Introduction

It is important to understand the national and state legislation to ensure proposed floodplain risk management measures are in keeping with national, state and local statutory requirements. This appendix describes the national and state legislative instruments that influence planning, specifically in relation to flood risk, at the local government level. Local planning instruments relating to flood risk in Gundagai are described in Section 5.1 of the main report.

It is noted that the policies presented and summarised in this Appendix were in force at the time of writing, and that this document may not remain current as policies are amended (or repealed) over the years.

D.2. National Provisions – Building Code of Australia

The Building Code of Australia (BCA) is part of the National Construction Code (NCC) Series, an initiative of the Council of Australian Governments (COAG) developed to incorporate all on-site construction requirements into a single code. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian Government and each State and Territory Government.

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

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the 'defined flood event'. The 'Defined flood event' (DFE) is "*the flood event selected for the management of flood hazard for the location of specific development as determined by the appropriate authority."* In NSW this is typically the 1% AEP event.

Flood hazard areas are identified by the relevant State/Territory or Local Government authority (such as via a Floodplain Risk Management Study). The BCA is produced and maintained by the Australian Building Codes Board and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

The BCA provides general requirements for measures to keep water out of the building structure and foundations, such as setting minimum heights above ground, and minimum paved apron requirements graded to direct runoff away from the building. Additional requirements for buildings in flood hazard areas, consistent with the objectives of the BCA, primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

D.3. State Provisions – NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling the impact of development. Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below:

Environmental Planning and Assessment Act 1979 No 203

1.3 Objects of Act

The objects of this Act are as follows:

(a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,

(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,

(c) to promote the orderly and economic use and development of land,

(d) to promote the delivery and maintenance of affordable housing,

(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,

(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),

(g) to promote good design and amenity of the built environment,

(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,

(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,

(j) to provide increased opportunity for community participation in environmental planning and assessment.

D.3.1. Ministerial Direction 4.3

Direction 4.3 was one in a list of directions issued on the 1st July 2009. The directions were issued by the Minister for Planning to relevant planning authorities under section 117(2) of the *Environmental Planning and Assessment Act 1979.* Each of the directions apply to planning proposals lodged within the Department of Planning on or after the date the particular direction was issued. Direction 4 pertains to "Hazard and Risk", with Direction 4.3 relating specifically to Flood Prone Land. Direction 4.3 is provided below:

Objectives

(1) The objectives of this direction are:

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

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

Clause (3) of Direction 4.3 states:

(3) This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (4)-(9) of Direction 4.3 state:

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

(a) permit development in floodway areas,
(b) permit development that will result in significant flood impacts to other properties,
(c) permit a significant increase in the development of that land,
(d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or
(e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

(9) A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:

(a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or
(b) the provisions of the planning proposal that are inconsistent are of minor significance.

Note: "Flood planning area", "flood planning level", "flood prone land" and floodway area" have the same meaning as in the Floodplain Development Manual 2005.

D.3.2. NSW Flood Prone Land Policy

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

(a) to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and

(b) to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy. Section 733 of the Local Government Act 1993 provides councils and statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Manual).

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

D.3.3. Planning Circular PS 07-003

Planning Circular PS 07-003 (31 January 2007) provides advice on a package of changes concerning flood-related development controls for land above the 1-in-100 year flood and up to the Probable Maximum Flood (PMF). These areas are sometimes known as low flood risk areas. The package includes:

- an amendment to the EP&A Regulation 2000;
- Revised ministerial direction regarding flood prone land (issued under section 117 of the EP&A Act 1979); and
- A new Guideline concerning flood related development controls in low flood risk areas.

The changes follow community concern over notations about low flooding risk being included on Section 149 Planning Certificates *[now known as Section 10.7 Planning Certificates]* and the appropriate development controls that should apply to residential development in low flood risk areas.

The new Guideline notes that *"unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential flood planning level (FPL) (low flood risk areas)."*

The circular goes on to note: *"However the Guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year flood."*

In Planning Circular PS 07-003 it is noted that: *"Section 733 of the* Local Government Act 1993 *(the LG Act) protects councils from liability if they have followed the requirements of the Manual. The Minister has notified that the Guideline should be considered in conjunction with the Manual under section 733(4) and (5) of that Act. Councils will need to follow both the Manual and the Guideline to gain the protection given by section 733 of the LG Act".*

D.3.4. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the controls on development applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2010 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

Section 10.7 of the EP&A Act states:

(1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.

(2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).

(3) (Repealed)

(4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.

(5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.

(6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.

(7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2000, Schedule 4 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular Schedule 4, 7A refers to flood related development control information and requires Councils to provide the following information:

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

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

3) *Words and expressions in this clause have the same meanings as in the Standard Instrument.*

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 4 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property.

D.3.5. State Environmental Planning Policy (Exempt and Complying Development Codes (2008))

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are presented below.

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

(a) providing exempt and complying development codes that have State-wide application, and

(b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and

(c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and

(d) enabling the progressive extension of the types of development in this Policy, and

(e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.

D.3.5.1. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the *"Housing Code".* This section replaces the former *"General Housing Code",* which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots.

Section 3.5 is reproduced below.

3.5 Complying development on flood control lots

1) Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following:
   a) a flood storage area,
   b) a floodway area,
   c) a flow path,
   d) a high hazard area,
   e) a high risk area.

2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:

a) *if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*
b) *any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,*
c) *any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),*
d) *the development must not result in increased flooding elsewhere in the floodplain,*
e) *the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,*
f) *vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,*
g) *the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.*

3) *The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*

4) *A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Policy.*

5) *In this clause:*
flood compatible material *means building materials and surface finishes capable of withstanding prolonged immersion in water.*

flood planning level *means:*
(a) the flood planning level adopted by a local environmental plan applying to the lot, or
(b) if a flood planning level is not adopted by a local environmental plan applying to the lot, the flood planning level adopted in a development control plan by the relevant council for the lot.

Floodplain Development Manual *means the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005.*

flow path *means a flow path identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

high hazard area *means a high hazard area identified in the council's flood study or floodplain risk management study carried out in accordance with the Floodplain Development Manual.*

D.3.5.2. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*, which applies to development that is specified in clauses 3A.2–3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5. Section 3A.38 contains “Complying development on flood control lots”. The standards contained in this section are the same as those in Clause 3.5 provided in Section D.3.5.1, with the exception of Clause 2 (c) which states:

> *2 (c) any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level)*

Appendix E

APPENDIX E. FREEBOARD ASSESSMENT

PAGE

E.1. EXECUTIVE SUMMARY

Planning measures (such as flood planning levels) and mitigation works are often designed based on a level of protection or capacity for a particular design flood event, such as the 1% AEP event. To provide reasonable certainty that this level is achieved, a freeboard is added to the selected design flood level. Freeboard is a factor of safety and can be different for flood planning levels and mitigation works due to the components applicable to each. The following components are generally included in the derivation of freeboard:

- Uncertainties in flood level estimates (due to ground survey, design flow accuracy, structure blockage);
- Local variations (surge) in flood level;
- Wind, wave action and surge;
- Changes in the catchment and design estimates over time resulting from climate change, development etc;
- Post construction settlement (for mitigation works); and
- Surface erosion, defects or shrinkage (for mitigation works).

This appendix assesses the freeboard requirements for residential Flood Planning Levels in Gundagai based on mainstream flooding from the Murrumbidgee River and Jones Creek. The assessment has not considered freeboard for mitigation works, which would additionally incorporate allowance for settlement, erosion and other defects. The results of the freeboard assessment are summarised in Table 1. Discussion of how each factor is calculated is provided in the subsequent sections of this document, as referenced in Table 1.

The assessment found that the minimum appropriate freeboard for flood planning levels for properties affected by mainstream flooding in Gundagai is at least 0.5 m.

Table 1 Gundagai Freeboard Assessment Results

	Jones Creek			Murrumbidgee River			Reference
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	**Allowance (m)**	**Probability**	**Final Jones Creek Component (m)**	**Allowance (m)**	**Probability**	**Final Murrumbidgee River Component (m)**	
Uncertainties in Estimated Flood Levels	0.1	1	0.1	0.2	1	0.2	E.2.1
Local Water Surge	0.4	0.5	0.20	0.12	0.5	0.06	E.2.2
Wave Action	0.2	0.5	0.1	0.17	0.5	0.085	E.2.3
Climate Change	0.1	1	0.1	0.25	1	0.25	E.2.4
Total			**0.50**			**0.60**	

E.2. DETERMINATION OF FREEBOARD COMPONENTS

Flood planning levels (FPLs) are an important tool in the management of flood risk. They are derived from a combination of a flood event (either an historic event or a design AEP event), and a freeboard (Reference 1). This section seeks to identify and subsequently quantify the various components making up freeboard as they apply to flood planning levels.

E.2.1. Uncertainties in Estimated Flood Levels

E.2.1.1. Discussion

The determination of design flood levels comprises a number of factors and parameters, each containing a degree of uncertainty. These factors may include:

- How well the theoretical ARI-Discharge curve fits known flood events, and if it has changed since an historic event;
- Availability of detailed survey and other topographic data;
- Reliability of historical flood data; and
- Estimated parameters including afflux, surface roughness, evapotranspiration, rainfall patterns etc.

These uncertainties can have localised or cumulative effects on the accuracy of hydrologic and hydraulic modelling, and hence, the resulting design flood levels produced. A component of the freeboard accounts for this uncertainty in the design flood levels.

E.2.1.2. Component Determination

Uncertainties in flood level estimates can be approximated through an analysis of the sensitivity of design flood levels to changes in various modelling assumptions. A sensitivity analysis was undertaken as part of the *Gundagai Flood Study* (Reference 3), which assessed the Murrumbidgee River flood model's sensitivity to factors including hydraulic roughness, flow and volume estimates, grid cell size and upstream attenuation. The sensitivity of modelled Jones Creek flood behaviour to rainfall estimates, hydraulic roughness, lag, culvert blockage and initial and continuing losses was also assessed. The model's sensitivity to these factors has been used to inform this freeboard component, as described in Table 33 and Table 34 in the *Gundagai Flood Study* (Reference 3). The resulting average increase in peak flood level, as determined in the original assessment (Reference 3), is applied as the appropriate freeboard component. Results are presented in Table 2.

Table 2 Uncertainties in Estimated Flood Levels - Freeboard Components

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.2
Jones Creek	0.1

E.2.2. Local Water Surge

E.2.2.1. Discussion

Local flood water levels can be higher than the general flood level due to local blockages or obstructions in the floodplain, or, for mitigation works, if the levee alignment is oblique to the direction of the flow. Local surge can also be generated by trucks or boats passing through floodwaters. Some examples of local surge are shown below.

E.2.2.2. Component Determination

Results of flood modelling can be used to understand the sensitivity of design flood levels to the influences that cause local surge. The impacts of blockage were considered as part of the sensitivity analysis undertaken in Reference 3, and this level of sensitivity has been used to derive the freeboard component related to local surge. The sensitivity assessment applied a blockage factor of 50% to bridges in the Murrumbidgee River and Jones Creek models.

A comparison of results in the blockage case and the design case indicated that the Murrumbidgee River is most sensitive to blockage at the Middleton Drive bridge, where flood levels increase locally by approximately 0.12 m. Local flood level increases at this location are likely to affect properties along Brungle Road. In terms of the Jones Creek catchment, blocking structures across the creek at Sheridan Street and Punch Street was shown to cause local increases in peak flood levels in the order of 0.3 m. Flood levels upstream of the Hume Highway bridge however are significantly more sensitive, increasing by over a metre due to blockage in the Jones Creek bridge crossing. This level of increase would impact on properties on Burra Road west of the Hume Highway. It is noted however that the increase of over 1.0 m is not representative of the broader Jones Creek catchment, and would therefore not be appropriate to apply as the Jones Creek freeboard component for local surge. Instead, a freeboard component of 0.4 m is considered appropriate. The results are presented in Table 3.

Table 3 Local Water Surge - Freeboard Components

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.12
Jones Creek	0.4

E.2.3. Wave Action

E.2.3.1. Discussion

Increases in water level as a result of wave action are not determined in floodplain modelling. Wind-induced waves across fetches of open water are important to consider in the wide floodplains of the Murrumbidgee River or areas of high wind speeds, that is towns in valleys such as Gundagai. Design wave actions are a product of:

- Fetch – the distance the wave is assumed to travel;
- Wind speed and direction;
- Wave Height;
- Wind Set-up, and
- Wave Run-up – when a wave reaches a sloping embankment (e.g. levee) it will break on the embankment and run up the slope. Run-up would not apply to flood planning levels.

E.2.3.2. Component Determination

For this freeboard assessment 'wave action' is assumed to mean the surface waves generated by wind across the water surface. The wave height is a product of the windspeed in the direction of the fetch, and the fetch distance across which the wind travels. These factors are described below.

Effective Fetch

Fetch describes the length of the water surface along which waves are generated. While waves can be generated across whichever direction the wind is blowing, only the direction that would direct waves onto properties in Gundagai is considered for this assessment. In Gundagai, the Murrumbidgee River fetch direction is approximately north-south across the Murrumbidgee River, perpendicular to Sheridan Lane. In a 1% AEP event, the Murrumbidgee River fetch is approximately one kilometre. The Jones Creek fetch is taken as east-west to account for waves generated by westerly winds towards properties, and is estimated to be approximately 300 m in a 1% AEP event.

Windspeed

Windspeed and direction data has been obtained from the Bureau of Meteorology (BoM) taken at Gundagai, Nangus Road (Site No. 073141), and is presented in Attachment A. For wind setup in a Murrumbidgee River flood event, the wind direction is taken as southerly, while for Jones Creek flooding, westerly wind would cause the most significant waves propagating towards properties. Wind speeds in each of the fetch directions are summarised in Table 4.

The "significant wave height", H_s, in metres, is derived by combining the fetch (in metres) and the windspeed (in m/s). For this freeboard assessment, the relationship has been derived from the chart presented in Diagram 1, taken from Reference 6, with the results presented in Table 4. The Wave Action freeboard component is taken as the Significant Height derived in this assessment.

Diagram 1 Simplified relationship between fetch length, wind speed and significant wave height (Reference 6)

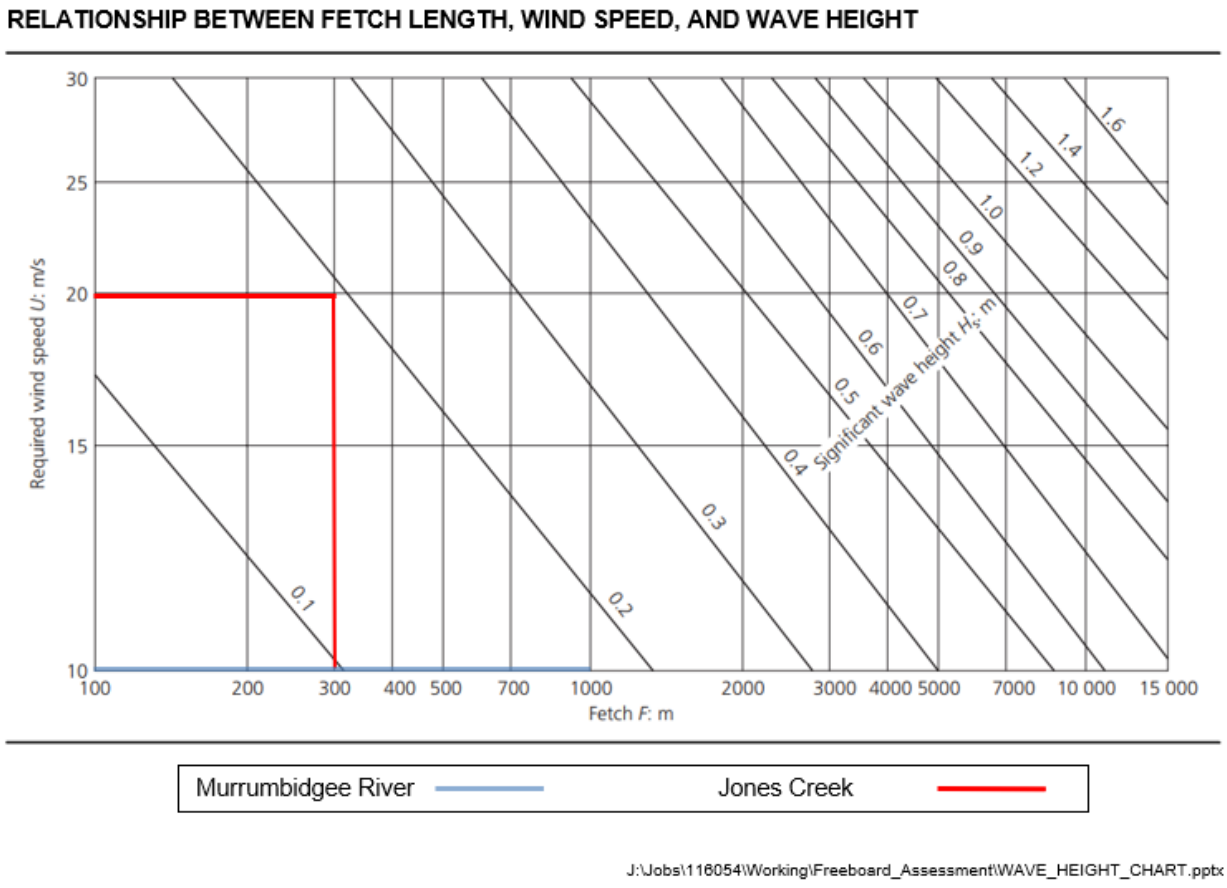


Table 4 Fetch, Wind speed, and wave height freeboard component

Mechanism	Fetch Direction	Wind speed (m/s)	Fetch (m)	Wave Height Freeboard Component
Murrumbidgee River	South to north	10	1000	0.17
Jones Creek	West to east	20	300	0.20

E.2.4. Climate Change

E.2.4.1. Discussion

The Floodplain Development Manual (Reference 1) indicates that climate change should be considered in the development and implementation of floodplain risk management works, to ensure that the level of protection can be maintained under future conditions. The impacts of climate change on flood-producing rainfall events will have a flow on effect on flood behaviour. This may result in key flood levels being reached more frequently. The freeboard allowance required to cater for climate change is greatly affected by the uncertainties in future climate model projections, and is therefore somewhat of an estimation, though is considered appropriate for the purpose of this assessment.

E.2.4.2. Component Determination

The potential impacts of climate change, and the flood model's sensitivity to these impacts were assessed as part of the *Gundagai Flood Study* (Reference 3). The sensitivity of riverine flooding was assessed by varying Murrumbidgee River flows by 10%. An increase in flow of 10% yielded an average increase in peak flood levels (in the 1% AEP event) of 0.25 m. Jones Creek flooding is controlled by rainfall, and as such the Flood Study (Reference 3) assessed the sensitivity of the Jones Creek model by varying the rainfall intensity. Results showed that, for an increase in rainfall of 10%, the peak flood levels would increase by 0.06 m on average. In parts of the Jones Creek catchment adjacent to properties (particularly Punch Street), variations of up to 0.15 m were noted. Therefore, a freeboard component of 0.1 m for climate change is considered appropriate. These components are summarised in Table 5.

Table 5 Climate Change Freeboard Component

Mechanism	Freeboard Component (m)
Murrumbidgee River	0.25
Jones Creek	0.10

E.3. JOINT PROBABILITY ANALYSIS

Joint probability analyses are used to address the chance of two or more conditions occurring at the same time. The analysis recognises that design flood characteristics could result from a variety of combinations of flood-producing factors, and that in reality not all freeboard components would occur concurrently. Assigning probability factors to each component is therefore undertaken to determine the appropriate design freeboard.

The following probability factors have been assigned in this freeboard assessment, and have been based on those applied in Reference 4:

Freeboard Component	Probability Factor
Uncertainties in Flood Levels	1
Local Water Surge	0.5
Wave Action	0.5
Climate Change	1

E.4. CONCLUSION

A freeboard assessment has been undertaken to determine the appropriate freeboard for residential flood planning levels in Gundagai. The assessment sought to quantify the following factors that can lead to flood levels being higher than the modelled estimates:

- Uncertainties in estimated flood levels;
- Local water surge;
- Wave action; and
- Climate change.

A summary of the freeboard assessment is presented in Table 6.

Table 6 Gundagai Freeboard Assessment Results

	Jones Creek			Murrumbidgee River			Reference
	(A)	(B)	(A x B)	(C)	(D)	(C x D)	
Component	**Allowance (m)**	**Probability**	**Final Jones Creek Component (m)**	**Allowance (m)**	**Probability**	**Final Murrumbidgee River Component (m)**	
Uncertainties in Estimated Flood Levels	0.1	1	0.1	0.2	1	0.2	E.2.1
Local Water Surge	0.4	0.5	0.20	0.12	0.5	0.06	E.2.2
Wave Action	0.2	0.5	0.1	0.17	0.5	0.085	E.2.3
Climate Change	0.1	1	0.1	0.25	1	0.25	E.2.4
Total			**0.50**			**0.60**	

Considering the above factors and likelihood of concurrence, a minimum freeboard of 0.5 m is deemed appropriate for flood planning levels in Gundagai. The appropriate flood planning level (FPL) for residential development in Gundagai is therefore the 1% AEP level plus 0.5 m freeboard. The Flood Planning Area is, as defined in the Floodplain Development Manual (Reference 1), is the area of land below the FPL. Given the relatively steep topography in Gundagai, adding 0.5 m freeboard to the 1% AEP level does not extend the FPA significantly, in fact no additional properties are captured in the revised FPA. However, the higher FPL will mean that when properties in the FPA are redeveloped (or raised via a voluntary house raising scheme), they will have a higher level of flood protection, thereby reducing flood damages.

Adopting a freeboard of 0.5m will also be consistent with State Government recommendations.

E.5. REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

2. Department of Environment and Climate Change
Floodplain Risk Management Guideline – Residential Flood Damages
NSW State Government, October 2007

WMAwater
3. **Gundagai Flood Study**
Cootamundra – Gundagai Regional Council, March 2018

4. NSW Department of Public Works
Wagga Wagga Levee upgrade
Flood Freeboard
Report No. DC 10096
November 2010

5. Sinclair Knight Merz
Deniliquin Flood Protection Levee Study
July, 1997.

6. Institute of Civil Engineers
Floods and Reservoir Safety
1996

Attachment A

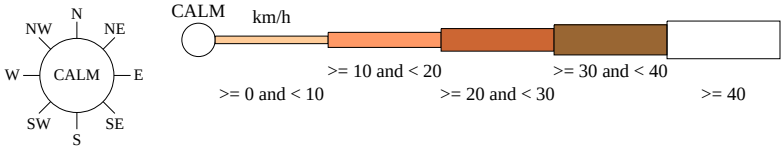
Rose of Wind direction versus Wind speed in km/h (10 May 1995 to 09 Aug 2018)

Custom times selected, refer to attached note for details

GUNDAGAI (NANGUS RD)

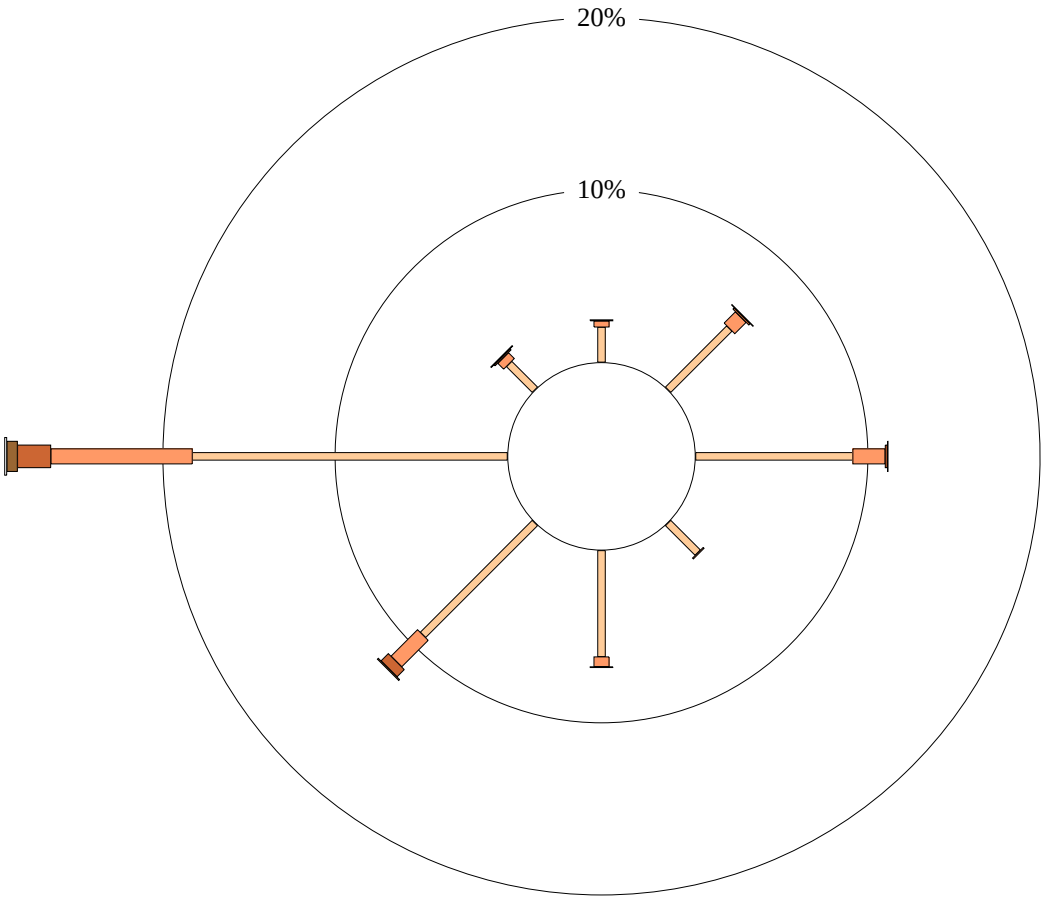
Site No: 073141 • Opened May 1995 • Still Open • Latitude: -35.064° • Longitude: 148.0986° • Elevation 225m

An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.



3 pm
6969 Total Observations

Calm 27%



Wind directions are divided into eight compass directions. The circles around the image represent the various percentages of occurrence of the winds. For example, if the branch to the west just reaches the 10% ring it means a frequency of 10% blowing from that direction. The scale factor can be ignored when interpreting these wind roses.
An observed wind speed which falls precisely on the boundary between two divisions will be included in the lower range (eg 10km/h is included in the 1-10 km/h range).
Calm has no direction. An asterisk(*) indicate that calm is less than 1%.
Only quality controlled data have been used.

Note copied from http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/windrose_selector.cgi?period=Annual&type=9&location=72150&Submit=Get+Rose