Moulamein Floodplain Risk Management Study and Plan

Final Report

Volume 1

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Table of Abbreviations

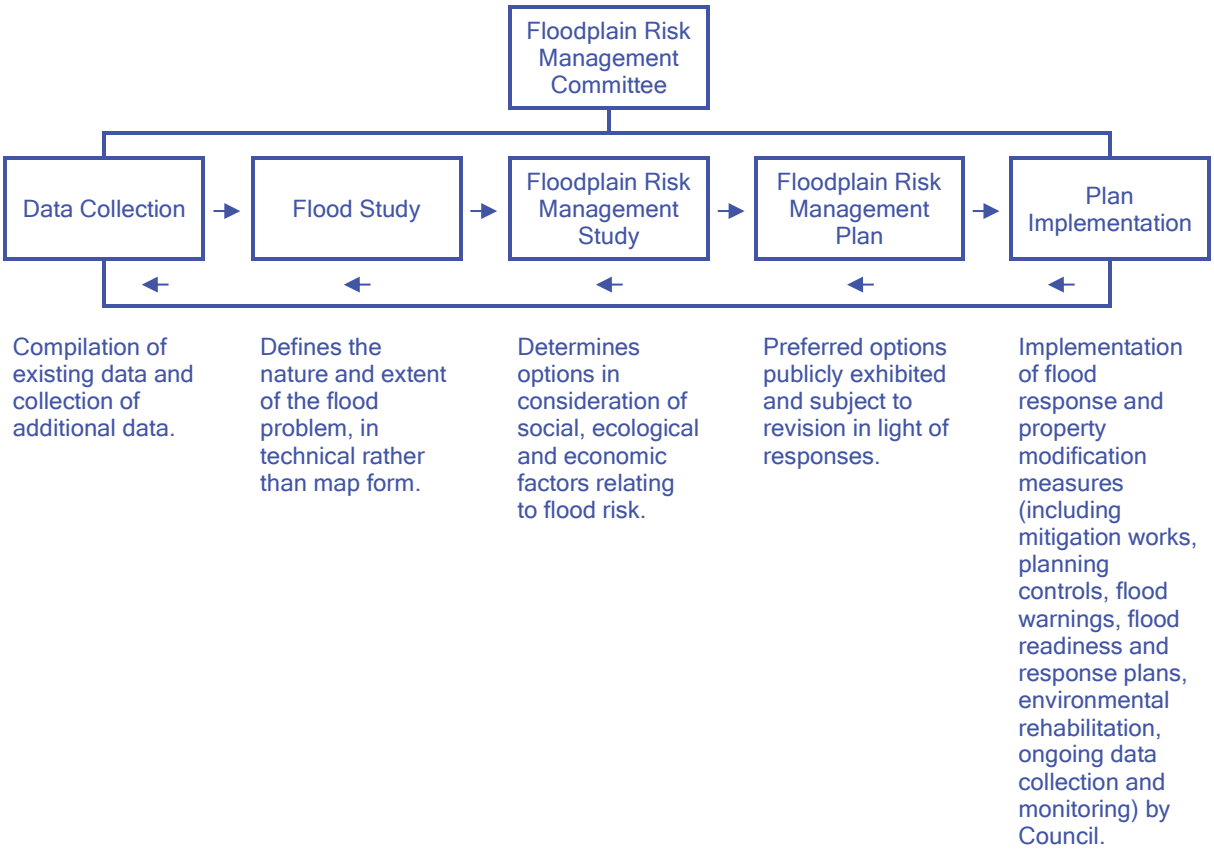
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AAD	Average Annual Damage
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ASS	Acid Sulfate Soils
DA	Development Application
DCP	Development Control Plan
DEM	Digital Elevation Model
DPIE	Department of Planning, Industry and Environment
EMPLAN	Emergency Management Plan
EY	Exceedances per Year
FRMC	Floodplain Risk Management Committee
FPA	Flood Planning Area
FPL	Flood Planning Level
LEMC	Local Emergency Management Committee
LEP	Local Environmental Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging
MDBA	Murray Darling Basin Authority
NSW	New South Wales
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SEPP	State Environmental Planning Policy
NSW SES	State Emergency Services

Forward

Flood-Related Legislation, Policies and Guidelines

The New South Wales (NSW) State Government's *Flood Prone Land Policy* places the primary responsibility for floodplain risk management with Councils and the *Local Government Act 1993 – Section 733* indemnifies Council from liability if the Council has acted in "good faith" in relation to floodplain risk management. Additionally, the State Government, through the Department of Planning, Industry and Environment (DPIE), provides financial and technical support to Council in meeting its floodplain risk management obligations.

The NSW *Floodplain Development Manual* (2005) supports the NSW *Flood Prone Land Policy*. The manual provides direction on the floodplain risk management process, as detailed below.



There are a number of industry guidelines that provide technical guidance through the floodplain risk management process. This includes the *Australian Emergency Management Series* (particularly *Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*), and *Australia Rainfall and Runoff* (ARR). ARR has undergone several revisions since its inception; with the first publication in 1958, the second publication in 1977, the third publication in 1987 and the fourth (and latest) publication in 2019.

The current study has been undertaken in accordance with the aforementioned legislation, policies and guidelines.

Acknowledgement

Murray River 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 Department of Planning Industry and Environment.

Terminology

ARR 2019 has standardised the design flood terminology used in the industry. Very frequent events are expressed as Exceedances per Year (EY), frequent to very rare events are expressed as Annual Exceedance Probability (AEP) as a percentage, and very rare to extreme events are expressed as a 1 in x AEP. This is detailed in Table 1-1, which has been extracted from Section 2.2.5., Chapter 2, Book 1 of ARR 2019.

Table 1-1: Design Event Terminology

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	

Executive Summary

The NSW State Government, through the Department of Planning, Industry and Environment (DPIE), oversee the Floodplain Management Program. The program provides support to local councils in the implementation of the NSW Government's Flood Prone Land Policy as outlined in the NSW Government's Floodplain Development Manual. The primary objective of the policy and manual is to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property.

As part of the Floodplain Management Program and as a result of flooding experienced in 2016, Murray River Council and DPIE commissioned the Moulamein Flood Study and the Moulamein Floodplain Risk Management Study and Plan. HydroSpatial Pty Ltd were engaged to undertake both studies. The Moulamein Flood Study was completed in 2019 and the subsequent Moulamein Floodplain Risk Management Study and Plan is presented in the following.

Moulamein is located in the Murray River Council Local Government Area (LGA) in South West NSW. The town is a limited service town for the local area, with government administration, post office, a primary school, a residential aged care facility and some commercial facilities. The suburb of Moulamein has a population of 484 people, according to the 2016 Census.

The Moulamein town centre is located on the confluence of the Edward River and Billabong Creek. The town is largely surrounded by irrigation development that are protected by private rural levees; whilst the town itself is protected by a series of public town levees. The town levee system consists of three distinct levees; the northern levee, the southern levee and the western levee, shown on Figure B 1.

Existing Flood Behaviour and Consequences

Given the deficiencies identified in the levees in the Visual Audit Of Moulamein Levee Report (NSW Government, 2013), selected locations were identified where a levee breach could reasonably be considered to occur. In the scenario where the levees have been breached at these selected locations, the following was found:

- the northern levee area was found to experience wide-spread inundation in events equal to and greater than the 1% AEP event;
- the southern levee area was found to experience inundation in events equal to and greater than the 20% AEP event; and
- the western levee area was found to experience inundation in events equal to and greater than the 10% AEP event.

Direct flood damages as a result of riverine flooding outside the levee was estimated to have an Average Annual Damage (AAD) value of $91,139 and a Net Present Value (NPV) of $1,348,932. As a result of riverine flooding inside the levee, the estimated AAD was $207,122 and the NPV was $3,065,558 for direct flood damages. Whereas, the direct flood damages as a result of overland flooding within the levee was estimated to have an AAD value of $509,413 and a NPV of $7,539,698.

Identifying Options

A number of flood mitigation options were identified and investigated, including:

- Potential flood modification measures:
  - FM01 – Upgrade to increase the height of existing town levees (northern, southern and western levee)
  - FM02 – Upgrade to increase the height of existing town levee (northern levee only)
  - FM03 – Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)

  - FM04 – Construct new levee around water treatment plant
  - FM05 – Install flap gates on culverts through town levees
- Potential property modification measures:
  - PM01 – Update DCP Controls
  - PM02 – Voluntary property purchase
- Potential response modification measures:
  - Update emergency response plans

Assessing Options

The flood mitigation options investigated were assessed against a multi-criteria matrix. This included assessment of the change in flood behaviour, the economic impacts, the social impacts, the environmental and heritage impacts.

Recommended Options

Based upon the multi-criteria assessment of the flood mitigation options, a number of options were recommended for implementation and others were recommended for further investigation. This is summarised in Table 0-1.

Table 0-1: Summary of Recommended Measures

Measure ID	Measure Description	Cost	Priority
FM05	Install flap gates on culverts through the town levees	$387,000	High
FM04	Construct new levee around the water treatment plant	$314,000	High
FM03	Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)	$153,000	High
PM01	Update development controls	$10,000	High
RM01	Update emergency response plans	$80,000	High
PM02	Further investigation of voluntary property purchase	$296,000	Medium
	Further investigation of the structural integrity of the town levees via a detailed geotechnical report	$75,000	Medium

1 Introduction

1.1 Overview

Murray River Council, with the support of the NSW DPIE, has commissioned HydroSpatial Pty Ltd to prepare the following Moulamein Floodplain Risk Management Study and Plan (FRMS&P).

1.2 Study Objectives

The objectives of the FRMS&P were to utilise the hydrologic and hydraulic models, developed as part of the Moulamein Flood Study (HydroSpatial, 2019) to:

- Identify potential flood mitigation measures;
- Estimate the cost to undertake the potential mitigation measures;
- Assess the benefit-cost of the potential mitigation measures;
- Recommend mitigation measures to be implemented; and
- Provide input into the priorities and timing on implementation of recommended mitigation measures.

1.3 Study Area Description

Moulamein is located in the Murray River Council Local Government Area (LGA) in South West NSW. The town is a limited service town for the local area, with government administration, post office, a primary school, a residential aged care facility and some commercial facilities. The urban area of Moulamein has a population of 305 people, according to the 2016 Census.

The Moulamein town centre is located on the confluence of the Edward River and Billabong Creek, shown in Figure B 1. The town is largely surrounded by irrigation development that are protected by private rural levees; whilst the town itself is protected by a series of public levees.

The town levees were constructed prior to and in preparation for the 1956 flood event with minimal engineering or planning. Plans and design standards for the levees do not exist. Therefore, the integrity of the levees is largely unknown and recent work undertaken by NSW Public Works has identified a number of levee deficiencies.

Due to independent engineering concerns raised in relation to the integrity and stability of the existing levees during the October 2016 flood event, the NSW SES ordered the town to be evacuated in the interests of public safety. Fortunately the levees remained intact and held against flood waters preventing flooding of the town.

A levee upgrade study was completed, namely the Moulamein Levee Upgrade Flood Study (Patterson Britton & Partners Pty Ltd, 2006). This study is now largely obsolete in terms of the data used, the methods and software employed and the floodplain management process.

2 Study Methodology

The following tasks were undertaken as part of the Moulamein Floodplain Risk Management Study and Plan Project:

- Analysis of catchment characteristics;
- Review of hydrologic and hydraulic modelling;
- Assessment of flood behaviour;
- Assessment of flood response arrangements;
- Assessment of flood planning policies;
- Investigate the consequences of flooding; and
- Investigate flood modification measures.

An analysis of catchment characteristics was carried out to gather information on the varied effects of flooding. These included social, sensitive land use, cultural and heritage, environmental, and levee system characteristics. This data was later used to inform the assessment of mitigation options. Further details on the catchment characteristics analysis are discussed in Section 4.

A review of hydrologic and hydraulic modelling was undertaken to assess the effectiveness and accuracy of the modelling, as well as the currency of the data and guidelines used. As a result of this review, slight model refinements were made, and additional modelling was undertaken. Further details on the hydrologic and hydraulic modelling review are discussed in Section 5.

An assessment of existing flood behaviour was carried out to determine the effect on multiple relevant factors. These factors included levee effectiveness, bridge and culvert capacity, road access and duration of inundation. Further details on the existing flood behaviour assessment are discussed in Section 6.

An assessment of existing flood response arrangements was undertaken to determine the effectiveness of current response arrangements, as well as determine whether an update to existing arrangements was necessary. This included an assessment of the existing Local Emergency Plan, Flood Emergency Sub Plan, Emergency Service operators, evacuation centres, and historical flood responses. Further details on the existing flood response assessment are discussed in Section 7.

An assessment of existing flood planning policies was carried out to determine the effectiveness of current flood planning policies, as well as whether an update to existing policies was necessary. Multiple relevant NSW state planning policies were assessed, as well as applicable ministerial directions. Furthermore due to the 2016 local government amalgamations that formed the Murray River Council and the continuance of the former Council's planning policies, the Local Environmental Plans and Development Control Plans for both the former Wakool Shire and Murray Shire Council's were assessed. Further details on the existing flood planning policies assessment are discussed in Section 8.

An investigation into the consequences of flooding under existing conditions was carried out to assess the economic, social, heritage and environmental impacts of flooding. The economic impacts were also quantified for the direct flood damages impacting both residential and commercial premises. Further details on the flooding consequences investigation are discussed in Section 10.

An investigation into flood mitigation measures was carried out in order to identify, assess, recommend and prioritise a number of potential mitigation measures. Options were identified through the analysis of existing flood behaviour, as well as through consultation with Council and the community. Identified options were then assessed through a multi-criteria matrix system, in order to recommend and prioritise their implementation. Further details on the flood mitigation measures investigation are discussed in Section 11.

3 Consultation

As part of this study, consultation has been undertaken with a number of stakeholders, as discussed within the following.

3.1 Floodplain Risk Management Committee

The Floodplain Risk Management Committee (FRMC) included representatives from the NSW DPIE, NSW SES, Council, and community representatives.

3.2 Community Consultation

3.2.1 Flood Study

As part of the previous Moulamein Flood Study (HydroSpatial, 2019) process, two community consultation sessions were held at different stages of the study.

3.2.1.1 First Round

The first round of community consultation undertaken during this study occurred during the data collection stage through the July-August 2018 period. The purpose of this community consultation work was to gather data from the community on historical flood events in the study area. This was achieved by distributing an information sheet and conducting a community drop-in meeting.

The community drop-in meeting was held at the Moulamein Bowling Club on the 23 August 2018 between 6pm and 8pm. The community meeting was attended by representatives from HydroSpatial, the SES, Council and two Councillors. Three community members (including a member of the FMC) took part in the community meeting. A number of anecdotal historical flood data was provided by the community during this process.

3.2.1.2 Second Round

The second round of community consultation undertaken during this study occurred at the public exhibition stage through the October 2019 period. The purpose of this community consultation work was to inform the community of the Moulamein Flood Study Draft Report and gain feedback, including to stimulate discussion on possible mitigation measures to be investigated at the next stage of the process. However, no community feedback was received during this community consultation process.

3.2.2 Floodplain Risk Management Study and Plan

As part of the current study, one community consultation session has been undertaken and a second session is scheduled to occur following the Moulamein Floodplain Risk Management Study and Plan Draft Report.

3.2.2.1 First Round

The first round of community consultation undertaken during this study occurred as part of the process of assessing the potential flood mitigation measures. The purpose of this community consultation work was to gather feedback from the community on their preference for various mitigation measures and any feedback on refinement of the mitigation measures.

This community consultation was undertaken as part of a community meeting hosted by Council.

The community meeting was held at Moulamein Bowling Club on the 4 February 2020 between 5pm and 6pm. The community meeting was attended by representatives from HydroSpatial, the Floodplain Risk Management Committee, Council and Councillors. About half a dozen community members attended this community meeting.

At this consultation, HydroSpatial presented the general concept and preliminary results of each of the following mitigation measures:

- FM01 – Upgrade to increase the height of existing town levees (northern, southern and western levee)
- FM02 – Upgrade to increase the height of existing town levees (northern levee only)
- FM03 – Upgrade to increase the height of existing town levees (southern levee only)
- FM04 – Install flap gates on culverts through town levees
- FM05 – Maintenance unblocking culverts through road embankments
- PM01 – Update development controls
- PM02 – Floodproofing existing buildings
- RM01 – Update Emergency Response Plans

The community was then invited to discuss their thoughts regarding these mitigation measures. From this, the community and FRMC considered the benefit cost ratio of mitigation measure FM03 (to increase the southern town levee) to be too low. Subsequent discussions with the FRMC suggested that this measure might be replaced with the measure to increase the town levee between Moulamein Lake and Tchelery Road; with this revised measure to be complementary to the suggestion to relocate the emergency evacuation centre from Moulamein Bowling Club to Moulamein Swimming Pool (part of mitigation measure RM01).

Notwithstanding the changes to FM03, no mitigation measure appeared to have a higher community preference over the other mitigation measures.

3.2.2.2 Second Round

Following updates to the mitigation measures investigated, a second round of community consultation was undertaken over the February-March 2021 period. The purpose of this community consultation work was to gather feedback from the community on their preference for the updated mitigation measures. As part of this consultation, a newsletter and questionnaire were distributed to the community (refer to Appendix H), with plans to host a community meeting following the collection and review of the feedback from the questionnaire.

Unfortunately, there was an extremely low response rate to the questionnaire with only three responses received. From these responses, a consensus often could not be reached on preferences for mitigation measures; for instance, the question regarding the preference for the option FM01 (which was to increase the height of the northern, southern and western levees) resulted in one positive, one negative and one neutral response. Furthermore, with such a small sample size it could not be definitively concluded that the responses were fully representative of the community as a whole.

Given the lack of community feedback during the first and second round of the FRMS community consultation rounds, it was assumed that no additional feedback or information could be gathered through further community consultation on the mitigation measures.

4 Catchment Characteristics

4.1 Social Characteristics

The social characteristics of an area influences the community's response to a flood event; including the ability to prepare before a flood event, the ability to respond during a flood event and the ability to recover after a flood event has occurred.

4.1.1 Existing Social Characteristics

To quantify the social characteristics of the study area, the 2016 Australian Bureau of Statistics Census data was analysed. This is detailed in Table 4-1.

Table 4-1: Census Statistics (2016)

	Moulamein (UCL)	NSW
Population		
Total Population	305	7,480,228
< 4 years	7.5%	6.2%
5 - 14 years	12.3%	12.3%
15 - 64 years	50.4%	65.1%
> 65 years	29.8%	16.2%
Assistance		
Core activity need for assistance	7.9%	5.4%
Volunteering		
Provided unpaid assistance to a person with a disability (last two weeks)	7.7%	11.6%
Did volunteer work through an organisation or group (last 12 months)	32.9%	18.1%
Language		
English only spoken at home	85.3%	68.5%
Language top responses (other than English)	Filipino 4.9%	Mandarin 3.2%
	Bengali 1.0%	Arabic 2.7%
Internet Access		
Internet not accessed from dwelling	33.6%	14.7%
Internet accessed from dwelling	57.6%	82.5%
Not stated	8.8%	2.8%
Registered Motor Vehicles		
None	12.3%	9.2%
1 or more motor vehicles in occupied private dwellings	82.8%	87.4%
Not stated	4.9%	3.7%

	Moulamein (UCL)	NSW
Housing Density		
Average number of people per household	2	2.6
Median Weekly Income		
Personal	$517	$664
Family	$1,028	$1,780
Household	$778	$1,486
Property Tenure		
Owned outright	40.6%	32.2%
Owned with a mortgage	23.3%	32.3%
Rented	28.6%	31.8%
Not stated	7.5%	2.8%
Housing Payments		
Households where rent payments are greater than or equal to 30% of household income	5.2%	12.9%
Households where mortgage payments are greater than or equal to 30% of household income	3.5%	7.4%

According to the 2016 Census, Moulamein had a population of 305 people with a median age of 48. Of this population, the proportion of the people aged under 4 was relatively similar to the NSW average, though slightly higher. Whereas, the proportion of the population aged over 65 is significantly higher than the NSW average. Furthermore, the proportion of the population that requires assistance in one or more of the three core activities of self-care, mobility and communication accounted for 6.6% of the population. These vulnerable community members are likely to require additional assistance during a flood event.

While the proportion of the population that provided unpaid assistance to a person with a disability was slightly lower than the NSW average, the proportion that were involved in volunteer work was notably greater than the NSW average. This indicates a greater willingness to support others in the community and increases the likelihood that the community will provide assistance to each other during a flood event.

The linguistic diversity of Moulamein is relatively low, with a large proportion of the area speaking English exclusively at home. This proportion was far greater than the NSW average. Furthermore, of those that do speak another language at home, their proficiency in English was rated very well or well. Of the overseas migrants living in the area, all respondents had lived in Australia for at least 2 years as of 2016. As such, it is unlikely that translation services will be required to disseminate flood preparation material and flood warnings in the lead up to a flood event.

The median family/household income in Moulamein is markedly lower than the NSW average. However, the number of properties that are owned outright was much higher than the NSW average, and the proportion of the population experiencing housing payment stress (typically defined as mortgage/rent payments greater than 30% of the household income) was significantly lower than the NSW average. Therefore, the community are likely to be relatively financially resilient and able to recover after a flood event.

The proportion of the properties within Moulamein that were rented was relatively low, and the proportion of the population that had the same residential address 5 years prior to the 2016 census was relatively high (accounting for approximately 56% of the population). As such, the population of Moulamein could be considered relatively stable. This increases the likelihood that community flood preparation and/or flood awareness initiatives will be retained.

4.1.2 Historical Social Characteristics

To quantify the changing historical social characteristics of the study area, the 2006, 2011, and 2016 Australian Bureau of Statistics Census data was analysed. This is detailed in Table 4-2.

Table 4-2: Moulamein Census Statistics (2006, 2011, 2016)

Moulamein (UCL)	2006	2011	2016
Population			
Total Population	349	330	305
< 4 years	3.7%	7.9%	7.5%
5 - 14 years	13.2%	10.5%	12.3%
15 - 64 years	64.0%	59.3%	50.4%
> 65 years	18.3%	22.3%	29.8%
Assistance			
Core activity need for assistance	4.9%	5.4%	7.9%
Volunteering			
Provided unpaid assistance to a person with a disability (last two weeks)	10.8%	10.8%	7.7%
Did volunteer work through an organisation or group (last 12 months)	38.1%	30.4%	32.9%
Language			
English only spoken at home	95.4%	95.5%	85.3%
Language top responses (other than English)	Cantonese 1.1%	Cantonese 0.9%	Filipino 4.9%
			Bengali 1.0%
Internet Access			
Internet not accessed from dwelling	58.3%	41.7%	33.6%
Internet accessed from dwelling	36.8%	53.5%	57.6%
Not stated	4.9%	4.9%	8.8%
Registered Motor Vehicles			
None	7.7%	11.2%	12.3%
1 or more motor vehicles in occupied private dwellings	85.3%	81.8%	82.8%
Not stated	7.0%	7.0%	4.9%

Moulamein (UCL)	2006	2011	2016
Housing Density			
Average number of people per household	2.2	2.1	2.0
Median Weekly Income			
Personal	$341	$402	$517
Family	$822	$1,055	$1,028
Household	$629	$707	$778
Property Tenure			
Owned outright	41.1%	38.9%	40.6%
Owned with a mortgage	27.4%	27.1%	23.3%
Rented	28.8%	29.9%	28.6%
Not stated	5.5%	2.1%	7.5%
Housing Payments			
Households where rent payments are greater than or equal to 30% of household income	--	3.7%	5.2%
Households where mortgage payments are greater than or equal to 30% of household income	--	2.3%	3.5%

From the series of census data it was found that Moulamein has a growing vulnerable population with a rise in the proportion of people aged over 65 as well as a rise in the proportion of the population requiring assistance for core activities.

4.2 Sensitive Land Use Characteristics

Sensitive land uses can be characterised as:

- Vulnerable community facilities, such as aged care centres, child care centres, and schools, etc.
- Critical community facilities, such as law enforcement centres (police stations, correctional centres etc.), emergency services centres (fire stations, RFS Brigade Stations, NSW SES Unit Headquarters etc.) and health services centres (hospitals, medical centres etc).
- Critical community infrastructure, such as electricity substations, pumps for potable water or sewage water, sewage treatment plants, and waste depots etc.

The location and flood affectation of sensitive land uses in an area influences the community's response to a flood event; including planning before a flood event, the ability to respond during a flood event and the ability to recover after a flood event has occurred. Therefore, the sensitive land uses in the study area have been investigated.

The sensitive land uses found within the study area are detailed in Table 4-3 and the location of these sensitive land use sites is shown on Figure B 2.

Table 4-3: Sensitive Land Uses

Type	Name	Address	Population*
Vulnerable Community Facilities			
Preschool	Moulamein Pre-School	11 Turora Street, Moulamein	20
Primary School	Moulamein Public School	14 Brougham Street, Moulamein	50
Aged Care Facility	Moulamein Retirement Village	38 Turora Street, Moulamein	16 units
Caravan Park	Moulamein Lakeside Caravan Park	41 Brougham Street, Moulamein	Unknown
Critical Community Facilities			
Moulamein Police Station	Law Enforcement	Tallow Street	
Moulamein Rural Fire Service	Fire Service	Turora Street	
Critical Community Infrastructure			
	Power Station/Sub Station	Baratta Street, Moulamein	
	Water Treatment Plants/Storages	Pretty Pine Road, Moulamein	
	Sewage Treatment Plant	Baldon Road, Moulamein	
	Mobile Phone Infrastructure	Tallow Street, Moulamein	
	Radio Network Infrastructure	Baldon Road, Moulamein	

* Population numbers taken from the EMPLAN (discussed in Section 7.1.1)

4.3 Cultural and Heritage Characteristics

The preservation of the cultural and heritage characteristics of an area need to be considered when investigating modification measures. Therefore, the cultural and heritage characteristics of the study area have been investigated and discussed below; with the location of these sites are shown on Figure B 3.

4.3.1 Indigenous Australian Cultural Heritage

The Indigenous Australian cultural heritage sites were found through a search of the Aboriginal Heritage Information Management System (AHIMS) in December 2019. From this, 85 Aboriginal heritage sites were found in the study area. The heritage feature type of these sites included:

- 1 was the site of an artefact;
- 1 was the site of a hearth;
- 2 were the site of a pad;
- 17 were the site of an earthmound; and
- 64 were the site of a scarred tree.

The location of these 85 sites ranged from:

- 5 were on unallocated land;
- 9 were on Crown land; and
- 71 were on Freehold land.

A large number of these sites were located along the Edward River, in both the upstream portion of the hydraulic model area and in the vicinity of Moulamein Road (south of the Moulamein Bowling Club and north of Swan Hill Road).

The organisations that had recorded the heritage sites (and that may be contacted for further information) were the Wamba Wamba Local Aboriginal Land Council (LALC) and the Wannarua Tribal Council.

4.3.2 Non-Indigenous Australian Cultural Heritage

The non-Indigenous Australian cultural heritage sites were found through searches of:

- Local heritage items from the Wakool Local Environmental Plan (LEP) 2013 (although the Wakool Shire Council has since been amalgamated to form the Murray River Council, the pre-amalgamation LEP and DCP are still in use).
- State heritage items from the NSW State Heritage Inventory (which includes items listed on the State Heritage Register, items listed on State Agency Heritage Registers, and listed Interim Heritage Orders).
- National heritage items from the Australian Heritage Database (which includes the World Heritage List, the Commonwealth Heritage List, the National Heritage List, and the Register of the National Estate; however the latter register was closed in 2007 and is no longer a statutory list).

From this, the Old Court House was the only non-Indigenous Australian cultural heritage site within the study area.

4.4 Environmental Characteristics

The preservation of the environmental characteristics of an area need to be considered when investigating modification measures. To identify the environmental characteristics of the study area the following searches have been undertaken.

4.4.1 Contaminated Land

The NSW Environmental Protection Agency's (EPA) list of notified contaminated land was consulted to determine whether any known contaminated sites existed within the Moulamein study area. No known sites were discovered in the study area.

4.4.2 Acid Sulfate Soils

Acid Sulfate Soils (ASS) are the result of soils containing iron sulfides being exposed to air and consequently oxidizing to sulfuric acid. In inland regions this occurs most commonly as the result of excavation. As the presence of sulfuric acid can detrimentally affect the environment, it is important to be aware of the distribution of ASS throughout the study area.

The NSW Government has little data available regarding inland acid sulfate soil distribution in or around the study area. However, in 2013 the Office of Environment and Heritage (OEH), in conjunction with the Murray Darling Basin Authority (MDBA) released a report detailing the location and risk of acid sulfate soils in the Edward-Wakool channel system. The finding from this report indicates a low to moderate distribution of sulfidic and/or sulfuric soils in the Moulamein area. However, more extensive soil investigations of the Moulamein study area may be necessary to further assess ASS levels in areas of potential flood mitigation construction works.

4.4.3 Flora and Fauna

A search was conducted using the NSW Bionet Wildlife Atlas in January 2020 for sighted flora and fauna across the 32 km by 22 km study area. This search returned a total of 111 species of fauna, most of which were vulnerable, protected, or endangered, and 277 species of flora.

A search was conducted in the area utilizing the Environmental Protection and Biodiversity Act 1999 (EPBC Act) Protected Matters Search Tool. This search identified:

- 4 wetlands of international importance
  - Banrock Station Wetland Complex
  - Hattah-Kulkyne Lakes
  - Riverland
  - The Coorong, and Lakes Alexandrina and Albert Wetland
- 4 threatened ecological communities
  - Buloke Woodlands of the Riverina and Murray-Darling Depression Bioregions
  - Grey Box (Eucalyptus microcarpa) Grassy Woodlands and Derived Native Grassylands of South-Eastern Australia
  - Natural Grasslands of the Murray Valley Plains
  - Weeping Myall Woodlands
- 25 threatened species
- 9 migratory species

Table 4-4: Flora and Fauna

Name	Status
Birds	
Botaurus Poiciloptilus Australasian Bittern [1001]	Endangered
Calidris Ferruginea Curlew Sandpiper [856]	Critically Endangered
Grantiella Picta Painted Honeyeater [470]	Vulnerable
Lathamus Discolor Swift Parrot [744]	Critically Endangered
Leipoa Ocellata Malleefowl [934]	Vulnerable
Numenius Madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered
Pedionomus Torquatus Plains-Wanderer [906]	Critically Endangered
Pezoporus Occidentalis Night Parrot [59350]	Endangered
Polytelis Swainsonii Superb Parrot [738]	Vulnerable
Rostratula Australis Australian Painted Snipe [77037]	Endangered
Fish	

Name	Status
Bidyanus Bidyanus Silver Perch, Bidyan [76155]	Critically Endangered
Craterocephalus Fluviatilis Murray Hardyhead [56791]	Endangered
Galaxias Rostratus Flatheaded Galaxias, Beaked Minnow, Flat-headed Galaxias, Flat-Headed Jollytail, Flat-headed Minnow [84745]	Critically Endangered
Maccullochella Peelii Murray Cod [66633]	Vulnerable
Macquaria Australasica Macquarie Perch [66632]	Endangered
Frogs	
Litoria Raniformis Growling Gras Frog, Southern Bell Frog, Green and Golden Frog, Warty Swamp Frog [1828]	Vulnerable
Mammals	
Nyctophilus Corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable
Phascolarctos Cinereus Koala [85104]	Vulnerable
Plants	
Austrostipa Metatoris [66704]	Vulnerable
Austrostipa Wakoolica [66623]	Endangered
Brachyscome Papillosa Mossgiel Daisy [6625]	Vulnerable
Caladenia Tensa Greencomb Spider-orchid, Rigid Spider-orchid [24390]	Endangered
Lepidium Monoplocoides Winged Pepper-cress [9190]	Endangered
Maireana Cheelii Chariot Wheels [8008]	Vulnerable

Name	Status
Swainsona Murrayana Slender Darling-pea, Slender Swainson, Murray Swainson-pea [6765]	Vulnerable

4.4.4 Biodiversity

A biodiversity map was provided by Council based upon the Wakool Local Environmental Plan (LEP) 2013 (although the Wakool Shire Council has since been amalgamated to form the Murray River Council, the pre-amalgamation LEP and DCP are still in use). From this four (4) vegetation types were identified within the study area, being:

- Cyprus Pine/ Yellow Box woodlands, mostly located in small clusters to the North and North-west of the study area, away from water courses
- Floodplain forests/woodlands, consisting of sclerophyll tress and located in small to medium clusters either alongside water courses, or in low lying flood prone areas throughout the study area.
- Floodplain wetlands, located in small medium clusters in low lying flood prone areas, or most commonly located in large clusters alongside major watercourses.
- Grey Box/ White Cyprus Pine/ Yellow Box woodlands, located in small clusters to the South-east and South-west of the study area.

4.5 Levee System Characteristics

The town levee system influences the existing flood behaviour as well as the community's response to a flood event. It consists of three distinct levees; the northern levee, the southern levee and the western levee. The locations of these levees are shown on Figure B 1B.

4.5.1 History of Construction

The town levee system is thought to have been constructed and upgraded at various points in the past, although engineering design drawings for these were unable to be located. According to the Patterson Britton Report (2006) the levee system was initially constructed in the early 1950's. The levee system was then subject to additional work as a response to the approach of the 1956 flood. Further work was then undertaken in 1984 to achieve a crest level corresponding to the 1956 peak flood level plus a freeboard of 800 mm.

4.5.2 Physical Description

The current physical description of the town levee system has been considered using ground survey data collected by the NSW SES in 2003.

The northern levee surrounds the majority of the urban township located to the north of Billabong Creek. It extends from the Moulamein Lakeside Caravan Park (to the north), Tchelery Road (to the east), Hay Street (to the west), and Billabong Creek (to the south). Access to within the northern levee area is available through Balranald Road, Moulamein Road, Pretty Pine Road, Maude Road and Baldon Road. The northern levee has the longest length of the three town levees, spanning a length of approximately 4,500 m and encompassing an area of approximately 854,400 m^2. The highest point on this levee is 71.83 m AHD, which is located at northern boundary adjacent to the Moulamein Lakeside Caravan Park. The lowest point on this levee is 69.90 m AHD, which is located at the western boundary of Hay Street. Furthermore, there are a number of culverts through the northern levee, designed to drain overland flooding due to local rainfall over the area. However, these culverts do not have flap gates fitted and so some riverine flooding can enter the levee area through these culverts (as was anecdotally reported to have occurred during the 2016 flood

event). The ground level of the area inside the levee was on average 70.2 m AHD, which was the highest internal ground level of the three levee systems.

The southern levee is located between the Edward River and Billabong Creek, upstream of the confluence of these two river systems and downstream of the railway track. The southern levee spanned a length of approximately 3,100 m and encompassing an area of approximately 503,200 m^2. Access to within the southern levee is available through Pretty Pine Road, which is also an access route into the northern levee area. The highest point on this levee is 72.46 m AHD, which is located at the eastern boundary adjacent to the Edward River. The lowest point on this levee is 70.06 m AHD, which is located at north-western boundary adjacent to Billabong Creek and near the Old Court House. The ground level of the area inside the levee was on average 70.0 m AHD.

The western levee surrounds Moulamein Bowling Club, which is an official evacuation centre (discussed in Section 7). It is bounded by Moulamein Road (which also acts as the eastern ridge of the levee) and the Edward River. The western levee has the shortest length of the three town levees, spanning a length of approximately 1,250 m and encompassing an area of approximately 91,700 m^2. Access to within the western levee is available through Moulamein Road, which is also an access route into the northern levee area. The highest point on this levee is 71.72 m AHD, which is located on Moulamein Road at the vehicle entrance to the levee area. The lowest point on this levee is 70.49 m AHD, which is located at south-western boundary. The ground level of the area inside the levee was on average 69.7 m AHD, which was the lowest internal ground level of the three levee systems.

4.5.3 Structural Description

The Patterson Britton Report (2006) also referenced a 1992 NSW Public Works Department report titled: *Audit of Flood Levees for NSW – Town of Moulamein*. In this report, it was noted that a range of deficiencies were identified in the levee system. The Patterson Britton Report (2006) investigated a range of potential remediation options and recommended a number of remediation works; including excavating and reconstructing the top 500 mm of the existing levee system (which was found to have experienced cracking) and raising the levee crest to the 1% AEP peak flood level plus a freeboard of 1 m (through a mixture of road raising, earth levee construction and construction of concrete walls). These remediation works are yet to be undertaken.

Due to these known levee deficiencies and the risk of a structural failure of the levee system during a flood event, it is the responsibility of the NSW SES to issue Evacuation Warnings and Evacuation Orders when a flood threatens life and property, as was the case during the 2016 flood event. As a result of the 2016 flood evacuation warnings, the aged care facility in Moulamein evacuated their residents; however, it was anecdotally reported that many other residents chose not to evacuate. Furthermore, as the levee system was found to withstand the 2016 flood event, the NSW SES's decision to issue the evacuation warnings has generated a degree of community scepticism of flood evacuation warnings in the area.

4.5.4 Levee Breach Scenario

Due to the poor structural integrity of the existing levees it is not reasonable to assume the failure mechanism is by overtopping. Even properly designed and constructed levees are only considered structurally sound up to the design flood level with the freeboard component (from the design flood to the crest) only providing a safety margin to guarantee the level of protection is realised. As such, a breaching scenario has been assumed in the modelling to represent a more realistic failure mechanism for the existing levees.

Selected locations were identified where a levee breach could reasonably be considered to occur. This was based on locations where a known levee deficiency was identified in a Visual Audit Of Moulamein Levee Report (NSW Government, 2013), where localised low points in the levee were situated as well as where the flood trajectory would be close to perpendicular

to the levee alignment (such as on the outer bends of the river or creek). From this, five locations along all the town levees were selected, being:

- The northern levee between chainages 1250 and 1550 (see Figure B 5B) (between Jebb Street and Tallow Street).
- The northern levee between chainages 2580 and 2680 (see Figure B 5B) (between Tchelery Road and Moulamein Lake).
- The southern levee between changes 475 and 735 (see Figure B 5D).
- The southern levee between chainages 2080 and 2280 (see Figure B 5D).
- The western levee between chainages 1000 to 1180 (see Figure B 5F) (to the west of Moulamein Road Bridge).

At these locations the breached levee height was assumed to be approximately halfway between the existing level of protection and the adjacent ground level inside the levee. The breach was assumed to commence when the flood level outside the levee reached the breached levee height and was assumed to erode over a period of 60 hours, corresponding to the rate of rise of the flood waters.

4.5.5 Levee Freeboard Assessment

Within Section 11 several flood modification options have been proposed that centre around upgrading the town levees, and as such include a recommended allowance for freeboard. This section details how the proposed freeboard was calculated for levees in the study area.

The purpose of freeboard is to provide a reasonable certainty that the risk exposure associated with a particular design flood is actually provided .Freeboard is incorporated into the final levee design and is defined as the difference in height between the level of floodwaters the levee is designed to protect against, and the crest height of the design levee. This assessment is adequate for a concept design, however feasibility studies undertaken for any of these recommended upgrades works should include a review of the freeboard assigned.

4.5.5.1 Estimated Flood Levels

Several factors affect the uncertainty in estimating flood levels, including:

- The accuracy of theoretical ARI-discharge curves compared to historical events;
- Level of detail in available survey data;
- Reliability of historical flood data, and;
- Any other estimated parameters, such as surface roughness, rainfall patterns, etc.

These factors can cause varying levels of uncertainty regarding the accuracy of hydrologic and hydraulic models, and consequently the design flood levels. The severity of these uncertainties can be determined by undertaking a sensitivity analysis of the design flood levels. Such an analysis was carried out as a part of the Moulamein Flood Study (HydroSpatial, 2019). The results showed that the model was largely insensitive to a change in model assumptions, with an average result fluctuation of +/- 0.02 m. As such, a value of 0.02 m has been assigned to the uncertainty due to estimations in flood levels.

4.5.5.2 Local Water Surge

Blockages or obstructions in hydraulic structures in the floodplain can cause local flood water levels to be higher than general flood levels. As such the impact of blockages was taken into account when conducting the sensitivity analysis carried out as a part of the Moulamein Flood Study (HydroSpatial, 2019). Results showed a very minor fluctuation in flood levels up to a maximum of +/- 0.02 m. Hence a value of 0.02 m has been assigned to the local water surge allowance in the freeboard calculations.

4.5.5.3 Wave Action

In the event of windy conditions, expanses of the levee exposed to large areas of flood water may be subject to significant wave action, which may cause floodwaters to overtop the levee. Wave actions can be a product of:

- Wave run-up – the maximum vertical travel of wave waters after breaking above the water level;
- Fetch – the assumed travel distance of the wave;
- Wind setup;
- Design wind, and;
- Wave height.

Based on the conditions present at Moulamein, a value of 0.4 m has been assigned to the wave action allowance in the freeboard calculations.

4.5.5.4 Defects in Embankment

Earthen levees are relatively prone to defects, and hence require ongoing maintenance. The defect uncertainty allows for multiple defect types in earthen levees including:

- Erosion;
- Holes;
- Cracking;
- Low points, and;
- Ongoing maintenance standards.

Given the uncertainty of the current structural integrity of the levees, a defect allowance of 0.3 m has been assigned to the embankment settlement allowance in the freeboard calculations.

4.5.5.5 Climate Change

The NSW Floodplain Development Manual (2005) indicates the importance of considering climate change in the future effectiveness of floodplain risk management options. The future effects of climate change may impact rainfall events in the study area. This could potentially result in an effect on the frequency and magnitude of flooding in the area. Hence a climate change allowance of 0.1 m is proposed.

4.5.5.6 Summary of Mitigation Work Freeboard Components

In considering the above allowances, it is important to recognise the unlikelihood of all uncertainty events occurring simultaneously. Therefore, a relative probability of occurrence has been included in the determination of the final design freeboard. As above, please note that this is a preliminary assessment of an appropriate freeboard for design concepts, and any feasibility studies for proposed works should include a detailed assessment of the proposed freeboard.

Table 4-5: Levee Freeboard Components

Component	Allowance (m)	Probability	Final Component (m)
Uncertainties in Flood Model	0.02	1.0	0.02
Local Water Surcharge	0.02	0.75	0.015

Component	Allowance (m)	Probability	Final Component (m)
Wave Action	0.4	0.5	0.2
Levee Settlement	0.025	0.5	0.0125
Defects in Embankment	0.3	0.5	0.15
Climate Change	0.1	1.0	0.1
Total			0.4975

In considering these factors specific to Moulamein, a levee freeboard of 0.5 m is proposed. This freeboard should be reviewed in future detailed designs.

4.5.6 Levee Owner's Manual

The Moulamein Levee: Levee Owner's Manual (LOM) has been prepared in accordance with the Levee Owners Guideline by Public Works NSW. It identifies the levee systems in Moulamein covered by the LOM and outlines the roles and responsibilities of levee owners in relation to levee operation and maintenance. In particular, the manual covers the 3 individual levee rings protecting the town, referred to as the North, South and West Levees. Currently, the Levee Owner's Manual is still in draft form.

The LOM identifies Murray River Council as the owner and maintainer of all three town levees. It also details all known levee history, surveys, flood studies, geotechnical testing and all other related documentation. The manual describes the various types of necessary levee inspections and audits, as well as when in the flood cycle they should be undertaken.

The LOM stresses the importance of maintaining the height and side slope of the earthen levees to avoid adverse flood effects. It also details proposed methods for maintaining optimum vegetation cover on earthen levee batters. In the event of minor or major levee failure, the LOM lays out recommended repair methods. Also detailed are methods of constructing temporary sandbag levees in events such as water seepage causing sand boils.

The LOM lays out flood time and maintenance procedures for the Moulamein levee systems multiple stormwater drainage structures. It discussed the limitations of visual inspections/audits in relation to culvert pipes and suggested a schedule of CCTV internal inspections. The manual also stresses the importance of keeping all pipe culverts and inlet and outlet structures clear of blockage materials. Due to the current lack of floodgates, the manual suggests the use of pipe plugs and details the inspections and proper usage of the plugs.

5 Computational Modelling

The previous Moulamein Flood Study (HydroSpatial, 2019) included computational hydraulic modelling of the study area under existing conditions. This model was reviewed and discussed below.

5.1 Review Hydraulic Modelling

The hydraulic model developed in the flood study used the TUFLOW software package. The input data used and parameters applied are discussed in detail in the flood study report.

Given the short timeframe between the completion of the previous flood study and the commencement of the current study, it was found that the input data used in the hydraulic model remains relevant to the current study. Furthermore, the parameters applied remain consistent with the current industry guidelines, which have not undergone any significant change during this period.

With regards to the assumptions made, there were some updates applied to the hydraulic model, being:

- The riverine flows for the PMF event were assumed to be three times the 1% AEP riverine flows. This was to coincide with the assumptions used in the Edward River at Deniliquin Flood Study (WMAwater, 2014), as this was the most recent adjacent study available. The Moulamein Flood Study (HydroSpatial, 2019) had previously assumed the PMF riverine flows to be two times the 1% AEP riverine flows, based upon the older Moulamein Levee Upgrade Flood Study (Patterson Britton & Partners, 2006).
- The town levees were assumed to breach in localised areas across all design flood events. This was a conservative assumption to account for the uncertainties regarding the structural integrity of the town levee system. Further details on the levee breach scenario are discussed in Section 4.5.4.

Furthermore, flood impacts within the study area were broken down into three scenarios:

1. Riverine flooding outside the town levees. This scenario was schematised as follows:
    - Larger grid resolution (24 m).
    - Town levees assumed to breach.
    - Culverts through the town levees assumed to be blocked, thereby preventing back-flow from the river to inside the levees.
    - Riverine flooding with no overland flooding.
2. Riverine flooding inside the town levees. This scenario was schematised as follows:
    - Smaller grid resolution (6 m).
    - Town levees assumed to breach.
    - Culverts through the town levees assumed to be unblocked, thereby allowing back-flow from the river to inside the levees.
    - Riverine flooding with no overland flooding.
3. Overland flooding inside the town levees. This scenario was schematised as follows:
    - Smaller grid resolution (6 m).
    - Town levees assumed to breach.
    - Culverts through the town levees assumed to be unblocked.
    - Overland flooding with riverine water levels equivalent to a 20% AEP riverine flood level.

The results of these three scenarios are shown on Figure B 6 to Figure B 12.

6 Assessment of Existing Flood Behaviour

6.1 Overview

The study area is subject to riverine flooding and overland flooding. Both flood mechanisms have been investigated as part of the previous Moulamein Flood Study (HydroSpatial, 2019) and as part of this current study.

6.2 Assessment of Levee Profile

Figure B 5 shows the elevation of the levee crests compared to the riverine flood levels adjacent to and outside the levee systems.

6.2.1 Northern Levee

The area inside the northern levee was found to experience no inundation in the 20% AEP riverine flood event, either through the breaching of the levee or through backwatering of the culverts through the levee. This was due to the higher ground level inside the levee compared to the other levee systems (as discussed in Section 4.5.2). In the 10% AEP riverine flood event, the area inside the northern levee system was found to experience minor inundation on Nyang Street as a result of backwatering of the culverts through the levee. However, the breaching of the levee was not a source of inundation in the 10% AEP riverine flood event. Similar to the 10% AEP riverine flood event, the 5% AEP riverine flood event was inundated via the backwatering of the culverts through the levee and not the breaching of the levee. Although the inundation due to the backwater extended further north, it was also of a very shallow depth. By the 2% AEP riverine flood event, minor inundation was found to occur as a result of the levee breach adjacent to Billabong Creek (to the south-east), the levee breaching between Moulamein Lake and Tchelery Road (to the north-east), and the levee overtopping along Tallow and Hay Street. However the depth and extent of this inundation was minimal due to the relatively high ground level inside the levee. The backwatering of the culverts through the levee system again extended further north in the 2% AEP riverine flood event, although it was of a relatively shallow depth. In the 1% AEP riverine flood event the inundation due to backwatering of the culverts, breaching of the levee and overtopping of the levee was similar to the 2% AEP riverine flood event; with the exception of the levee breach between Moulamein Lake and Tchelery Road that extended further to the west with slightly higher flood depths. By the PMF riverine flood event, the entire area within the northern levee system is inundated.

6.2.2 Southern Levee

The area inside the southern levee was found to experience some inundation in the 20% AEP riverine flood event, via the breaching of the levee at the western most point near the confluence of the Edward River and Billabong Creek. However, the second breach location on this levee system (located adjacent to the Edward River) was not a source of inundation in the 20% AEP riverine flood event. In the 10% AEP riverine flood event, a larger area inside the southern levee was found to experience inundation with the levee breaching at the confluence of the Edward River and Billabong Creek as well as upstream on the Edward River. A similar area of inundation was found in the 5% AEP riverine flood event as the 10% AEP riverine flood event, however the flood depths were greater. This was mainly due to the flood water being restricted from extending by the slight embankments along roads within the levee system. By the 2% AEP riverine flood event, it was found that the entire area inside the southern levee system was inundated due to the breaching of the levee.

6.2.3 Western Levee

The area inside the western levee was found to experience some inundation in the 20% AEP riverine flood event, via the breaching of the levee. In the 10% AEP riverine flood event, it was found that the entire area inside the western levee system was inundated due to the breaching

of the levee. This was due to the lower ground level inside the levee compared to the other levee systems (as discussed in Section 4.5.2).

6.3 Assessment of Bridge and Culvert Capacity

The magnitude of the riverine flood events that result in the bridges and culverts reaching capacity is shown in Figure B 13.

From this, it was found that the majority of culverts through road embankments reach capacity in events greater than and equal to the 10% AEP event.

However, it should be noted that the culverts along Maude Road likely do not reach capacity in smaller events (such as the 20% AEP event) due to the banks of the adjacent Billabong River not reaching capacity in these smaller events. Furthermore, the culverts along Balpool Road tend to require significantly larger flood events to reach full capacity compared to those along Pretty Pine Road (the 2% AEP event and the 20% AEP event, respectively) despite both roads being a similar distance from the Edward River. This is likely due to Edward River overtopping it's northern bank in smaller events before overtopping it's southern bank.

6.4 Assessment of Road Access Duration of Inundation

Road accessibility was assessed using the ARR 2019 vehicle stability criteria, detailed in Table 6-1. From this, the duration of road inaccessibility was assessed for a range of riverine flood events for a number of access roads into Moulamein, detailed in Table 6-2. From this, only one road out of the ten was inaccessible to a large 4WD vehicle in the 20% AEP flood event, with this number increasing to four in the 5% AEP event, and six in the 1% AEP event. It should be noted that if there is water over the road it is likely to be closed by the NSW SES and/or Council in the interests of public safety and to prevent damage to the road itself.

Table 6-1: Stability Criteria for Vehicles

Class of vehicle	Limiting still water depth (m)	Limiting velocity (m/s)	Equation of stability
Small passenger	0.3	3.0	DV ≤ 0.3
Large passenger	0.4	3.0	DV ≤ 0.45
Large 4WD	0.5	3.0	DV ≤ 0.6

Table 6-2: Duration of Road Inaccessibility

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
20% AEP riverine flood event			
Balpool Road	N/A	N/A	N/A
Balranald Road	12.4 days	7.8 days	3.2 days
Maude Road	N/A	N/A	N/A
Morton Road	0.5 days	0.2 days	N/A
Moulamein Road	4.2 days	1.2 days	N/A
Nacurrie Road North	N/A	N/A	N/A
Pretty Pine Road	N/A	N/A	N/A
Robb Road	N/A	N/A	N/A
Swan Hill Road	N/A	N/A	N/A

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
Tchelery Road	N/A	N/A	N/A
5% AEP riverine flood event			
Balpool Road	4.0 days	N/A	N/A
Balranald Road	36.7 days	35.7 days	34.7 days
Maude Road	N/A	N/A	N/A
Morton Road	15.2 days	7.1 days	0.2 days
Moulamein Road	32.2 days	29.1 days	25.8 days
Nacurrie Road North	14.8 days	7.2 days	N/A
Pretty Pine Road	22.4 days	14.0 days	6.5 days
Robb Road	N/A	N/A	N/A
Swan Hill Road	N/A	N/A	N/A
Tchelery Road	N/A	N/A	N/A
1% AEP riverine flood event			
Balpool Road	41.7 days	41.7 days	41.5 days
Balranald Road	42.0 days	42.0 days	42.0 days
Maude Road	N/A	N/A	N/A
Morton Road	42.0 days	41.0 days	40.5 days
Moulamein Road	41.2 days	41.1 days	40.9 days
Nacurrie Road North	41.0 days	40.6 days	40.3 days
Pretty Pine Road	41.2 days	41.1 days	41.1 days
Robb Road	N/A	N/A	N/A
Swan Hill Road	N/A	N/A	N/A
Tchelery Road	N/A	N/A	N/A
0.5% AEP riverine flood event			
Balpool Road	41.8 days	41.7 days	41.7 days
Balranald Road	42.0 days	42.0 days	42.0 days
Maude Road	2.0 days	N/A	N/A
Morton Road	42.0 days	41.3 days	40.8 days
Moulamein Road	41.2 days	41.2 days	41.0 days
Nacurrie Road North	41.1 days	40.7 days	40.6 days
Pretty Pine Road	41.3 days	41.3 days	41.3 days
Robb Road	N/A	N/A	N/A
Swan Hill Road	12.3 days	N/A	N/A
Tchelery Road	11.6 days	N/A	N/A

7 Assessment of Existing Flood Response Arrangements

7.1 Flood Emergency Response Documents

7.1.1 Local Emergency Management Plan

The Local Emergency Management Plan (EMPLAN) (Murray River Council, 2017) governs a range of potential hazards across the council area; including flood hazards, fire hazards, and earthquake hazards, etc. The EMPLAN was prepared in accordance with the *State Emergency & Rescue Management Act 1989* by the Murray River Council Local Emergency Management Committee (LEMC). The purpose of the EMPLAN is to detail the roles and responsibilities of various agencies in an emergency (including preparing for, responding to and recovering from emergencies). The EMPLAN is supported by a collection of hazard/emergency specific sub plans, such as the Murray River Flood Emergency Sub Plan (discussed in Section 7.1.2)

From the EMPLAN, the NSW SES are tasked with the role of combat/responsible agency for both riverine flood emergencies and flash (or overland) flood emergencies in the Murray River Council area. Across the council area, the NSW SES units available are the NSW SES Barham Unit, the NSW SES Moama Unit, and the NSW SES Mathoura Unit.

According to the EMPLAN, the LEMC are expected to review the EMPLAN every three years, which is scheduled for November 2020 based upon the date the current EMPLAN was approved.

7.1.2 Flood Emergency Sub Plan

The Murray River Council Flood Emergency Sub Plan is prepared in accordance with the *State Emergency Service Act 1989 (NSW)* by the NSW SES and the Murray River Council LEMC. It is the flood specific sub plan that supports the Local EMPLAN (discussed in Section 7.1.1).

The Flood Emergency Sub Plan outlines the preparation, response, and recovery steps for flood emergencies in the Murray River Council area. It solely focuses on flooding emergencies and details the roles and responsibilities of all parties involved in the event of a flood. It also notes key roads that may become flood affected, and lists Council as being responsible for road closures and reopening.

Notably, due to the high number of caravan parks located within the council area, the Flood Emergency Sub Plan places special focus on the responsibilities of caravan park and mobile home owners during a flood event. The Flood Emergency Sub Plan also acknowledges that caravan parks are especially flood liable.

7.2 Roles of the NSW SES and other Emergency Service Organisations

The EMPLAN lists the NSW SES as the combat or lead agency for response operation for flash and riverine flooding. The roles of the NSW SES and other Emergency Service organisations can be found in The Murray River Council Flood Emergency Sub Plan.

Moulamein lies within the NSW SES Southern Zone, with its closest NSW SES Unit being the Barham Unit. The Southern Zone Headquarters is located at 206 Fernleigh Road, Wagga Wagga NSW 2650.

Table 7-1 lists the emergency service providers in or around the Moulamein region.

Table 7-1: Emergency Service Providers

Emergency Service	Location
NSW SES Local Unit Headquarters (Barham)	51 Forest Street, BARHAM NSW 2732
Barham Hospital	70 Punt Road, BARHAM NSW 2732
Deniliquin Hospital	411 Charlotte Street, DENILIQUIN NSW 2710
Moulamein Police Station	Corner of Brougham and Tallow Streets, MOULAMEIN NSW 2733
Moulamein Rural Fire Service	Turora Street, MOULAMEIN NSW 2733
Barham Fire Station	40 Wakool Street, BARHAM NSW 2732
Barham Ambulance Station	48-50 Gonn Street, BARHAM NSW 2732

7.3 Evacuation Centres

The EMPLAN provides details for several evacuation centres across the council area. The evacuation centres that were located in the study area were the Moulamein Bowling Club and the Murray River Council Moulamein Office.

The Moulamein Bowling Club evacuation centre is located within the western town levee system, adjacent to Moulamein Road. Adjacent fields and sporting facilities are also located within this levee system, although no residential dwellings are located within the western town levee system.

The Murray River Council Moulamein Office is located on Tualka Terrace, within the northern town levee system. A large number of the study area's residential dwellings are also located within this same levee system.

7.4 Historical Flood Response

The most recent flood event to have affected the study area occurred in 2016. The 2016 flood event pre-dated the current EMPLAN (Murray River Council, 2017) and the current Flood Emergency Sub Plan (NSW SES, 2018).

During this event, the NSW SES were the combat/responsible agency for the flood emergency response arrangements across the study area. The NSW SES made the decision to issue Evacuation Warnings and Evacuations Orders for Moulamein after independent engineering advice was received from Public Works NSW questioning the stability and structural integrity of the existing levee system. As a major flood was predicted that would threaten both life and property if the levee failed the NSW SES made the difficult decision to evacuate Moulamein in the interests of public safety.

8 Assessment of Existing Flood Planning Policies

8.1 State Government Planning Policies

The state government legislation is the overarching framework for all local legislation. Floodplain risk management measures must be developed in accordance with both state and local legislation. This section discusses the state legislation that is applicable to planning for flooding.

8.1.1 NSW Environmental Planning and Assessment Act 1979

The Environmental Planning and Assessment Act 1979 establishes a framework for planning the use, development and protection of land in NSW. 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.

8.1.2 Ministerial Direction 4.3 (issued 1 July 2009)

Pursuant to Section 9.1 of the EP&A Act (previously section 117(2)), the Minister has directed that Councils have a responsibility to facilitate the implementation of the Government's Flood Prone Land Policy.

Direction 4.3 Flood Prone Land, contained in Section 9.1 of the Act, includes objectives for planning proposals on flood prone land, as follows:

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.

Where this direction applies

2) This direction applies to all relevant planning authorities that are responsible for flood prone land within their LGA.

When this direction applies

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.*

What a relevant planning authority must do if this direction applies

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).*

Consistency

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.

8.1.3 NSW Flood Prone Land Policy (2005)

The NSW Government's *Flood Prone Land Policy* is incorporated in and supported by the NSW Government's *Floodplain Development Manual* (2005). The *Flood Prone Land Policy* places the primary responsibility for floodplain risk management with Councils; whilst the *Floodplain Development Manual* provides guidance for Councils in undertaking flood studies and developing floodplain risk management studies and plans to meet their responsibilities.

The primary objectives of the *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 *Floodplain Development Manual* details the roles and responsibilities of various NSW agencies and includes information on:

- *the preparation of flood studies, floodplain risk management studies and plans;*
- *floodplain risk management options;*
- *flood planning levels and areas;*
- *hydraulic and hazard categorisation; and*
- *emergency response planning.*

Of further note, the *Floodplain Development Manual* (NSW Government, 2005) is currently undergoing a review. Following this review, it is expected that an updated manual will be released that will be compatible with the latest releases of various industry guidelines (such as *Australian Rainfall and Runoff* (2019) and the *Australian Emergency Management Handbook Series* (2017)).

8.1.4 Planning Circular PS 07-003

Planning Circular PS07-003 (31 January 2007) provides advice on changes relating to flood development controls on land above the 1 in 100 year flood and up to the probable maximum flood level (PMF). Councils can apply to the Department of Planning, Industry and Environment for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in its Local Environmental Plan (LEP). This may be useful for areas where there are flood risk associated with flood magnitude above the 1% AEP event, and they wish to prohibit specific land uses below the PMF.

8.1.5 State Environmental Planning Policy 2008 – Exempt and Complying Development Codes

The State Environmental Planning Policy (SEPP) aims to provide streamlined assessment processes for developments that comply with specified development standards by providing state-wide exempt and complying development codes. Developments that are of minimal environmental impact are able to proceed without the need for development consent.

Subdivision 9 Clause 3.36C of this policy applies to development on “flood control lots” (the specification of which is determined by Council) and must satisfy the following criteria:

1) This clause applies:
   a) to all development specified for this code that is to be carried out on a flood control lot, and
   b) in addition to all other development standards specified for this code.
2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering 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.
3) The development must, to the extent it is within a flood planning area:
   a) have all habitable rooms no lower than the floor levels set by the council for that lot, and
   b) have the part of the development at or below the flood planning level constructed of flood compatible material, and

c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and
d) not increase flood affectation elsewhere in the floodplain, and
e) have reliable access for pedestrians and vehicles from the development, at a minimum
f) level equal to the lowest habitable floor level of the development, to a safe refuge, and
g) have open car parking spaces or carports that are no lower than the 20-year flood level, and
h) have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.

4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:
a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level
(or if on-site refuge is proposed, the probable maximum flood level), or
b) will not increase flood affectation elsewhere in the floodplain.

Development occurring under this policy would bypass Council's full Development Application (DA) requirements, including some of the flood-related requirements of the Council Development Control Plan (DCP). While the SEPP requirements echo the broader requirements outlined in the DCP, they are less nuanced in some regards.

8.2 Local Government Planning Policies

It is important for local Councils to ensure land use and development is compatible with flood risk and does not increase the impact of flooding or the damage to public or private assets associated with flooding.

Environmental planning tools, such as Local Environmental Plans (LEPs) guide planning decisions for local government areas. This is done through zoning and development controls that provide a framework for the way land can be used and developed. Development Control Plans (DCPs) are a planning tool that provides detailed planning and design guidelines to support the planning controls detailed in the LEPs.

LEPs are made under the *Environmental Planning and Assessment Act 1979*. All LEPs should conform to a standard format. This standardisation was initiated by the NSW state government in 2006, through the Standard Instrument LEP program.

8.2.1 Council Formation

The Murray River Council was formed in 2016 as part of the NSW state government's push for Council amalgamations. This local government area encompasses the former Murray Shire Council and former Wakool Shire Council; with the latter covering the township of Moulamein.

The Murray River Council planning controls, including the LEPs and DCPs are still separated according to the former Council areas. The flood objectives for the Wakool Shire and the Murray Shire LEPs are very similar; but the objectives, planning approach and controls of the two DCPs vary considerably.

A summary of the similarities and differences between the flood controls in the Wakool Shire DCP and the Murray Shire DCP are provided in the following.

8.2.2 Murray Local Environmental Plan 2011

The Murray Local Environmental Plan was adopted in December 2011. In this, the flood controls are stated in Clause 7.8 as follows:

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:*
   a) *land that is shown as "Flood planning area" on the Flood Planning Map, and*
   b) *other 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 a minimum 0.5 metre freeboard.*

8.2.3 Wakool Local Environmental Plan 2013

The Wakool Local Environmental Plan was adopted in November 2013. In this, the flood controls are stated in Clause 6.2 as follows:

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 flood liable land.*
3) *Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:*
   a) *is compatible with the flood hazard of the land, and*
   b) *will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
   c) *incorporates appropriate measures to manage risk to life from flood, and*
   d) *will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
   e) *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*
4) *A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.*

8.2.4 Murray Development Control Plan 2012

The Murray Development Control Plan was adopted in June 2012 and applies to land which was previously part of Murray Shire Council. It is located to the south-east of the Wakool

Development Control Plan area and extends north to Burraboi, east to Tocumwal, south to Moama and west to Barham.

The purpose of this DCP is to provide planning and design guidelines to support the planning controls detailed in the Murray LEP 2011.

Part 11 of the DCP relates to Flood Prone Land and applies to all flood prone land which is all land susceptible to flooding in PMF event. The flood prone land within the Murray DCP area is divided into three flood planning areas, being Flood Planning Area 1 (FPA1), Flood Planning Area 2 (FPA2) and Flood Planning Area 3 (FPA3). FPA1 and FPA2 are defined as land in the *Moama Floodplain Management Study* (1999). FPA3 is defined as land within the Land Application Area that was not included in the *Moama Floodplain Management Study* (1999).

The guidance and controls relating to development are provided in Table 1 in the DCP. The controls in this table apply to development in FPA1. These controls are applied to FPA2 and FPA3 at Council's discretion.

The DCP states that:

> *'Outside of Moama the extent of flooding in a PMF is not known and consequently Council will use its discretion in applying this chapter of the DCP to land considered to potentially lie between the 1 in 100 year ARI flood level and the PMF.'*

The objectives of this part of the DCP are to:

a) *provide detailed controls and criteria for the assessment of development applications on land affected by flooding in Murray Shire;*
b) *consolidate existing flood planning principles and policies from relevant government agencies into a coherent framework for application at the development control level by Murray Shire Council;*
c) *reduce the impact of flooding and flood liability on individual property owners and occupiers;*
d) *reduce private and public losses resulting from flooding;*
e) *restrict the intensification of development below the Flood Planning Level (FPL);*
f) *limit development below the FPL to those activities and works considered to have an essential relationship with the river and its floodplain;*
g) *provide specific measures for the control of caravan parks and associated development types within flood affected areas;*
h) *provide for the consideration of the cumulative effects of any development on flood affected land, which in or of itself may be considered to be insignificant;*
i) *provide for and protect the natural passage, storage and quality of flood waters;*
j) *recognise and help sustain the natural ecosystems of floodplains and riparian zones including the protection of associated vegetation and wetlands;*
k) *inform the community as to the extent and hazard of flood affected land in Murray Shire;*
l) *deal consistently with applications for development on flood affected land, generally in accordance with the Floodplain Management Manual: The Management of Flood Liable Land issued by the New South Wales Government 2005; and*
m) *encourage the development and use of land which is compatible with the indicated flood hazard.*

In accordance with the DCP, the decision guidelines for consideration of development proposals on flood prone land are:

- *Whether the proposed development is reasonable having regard for the flood risk and resources available to the location. Applicants should place no reliance on the implementation of a condition specifying a private evacuation/flood management plan as a means to overcome an unacceptable flood risk.*

- *The need for a benefit/cost assessment that takes account of the full cost to the community of the flood response and flood damage likely to be incurred to the development and upon other development.*
- *Specific principles relating to flood liable land contained within Murray Regional Environmental Plan No.2 - -Riverine Land (MREP2) including:*
    - *the benefits to riverine ecosystems of periodic flooding;*
    - *the hazard risks involved in the development of that land;*
    - *the redistribution effect of the proposed development on floodwater;*
    - *the availability of other suitable land in the locality not liable to flooding;*
    - *the availability of flood free access for essential facilities and services;*
    - *the pollution threat represented by any development in the event of a flood;*
    - *the cumulative effect of the proposed development on the behaviour of floodwater;*
    - *the cost of providing emergency services and replacing infrastructure in the event of a flood; and*
    - *flood mitigation works constructed to protect new urban development should be designed and maintained to meet the technical specifications of the NSW government department responsible for such works.*
- *The Floodplain Development Manual – the Management of Flood Liable Land (2005).*

8.2.5 Wakool Development Control Plan 2013

The Wakool Development Control Plan was adopted in October 2013 and applies to land which was previously part of Wakool Shire Council. It covers land extending north to Waugorah, south to Barham, east to Burraboi and west to Tooleybuc. This DCP includes Moulamein, which is located in the north-east.

The purpose of the DCP is to provide planning and design guidelines to support the planning controls detailed in the Wakool LEP 2013.

Part B.2.4 of the DCP relates to Flood Planning and applies to all flood liable land which is all land below the Flood Planning Level (FPL). The FPL is described as:

a) The Crown of the adjacent road (or highest level of road where the crown is not established) in the urban areas of Barham and Moulamein (until such time as a Flood Study is adopted by Council); and
b) 1:100 ARI (average recurrence interval) flood event for the remaining areas of the Shire.

The objectives of this section of the DCP are:

a) To minimise any increased risk to human life from flooding;
b) To minimise any additional economic and social costs arising from damage to property from flooding that are greater than that which can reasonably be managed by the property owner and general community;
c) To permit development only where there is either a controlled levee system or effective warning time and reliable access available for the evacuation of an area potentially affected by floods,;
d) To avoid detrimentally increasing the potential flood affectation on other development or properties (except where levee banks are approved by Council);
e) To ensure construction methods and materials are compatible with flooding and flood conveyance.

Flood maps are incorporated at Appendix 6 of the DCP.

The Wakool DCP stipulates controls and design requirements for land development, including land behind levees, development of floodways, development of the flood fringe outside a controlled levee bank, on-site sewage management within the flood fringe, residential development outside a controlled levee bank, commercial/retail/industrial development

outside a controlled levee bank and access to lots, subdivision, land filling, fencing of sites and raising dwelling flood levels within the flood fringe.

Where floor levels are below the FPL, a Flood Management Plan must accompany the application.

In accordance with the DCP, *'a Flood Management Plan is usually prepared in response to a Flood Study that states that the proposed development site is Flood Liable Land. The Flood Management Plan seeks to demonstrate how the proposed development will address any flooding issues raised by the Flood Study and provide details of any mitigating measures and their potential effect on flood levels in accordance with the planning controls and state legislation and policy. In addition to the requirements for a Flood Study, a Flood Management Plan must include:*

a) A reliable emergency escape route, with regular levels to Australian height datum along the centreline of this route;
b) How the materials and construction of any proposed buildings or structures will be able to withstand flood water or overland flows (see DCP Appendix 4 - Flood Construction Guidelines);
c) How the proposed development does not exacerbate or increase the risk of flooding or overland flows to adjoining land or downstream properties.

The Flood Construction Guidelines are incorporated at Appendix 4 of the DCP.

8.2.6 Comparison of the Murray Shire and Wakool Shire Policies

The Murray Shire DCP and Wakool Shire DCP vary significantly in their approach to flood planning. The two DCP's contain a number of differences in objectives and guidance and controls applicable to different types of development; summarised in Table 8-1.

The Murray Shire Development Control Plan 2012 was prepared with consideration given to the *Moama Floodplain Management Study* (1999). This policy provides flood planning directions for flood prone land included in the *Moama Floodplain Management Study* (1999). For development proposals in locations where the limits of the PMF level were not obtained as part of the *Moama Floodplain Management Study* (1999), the policy directs Council to use discretion in determining whether land to which a proposal relates is within the PMF.

The Wakool Development Control Plan 2013 was prepared at a time when the Council was planning to prepare a new flood study to determine the flood planning level for the Shire. However, this flood study was not completed and therefore, the DCP does not reference any adopted flood studies. The DCP does refer to flood maps, utilising the available flood information, which identify flood liable land and categorises flooding as 'low' or 'high' risk within the flood storage and floodway areas. This policy directs Council to use discretion in determining what land is flood liable, taking into account a range of factors, including the flood maps, flood studies identifying 1:100 ARI, modelling for specific sites which identifies the 1:100 ARI and historic flood inundations records.

Table 8-1: Comparison of the Murray Shire DCP and Wakool Shire DCP Flood Controls

	Murray DCP	Wakool DCP
Objectives	13 objectives in total. Some objectives in the Murray DCP are recommendations for Council to complete additional works or	5 objectives in total.

	Murray DCP	Wakool DCP
	directions for internal processes.	
Land to which the DCP applies - **Flood Planning Area (FPA) &** **Flood Planning Level (FPL)**	Mapping provided, with 3 FPAs shown. However, knowledge of flood planning levels outside the Moama floodplain is limited. The Moama floodplain was subject to a floodplain study in 1999. The Moama study is referred to in the policy and was the basis for identifying and mapping the 200 year ARI and PMF levels referred to in the policy. The FPL is the level 500mm above a 1% AEP or 100 year ARI flood event. The height of the 1% AEP was modelled in the Moama Floodplain Management Study 1999. The height was based on a height of 95.34 m AHD at the Echuca Wharf gauge. Mapping provides some clarity for development proponents and planners. However, there is still discretion applied for areas outside of flood liable land identified in the Moama floodplain study 1999, where knowledge of flood levels is limited.	Mapping provided, but knowledge of flood planning levels is limited across the Wakool area. This DCP does not reference any adopted flood studies. The policy refers to flood maps which identify flood liable land and categorise it as 'low' or 'high' risk in the flood storage and floodway areas. This policy directs Council to use discretion in determining what land is flood liable. The FPL is defined as: a) The crown of the adjacent road (or highest level of road where the crown is not established) in the urban areas of Barham and Moulamein (until such time as a Flood Study is adopted by Council); b) 1:100 ARI flood event for the remaining areas of the Shire.
Specified development types	Development categories include: • General • Flood control works • Residential, commercial and industrial development • Caravan parks and tourist developments.	Development categories include: • Land behind levees • Development of floodways • Development of the flood fringe outside a controlled levee bank • On-site sewage management within the flood fringe • Residential development outside

	Murray DCP	Wakool DCP
		a controlled levee bank • Commercial/retail/industrial development outside a controlled levee bank • Subdivision within the flood fringe • Land filling within the flood fringe; and • Specific works including fencing, raising dwelling floor levels and access to lots.
Floor level controls	**FPA1 Low Hazard Flood Storage (depth of water generally <1m)** Residential/commercial and industrial development: Height of floor levels will be at least the height of FPL. Caravan parks and tourist developments: Height of floor levels of any permanent structures will be at least the height of the FPL. **FPA1 High Hazard Flood Storage (depth of water generally >1m)** New residential/commercial and industrial development: Height of floor levels to be at least the height of FPL. Caravan parks and tourist developments: No approval will be considered for any permanent facilities. **FPA1 Low Hazard Floodway (depth of water generally <1m)** Commercial and industrial development: unsuitable for low hazard floodway. New residential development must have a	Residential development outside a controlled levee bank must not be lower than: • 300mm (freeboard) above FPL in the urban areas of Barham and Moulamein; or • 500mm (freeboard) above the FPL for all other areas. Commercial/retail/ industrial development outside a controlled levee bank must: • have a minimum floor level at or above the FPL (variation may be approved by Council if flood planning level is unreasonable).

	Murray DCP	Wakool DCP
	floor level at least the height of the FPL. Caravan parks and tourist developments: No approval will be considered for any permanent facilities. **FPA1 High Hazard Floodway (depth of water generally >1m)** New residential/commercial and industrial development: not suitable for high hazard floodways. Caravan parks and tourist developments: No approval will be considered for any permanent facilities.	
Flood compatible materials	Development where any part of the building is below flood level shall be constructed from flood compatible materials. There are no specific guidelines which list compatible materials.	Development of the flood fringe outside a controlled levee bank, commercial/retail/ industrial development outside a controlled levee bank and any application requiring a flood management plan to be prepared, must demonstrate how the materials and construction of any proposed buildings or structures will be able to withstand flood water or overland flood in accordance with the attached Flood Construction Guidelines. These guidelines incorporate construction methods and materials, including flooring structures, floor coverings, wall structures, roof structures, doors, insulation, windows, mechanical equipment etc.
Access/Egress	Access is considered for applications in the low and high flood storage area and low and high floodway area. New development is not generally considered	Requirements apply to access to lots within the flood fringe. The DCP states that: a) Flood free vehicle access is required

	Murray DCP	Wakool DCP
	appropriate in high hazard areas, but may be acceptable in some conditions. Evacuation and personal safety is one of the considerations, but no specific levels/wading criteria are mentioned.	for all lots created by subdivision and may be achieved by the construction of a controlled levee; b) For development of existing lots, where flood free access is not possible, the development must be able to achieve safe wading criteria as specified in Figure L1 of the Floodplain Management Manual (as amended).
Emergency response and warning systems	In high hazard flood storage and low and high hazard floodway applicants must demonstrate the feasibility of effective evacuation including *'permanent, fail-safe measures to ensure timely, orderly and safe evacuation of people from the area.'*	For applications where a Flood Management Plan is required, applicants must provide *'a reliable emergency escape route, with regular levels to Australian height datum along the centreline of this route.'*
Location of sensitive equipment	Not specifically listed in the guidance and controls in the DCP.	The flood proofing code included in the Flood Construction Guidelines require that all equipment installed below or partially below the flood planning level should be capable of disconnection by a single plug and socket assembly.
Flood affectation	There are decision guidelines contained in the DCP which includes consideration of *'the redistribution effect of the proposed development on floodwater'* There are guidelines relating to access roads and maximum built up levels for access roads for some developments.	Applications requiring a flood management plan must demonstrate in the Flood Management Plan that the proposed development will not exacerbate or increase the risk of flooding or overland flows to adjoining land or downstream properties.

8.2.7 Existing DCP Controls Specific to Moulamein

As Moulamein is within the former Wakool Shire Council LGA, the Wakool DCP 2013 is currently applicable to the study area. Prior to the adoption of the Moulamein Flood Study and Floodplain Risk Management Study, the only flood-related development controls applicable to the Moulamein urban area inside the levee is that the FPL is to be the height of the adjacent road crown or the highest level of the road where the crown is not established.

8.2.8 Murray River Council's Local Strategic Planning Statement 2020-2040

The Local Strategic Planning Statement 2020-2040 (LSPS) (Murray River Council, 2020) was adopted by Council in July 2020. The LSPS describes the Council's plan for land usage within the LGA over the next 20 years. The LSPS was prepared in accordance with the recent 2018 amendments of the Environmental Planning and Assessment Act 1979 that introduced a requirement for all NSW councils to prepare a Local Strategic Planning Statement. The purpose of the LSPS is to outline how the Council will manage growth and change while still preserving key aspects of the area, including environmental amenity, liveability, and landscape quality, as well as community values and other special characteristics of the local identity.

While the LSPS covers the whole of the Murray River Council area, it focuses on Moulamein specifically in 4 of the planning priorities. Planning Priority 4 – *Housing growth, supply and density* acknowledges the desirability of riverfront housing in several settlements including Moulamein. While Council acknowledges the attraction of riverfront housing, it stresses the necessity of balancing this land use against the environmental, social and economic value of the river systems. The LSPS states that any housing strategy to develop riverfront land must consider the Priority 2 – *Riverfront development strategy*, as well as setback requirements. Although riverfront houses are significantly more likely to experience flooding, this action is unlikely to majorly affect flooding in the relevant areas so long as current DCP guidelines regarding development on flood prone land are maintained.

Planning Priority 5 – *Recreation and Open Space* highlights the need for well designed recreation and open space facilities to promote community health and wellbeing. It also specifically references the currently ongoing upgrade works at the Moulamein preschool as a key project. However, Moulamein preschool is largely unaffected by either riverine or overland flood events less than the PMF.

Planning Priority 8 – *Celebrate culture and heritage* outlines several plans for Council to better manage and protect heritage items throughout the LGA. It mentions the Moulamein Heritage Village project as one such plan to increase a sense of connection to the history of the area. The proposed site for the Moulamein Heritage Village project experiences partial flooding of less than 0.15m in the 1% AEP riverine flood event, and is fully inundated by 0.30 to 1m depths in 0.5% AEP riverine flood event. Due to the sensitive nature of the heritage buildings that are part of the project and the fact that the project is yet to fully commence, it is suggested that care is taken to ensure the heritage buildings are sufficiently raised above the PMF flood level when the project is undertaken.

Planning Priority 9 – *Climate change and natural hazards* focuses on understanding forecasted changes to the area's climate and natural hazards in order to best plan for the community's future. It specifies the Council's efforts to update the flood prone land mapping used in the application of the LEP through information gathered both from the NSW Flood Data Portal and recently undertaken flood studies, including the Moulamein Flood Study.

8.3 Previous Floodplain Risk Management Studies and Plans

A number of previous FRMS&P reports have been undertaken in the surrounding areas that recommended new or updated flood-related planning controls. These reports included the Barham Floodplain Risk Management Study and Plan (GHD, 2017), the Tooleybuc Floodplain Risk Management Study and Plan (GHD, 2017), and the Murray Downs Floodplain Risk Management Study and Plan (GHD, 2017). It should be noted that all three reports were

completed after the formation of the Murray River Council, but focused on areas that were previously part of the Wakool Shire Council.

Each of these reports recommended similar planning and development controls such as:

- The adoption of a Flood Planning Level (FPL) based on current modelling of the 100 year ARI flood level, plus a calculated freeboard for the study area.
- The adoption of a Flood Planning Area (FPA) based on the area below the FPL for the study area.
- The updating of the Wakool LEP (2013) to include an FPA map for the study area.
- The updating of the Wakool DCP to incorporate the Local Flood Policy planning and development controls for the study area.

Within the Draft Local Flood Policies these reports again recommended similar planning controls. In regards to high hazard floodway areas:

- Each policy generally discourages development, except in the case of minor developments that met the requirements of low hazard floodway areas.

Regarding low hazard floodway areas:

- Each policy requires the submission of a local hydraulic study and prior development consent for any ground level alterations of greater than 100 mm.
- Each policy requires all habitable structures built in floodways to not be built on high hazard land, and requires the submission of a local hydraulic impact study.
- The Tooleybuc and Barham policy restrict new extensions to 60 sqm, with the floor level being as high as practicable without modifying the existing roof line. Conversely, the Murray Downs policy allows extensions of less than 50% of the existing floor area to be at the existing floor level, while extensions of greater than 50% of the existing floor area must have a floor level at the FPL.
- Each policy prohibits continuous or impermeable fencing, and allows post and rail fencing only when they are designed to avoid impeding floodwater flow.

Regarding high hazard flood storage and flood fringe areas:

- Each policy requires the same controls as for low hazard floodway areas.

Regarding low hazard flood storage and flood fringe areas:

- Each policy requires development consent prior to works or building activity within the FPA, and notes council may require a hydraulic study also be submitted.
- Each policy requires all new residential buildings to have a floor level at the FPL.
- Each policy requires commercial or industrial developments have a floor level at the FPL, or be flood proofed to at least the FPL at Council's discretion.
- Each policy allows extensions of less than 50% of the existing floor area to be at the existing floor level, while extensions of greater than 50% of the existing floor area must have a floor level at the FPL.
- Each policy allows extensions to existing non-residential buildings to be at the existing floor level, however Council may require the complete building to be flood proofed to the FPL.
- Each policy allows carports and open sheds to be built at existing ground levels, however requires they be constructed of flood compatible materials.
- Each policy permits the construction of continuous fencing.

Additionally, each policy requires that development applications for developments within the FPA be accompanied by existing ground levels as certified by a registered surveyor. Also, in floodway and high hazard areas only, a report from a Consulting Engineer detailing all adverse effects and flood damages caused by the proposed development on the subject or any other properties, and an evacuation plan developed in consultation with local SES is required.

9 Review of Flood Planning Area and Level

9.1 Overview

Flood Planning Areas (FPA) and Flood Planning Levels (FPL) facilitate future Council assessments of proposed developments. The FPA identifies parcels of land that are subject to Section 10.7 flood-related development controls. The FPL identifies the minimum floor level required for proposed developments on parcels of land classified as within the FPA.

The Floodplain Development Manual recommends that the FPL be based upon the 1% AEP peak flood level plus a freeboard. Typically, a 0.5 m freeboard is applied; although the Manual does allow for a lower freeboard to be applied if local conditions justify doing so. Of further consideration is also the difference between riverine flood behaviour and local overland flood behaviour, with the former typically being the basis on which FPA and FPL methodologies have been developed and applied. Often these differences are seen in how great the difference in peak flood levels are between different magnitude events, whereby riverine flood levels vary to a greater degree between events whereas overland flood levels vary to a much smaller degree. As such, applying the typical freeboard of 0.5 m to overland flood levels can result in an FPL that is significantly greater than the PMF level.

9.2 Considerations for Riverine Flooding

9.2.1 Flood Magnitude

Given the relatively flat terrain of the study area, it was found that often an increase in riverine flows resulted in relatively large increases in flood extent, shown on Figure B 14. Such large variations in flood extents across flood events of varying magnitude present a risk to the community, particularly where it increases road inaccessibility (discussed in Section 6.4).

Another consequence of the flat terrain is that often an increase in riverine flows resulted in relatively small increases in flood level, shown in Table 9-1. Of particular note is that the difference between the 1% AEP riverine flood level and the PMF riverine flood level was slightly less than 0.5 m, which is the typical freeboard used to calculate the FPL for riverine flooding.

Table 9-1: Average Flood Level Difference - Riverine Flooding

	PMF	0.5% AEP	1% AEP	2% AEP
0.5% AEP	0.37 m	-	-	-
1% AEP	0.44 m	0.08 m	-	-
2% AEP	0.52 m	0.17 m	0.09 m	-
5% AEP	0.60 m	0.27 m	0.20 m	0.12 m

9.2.2 Flood Readiness

Flood warning times for riverine flooding in the study area are sufficient long enough to enable the SES to provide advanced warning to the community, as well as enable the community to take action based upon these warnings. Furthermore, both the SES and the community have experience with riverine flooding in the area due to previous flood events (such as the 2016 riverine flood event) and the stability of the community (with many residents having lived there for a number of decades). For these reasons, flood preparedness was not considered to be an issue in determining the FPA and FPL.

9.2.3 Land Availability and Land Use Type

The majority of the land outside of the town levee system that is affected by riverine flooding is currently zoned RU1 – Primary Production. For this reason, buildings (either residential, commercial or industrial) tend to be few and far between. Furthermore, there does not appear to be a large degree of development pressure in this area. For these reasons, land availability and needs were not considered to be an issue in determining the FPA and FPL.

9.3 Considerations for Overland Flooding

9.3.1 Flood Magnitude

Due to the comparatively shorter duration of overland flooding in the study area, it was found that an increase in overland flows resulted in relatively small increases in flood extent (with the exception of the PMF overland flood event), shown on Figure B 15.

Similarly, it was found that an increase in overland flows resulted in significantly smaller increases in flood level, shown in Table 9-2. Of particular note is that the difference between the 1% AEP overland flood level and the PMF overland flood level was slightly less than 0.3 m, which is the typical freeboard used to calculate the FPL for overland flooding.

Table 9-2: Average Flood Level Difference – Overland Flooding

	PMF	0.5% AEP	1% AEP	2% AEP
0.5% AEP	0.28 m	-	-	-
1% AEP	0.29 m	0.01 m	-	-
2% AEP	0.29 m	0.02 m	0.01 m	-
5% AEP	0.30 m	0.03 m	0.02 m	0.01 m

9.3.2 Flood Readiness

Flood warning times for overland flooding in the study area are relatively limited and would be insufficient for the SES or the community to respond to. Furthermore, there has not appeared to be a large overland flood event in recent times and so the community would be unfamiliar with the flood behaviour of this type of flooding, which is significantly different to the more familiar riverine flooding in the area. This presents a risk to the community.

9.3.3 Land Availability and Land Use Type

The majority of the land inside of the town levee system that is affected by overland flooding is currently zoned RU5 – Village. For this reason, the Moulamein urban area is relatively low density. Furthermore, there does not appear to be a large degree of development pressure in this area. For these reasons, land availability and needs were not considered to be an issue in determining the FPA and FPL.

9.4 Recommendations

9.4.1 Riverine vs Overland Flooding

It was found that across the study area, the riverine FPA and FPL were the prevailing criteria for flood-related development controls. Therefore, the overland FPA and FPL are not recommended for application in assessing development applications.

9.4.2 Riverine FPA and FPL

Taking the above into consideration, the standard 0.5 m freeboard was considered appropriate for the Moulamein study area. Therefore the FPL for residential development affected by riverine flooding is the 1% AEP riverine flood level plus a 0.5 m freeboard.

The FPA extent for riverine flooding was then classified as areas affected by the 1% AEP riverine flood level, plus a 0.5 m freeboard, extended perpendicular to the flow direction, and limited to the PMF riverine flood extent. This is shown on Figure F 1.

10 Consequences of Flooding

10.1 Overview

Flood damages (or the consequences of flooding) are typically broken down into four categories; tangible direct, tangible indirect, intangible direct and intangible indirect. Tangible damages are those that can be quantified in a monetary sense, such as the cost of rebuilding a house. Whereas intangible damages are generally difficult to quantify in terms of dollar value, such as the stress placed on families and business owners as a result of flooding. In-direct damages are those damages that occur but are not a direct result of flood waters, for example the loss of business after a flood occurs. This is shown graphically in Chart 10-1.

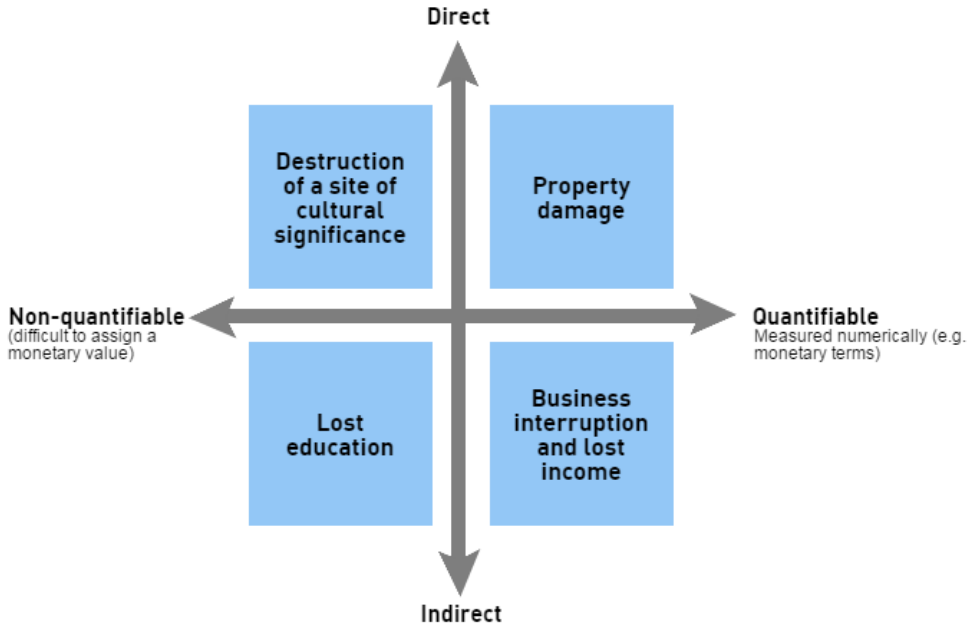


Chart 10-1: Flood Damage Representation (Source - UNISDR: Prevention Web, Direct and Indirect Losses, 2014)

The economic impacts, social impacts, heritage impacts and environmental impacts as a result of flooding are discussed in the following.

10.2 Economic Impacts

10.2.1 Methodology

There are a number of methods available for calculating tangible, direct flood damages, including; the Rapid Appraisal Method (RAM), ANUFLOOD Method and the depth-damage curves developed by the NSW Government (2007).

The tangible, direct flood damages to residential property were calculated using the depth-damage curves developed by the NSW Government (2007). This method requires a number of parameters to be specified for the catchment, which is discussed in Section 10.2.1.1.

The tangible, direct flood damages to commercial property were calculated using the depth-damage curves from the ANUFLOOD method. This method requires a number of parameters to be specified for the properties, which is discussed in Section 10.2.1.2.

These depth-damage relationships were then intersected with the number of properties affected by above floor flooding (with the floor level estimation discussed in Section 10.2.1.3) and above ground flooding (with the flood level estimation discussed in Section 10.2.1.4) to estimate the total tangible, direct flood damages within the study area.

The tangible, indirect flood damages to both residential and commercial properties were calculated as 15% of the tangible, direct flood damages.

10.2.1.1 Residential Depth-Damage Relationship

The NSW Government (2007) method calculates the depth-damage relationship based upon a number of parameters, the values and description of which is shown in Table 10-1.

Table 10-1: Residential damage parameters

Input Parameter	Value Adopted	Explanation
Regional Cost Variation Factor	1.15	Costs adjusted based on Rawlinsons (2019) for Deniliquin.
Post 2001 Adjustment Factor	1.83	Costs adjusted to account for changes to average weekly earnings since the estimates were calculated in 2001, based on the Australian Bureau of Statistics data from November 2019
Post Flood Inflation Factor	1.3	Ranges from 1.0 to 1.5 (NSW Government, 2007), based on the recommended factor for medium scale impacts on a regional town
Typical House Size	180 m^2	Based upon the digital schematisation of buildings in the study area from the aerial photography.
Typical Duration of Immersion	24 hours	
Building Damage Repair Limitation Factor	1.0	Based on a long duration flood event.
Average Contents Value	$45,000	Based upon the typical house size in the study area.
Contents Damage Repair Limitation Factor	0.9	Based on a long duration flood event.
Typical Table/Bench Height	0.9 m	0.9 m is the default.
Level of Flood Awareness	High	'Low' is the default. However, given the relatively stable population and their awareness of historical floods such as the

		1956 and 2016 floods, a classification of 'High' was deemed appropriate for the study area.
Effective Warning Time	24 hours	The maximum effective warning time allowed through this method was 24 hours.

These input parameters resulted in the following residential depth-damage curves.

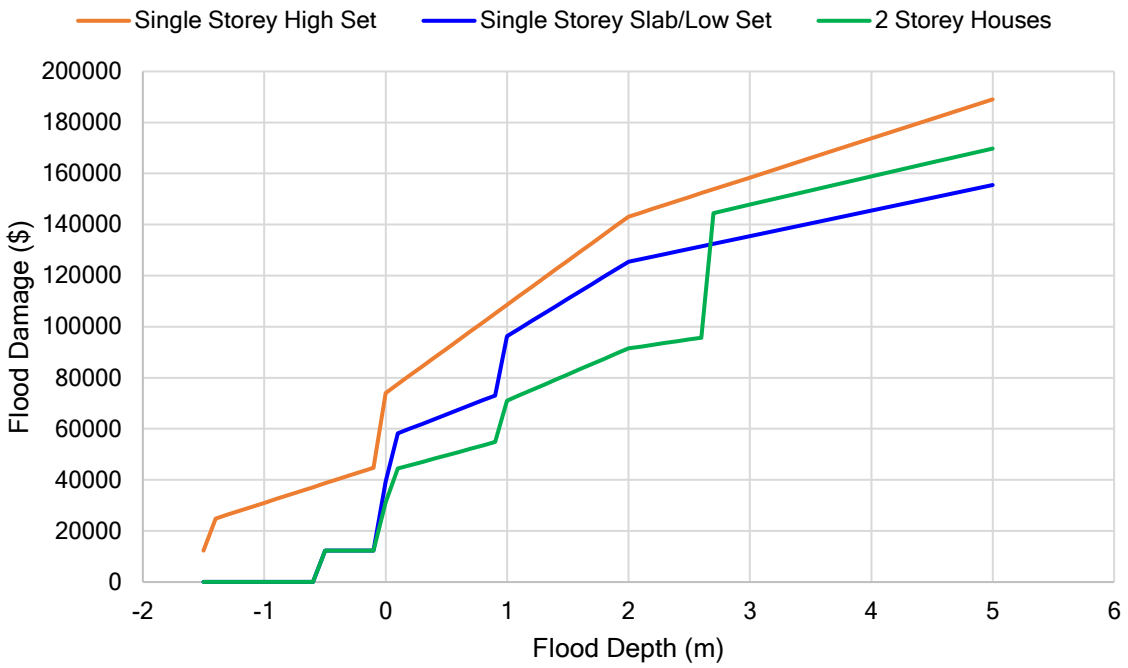
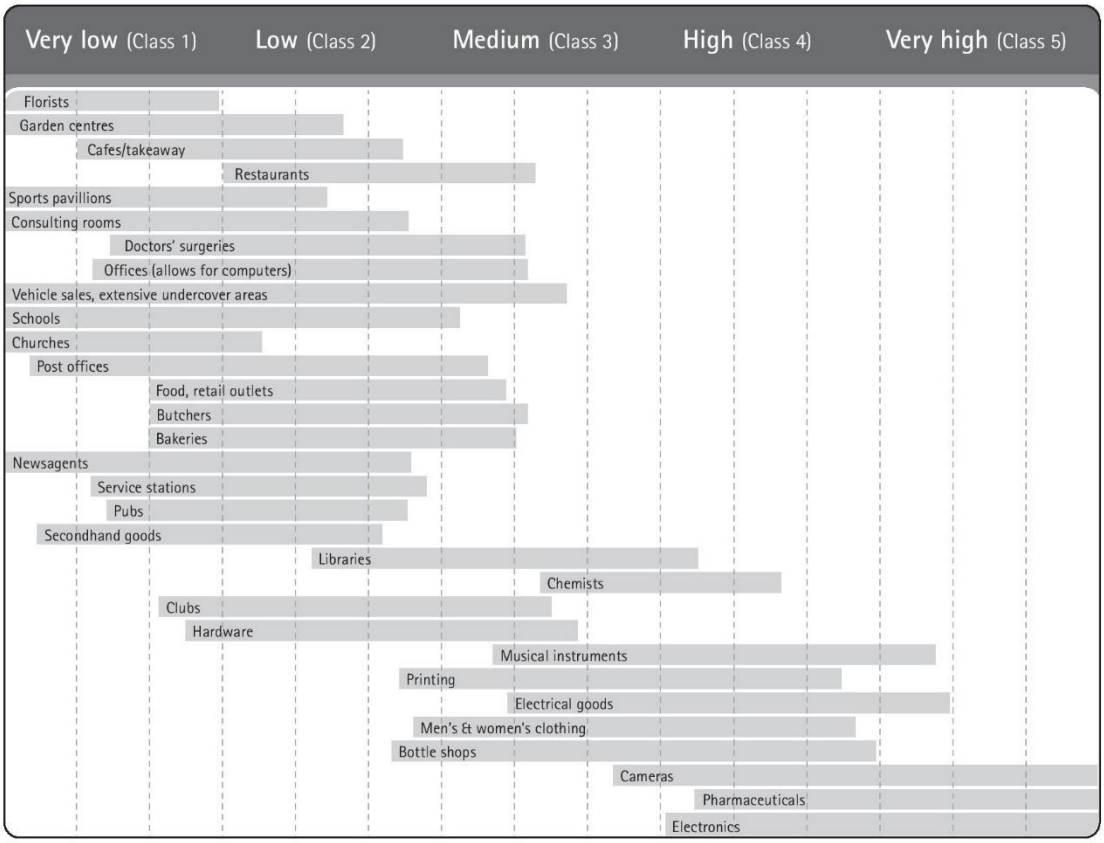


Chart 10-2: Residential Depth-Damage Curves

10.2.1.2 Non-Residential Depth-Damage Relationship

The ANUFLOOD method calculates the depth-damage relationship based upon the size of the commercial property and the commercial usage of the property. The commercial property sizes are classified as either small commercial (less than 186 m^2), medium commercial (between 186 m^2 to 650 m^2), or large commercial (greater than 650 m^2). The commercial usage is classified as either Class 1 (very low), Class 2 (low), Class 3 (medium), Class 4 (High), or Class 5 (very high); as shown in Chart 10-3.



Reproduced from Centre for Resource and Environmental Studies (Australian National University) 1992, ANUFLOOD: A Field Guide, *prepared by D.I. Smith and M.A. Greenaway, Canberra.*

Chart 10-3: Commercial damage categories based on the commercial usage of the property

Within the Moulamein study area it was found that all the commercial properties were within the Class 2 category, with varying commercial property sizes. This resulted in the following commercial depth-damage curves.

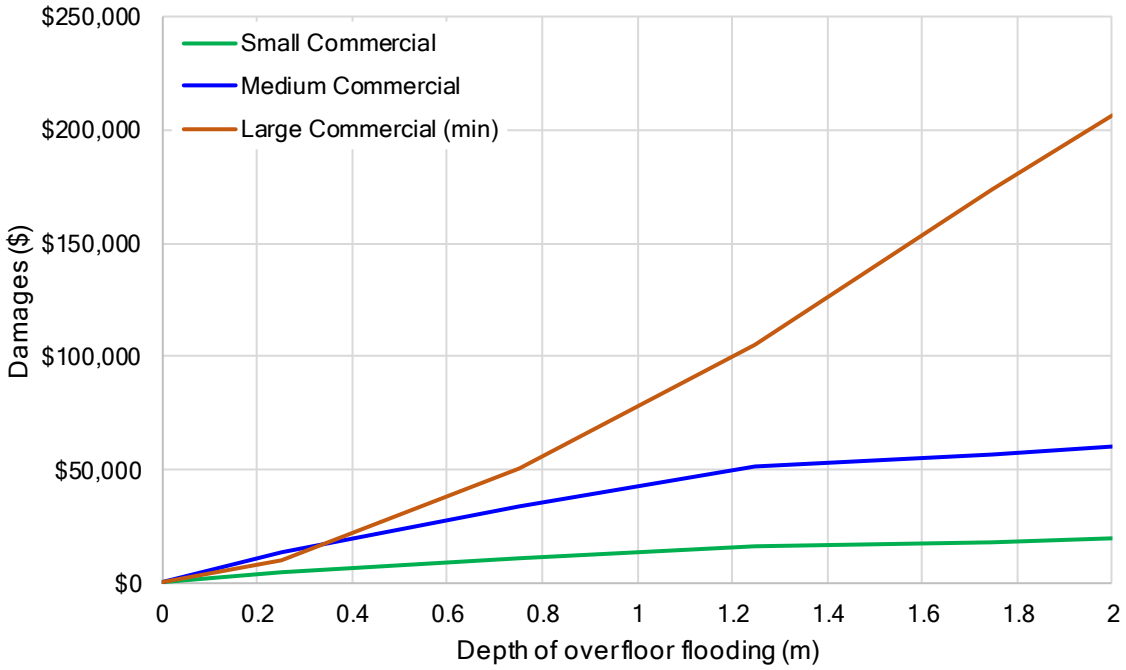


Chart 10-4: Commercial Depth-Damage Curves

10.2.1.3 Floor Level Estimation

Floor levels were estimated using Google Street View and the LiDAR data. Google Street View images were interrogated for each house within the study area to estimate the height above ground level of the lowest habitable floor based upon the entryway door. The estimated floor height above ground level was then intersected with the LiDAR surveyed ground level to produce an estimated floor level. However, buildings identified as sheds were excluded from the assessment.

10.2.1.4 Flood Level Estimation

The flood affectation of a building was estimated using the levee breach scenario. The maximum flood level from within a 3m radius of the building for each flood event was then assigned to each building.

10.2.2 Results

The direct damages as a result of flooding have been calculated for each individual flood event (including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events). The Average Annual Damages (AAD) and Net Present Value (NPV) of these direct flood damages have also been calculated. AAD is a measure of the average damage due to flooding experienced by an area over a large period of time. This is to account for the different amount of damage caused by different events of varying magnitude (i.e. large, less frequent floods generally cause more damage than small, more frequent floods). The AAD per annum in present terms is then adopted for each year of the NPV of damages estimation (assuming a 50 year economic life).

Table 10-2 details the direct flood damages due to riverine flooding outside the town levees. From this, the AAD of riverine flooding outside the levee was $91,139 and the NPV was $1,348,932.

Table 10-3 details the direct flood damages due to riverine flooding within the town levees. From this, the AAD of riverine flooding inside the levee was $207,122 and the NPV was $3,065,558.

Table 10-4 details the direct flood damages due to overland flooding within the town levees. From this, the AAD of overland flooding was $509,413 and the NPV was $7,539,698.

Of the three scenarios tabulated, the overland flooding within the town levees scenario resulted in the largest direct flood damages; however this scenario was found to have the smallest number of properties affected by above-floor flooding. The high flood damages in this scenario was attributed to the relatively large number of properties affected by above-ground (also known as below-floor) flooding. The reasons for this are due to a combination of naturally flat ground levels throughout Moulamein (with little to no ground slope to assist rainfall runoff to flow downstream), and road crowns/crests that are often slightly higher than the adjacent ground levels (which is alluded to in the Wakool Shire DCP discussed in 8.2.5, whereby the road crest was to be used as the FPL for development applications in Moulamein in the absence of a specific Moulamein Flood Study).

Of the riverine direct flood damages, the area inside the town levees was found to have higher flood damages compared to the area outside the town levees. This was due to the larger number of properties inside the levee being affected by both above-floor flooding and above-ground flooding.

Table 10-2: Direct Flood Damages - Riverine flooding outside of the town levees

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
PMF					
Residential	18	10	$1,200,273	$180,041	$1,380,314
Commercial	3	3	$86,257	$12,939	$99,196
Sub-Total	21	13	$1,286,530	$192,979	$1,479,509
0.5% AEP					
Residential	18	4	$940,915	$141,137	$1,082,053
Commercial	4	3	$84,423	$12,663	$97,086
Sub-Total	22	7	$1,025,338	$153,801	$1,179,139
1% AEP					
Residential	18	3	$842,342	$126,351	$968,693
Commercial	4	3	$84,423	$12,663	$97,086
Sub-Total	22	6	$926,765	$139,015	$1,065,779
2% AEP					
Residential	16	3	$738,991	$110,849	$849,840
Commercial	4	3	$84,423	$12,663	$97,086
Sub-Total	20	6	$823,414	$123,512	$946,926
5% AEP					
Residential	12	2	$528,387	$79,258	$607,645
Commercial	4	3	$61,297	$9,195	$70,492
Sub-Total	16	5	$589,684	$88,453	$678,137
10% AEP					
Residential	9	2	$394,390	$59,158	$453,548
Commercial	4	3	$61,297	$9,195	$70,492
Sub-Total	13	5	$455,687	$68,353	$524,040
20% AEP					
Residential	4	0	$169,540	$25,431	$194,971
Commercial	4	3	$35,970	$5,396	$41,366
Sub-Total	8	3	$205,510	$30,827	$236,337

Table 10-3: Direct Flood Damages - Riverine flooding inside the town levees

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
PMF					
Residential	150	26	$6,010,000	$901,500	$6,911,500
Commercial	22	3	$193,222	$28,983	$222,205
Sub-Total	172	29	$6,203,222	$930,483	$7,133,705
0.5% AEP					
Residential	89	7	$3,106,903	$466,035	$3,572,939
Commercial	13	2	$68,107	$10,216	$78,323
Sub-Total	102	9	$3,175,010	$476,252	$3,651,262
1% AEP					
Residential	65	5	$2,306,773	$346,016	$2,652,789
Commercial	12	2	$68,107	$10,216	$78,323
Sub-Total	77	7	$2,374,880	$356,232	$2,731,112
2% AEP					
Residential	59	4	$2,059,316	$308,897	$2,368,213
Commercial	12	2	$68,107	$10,216	$78,323
Sub-Total	71	6	$2,127,423	$319,113	$2,446,537
5% AEP					
Residential	38	2	$1,331,252	$199,688	$1,530,939
Commercial	8	1	$52,942	$7,941	$60,883
Sub-Total	46	3	$1,384,193	$207,629	$1,591,822
10% AEP					
Residential	11	1	$438,947	$65,842	$504,789
Commercial	5	1	$52,942	$7,941	$60,883
Sub-Total	16	2	$491,889	$73,783	$565,672
20% AEP					
Residential	3	0	$78,235	$11,735	$89,970
Commercial	3	0	$0	$0	$0
Sub-Total	6	0	$78,235	$11,735	$89,970

Table 10-4: Direct Flood Damages - Overland flooding within the town levees

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
PMF					
Residential	159	14	$5,308,065	$796,210	$6,104,275
Commercial	22	2	$188,817	$28,323	$217,139
Sub-Total	181	16	$5,496,882	$824,532	$6,321,414
0.5% AEP					
Residential	141	0	$4,143,785	$621,568	$4,765,353
Commercial	20	0	$0	$0	$0
Sub-Total	161	0	$4,143,785	$621,568	$4,765,353
1% AEP					
Residential	139	0	$4,069,011	$610,352	$4,679,363
Commercial	20	0	$0	$0	$0
Sub-Total	159	0	$4,069,011	$610,352	$4,679,363
2% AEP					
Residential	138	0	$4,022,491	$603,374	$4,625,864
Commercial	20	0	$0	$0	$0
Sub-Total	158	0	$4,022,491	$603,374	$4,625,864
5% AEP					
Residential	138	0	$4,012,052	$601,808	$4,613,860
Commercial	20	0	$0	$0	$0
Sub-Total	158	0	$4,012,052	$601,808	$4,613,860
10% AEP					
Residential	134	0	$3,907,198	$586,080	$4,493,278
Commercial	19	0	$0	$0	$0
Sub-Total	153	0	$3,907,198	$586,080	$4,493,278
20% AEP					
Residential	108	0	$3,119,781	$467,967	$3,587,749
Commercial	18	0	$0	$0	$0
Sub-Total	126	0	$3,119,781	$467,967	$3,587,749

10.3 Social Impacts

The social impact of flooding was assessed by considering the impact of flood events on key locations of importance to the community. Through analysing flooding behaviours, it was found that:

- The Mooloomoon tourist accommodation on Hay Street was found to experience flooding in the 10% AEP riverine flood event, and is fully inundated in events greater than and including the 2% AEP riverine flood event.
- Moulamein Public School on Tallow Street was found to experience flooding in events greater than and equal to the 0.5% AEP riverine flood event, with flood depths less than 0.3 m.
- Moulamein Lakeside Caravan Park on Brougham Street was found to experience flooding in events greater than and equal to the 0.5% AEP riverine flood event, with flood depths less than 1.0 m.
- Moulamein Retirement Village and Moulamein Preschool both on Turora Street were found to experience flooding in events greater than a 0.5% AEP riverine flood event.

10.4 Heritage Impacts

The Old Court House is located directly south-east of the confluence of the Edward River and Billabong Creek, and is not protected by the southern levee. Thus, the grounds surrounding the Old Court House are inundated in a 20% AEP riverine flood event. However, as Old Court House is likely to be relocated as part of the Moulamein Heritage Village project (discussed in 8.2.8) there is the future opportunity to raise the Old Court House above the PMF riverine flood level as part of this relocation.

Similarly, due to the proximity of many of the Aboriginal Heritage sites in the catchment to waterways, many are inundated in relatively small riverine flood events. In the group of 6 scarred trees directly south of the Moulamein Bowling Club, 4 are inundated in a 20% AEP riverine flood event, and all are inundated in a 2% AEP riverine flood event. In the large group of scarred trees and earth mounds to the east of town, between Edward River and Pretty Pine Road, approximately half of the sites are inundated in a 20% AEP riverine flood event, and all but 4 of the sites are inundated in a 2% AEP riverine flood event.

10.5 Environmental Impacts

The areas of environmental sensitivity most commonly found throughout the Moulamein catchment area were floodplain wetlands, floodplain forests and woodlands, and Cypress Pine/Yellow Box woodlands. As expected, the floodplain wetlands running alongside the Edward River and Billabong Creek are inundated in a 20% AEP riverine flood event or greater. The floodplain forests and woodlands, and the Cypress Pine/Yellow Box woodlands to the north and south of the town centre, typically become inundated in a 10% AEP to a 5% AEP riverine flood event. Notably, the floodplain forests and woodlands located along the minor Yarrien Creek typically do not become inundated in events smaller than the 2% AEP riverine flood event. Given the existing flood affectation of these environmentally sensitivity areas were assumed to be a contributing factor in the formation of these areas, it was considered important to maintain existing flood connectivity to these environmentally sensitivity areas.

11 Floodplain Risk Management Measures

11.1 Overview

The NSW Floodplain Development Manual (NSW Government, 2005), categorises the modification measures that can be investigated to mitigate the flood risks to a community as:

- Flood Modification Measures – These options aim to reduce flood risk by altering the flood behaviour, such as decreasing flood levels, velocities or extents.
- Property Modification Measures – These options aim to reduce flood risk by altering the existing properties and/or imposing planning controls to future properties.
- Response Modification Measures – These options aim to reduce flood risk by altering the way the community responds to a flood event.

The mitigation measures identified and investigated in this study span the range of mitigation measures (i.e. flood, property and response) and are discussed in the following.

11.2 Options Identified

11.2.1 Potential Flood Modification Measures

11.2.1.1 Option FM01 - Upgrade to increase the height of existing town levees (northern, southern and western levee)

This option involved levee construction works on the northern, southern, and western levee systems. This included remediation of the existing levee system (where previous studies deemed the levees deficient due to cracking in the top 500 mm of the levees) as well as construction to increase the levee heights to the 1% AEP riverine flood level plus a 0.5 m freeboard (as discussed in Section 4.5.5), where the existing level of protection is below this level. It was proposed that the increased levee heights could be constructed through a combination of road raising (where the roads formed part of the levee boundary), earthen levee construction (where the distance from existing buildings was sufficient to provide a batter to ground level), and construction of a concrete levee wall (where the distance from existing buildings was insufficient to provide a batter to ground level). Figure C 1 shows the proposed location of these various construction methods.

For the northern levee system, the consequences of failure are relatively high given that this levee system protects the larger town population. However, the probability of inundation with a levee failure of this system is relatively low due to the relatively high ground levels inside the levee area.

For the southern levee system, the consequences of failure are moderate given that this levee system protects the smaller town population. However, the probability of inundation with a levee failure of this system is relatively high due to the low ground levels inside the levee area.

For the western levee system, the probability of inundation with a levee failure of this system is relatively high due to the low ground levels inside the levee area. As for the consequences of failure, these are dependent upon the emergency response plans. With the current emergency response plans listing the Moulamein Bowling Club (which is inside the western levee area) as an emergency evacuation centre, the consequences of failure are relatively high. However, if the emergency response plans were to be revised to delist the Moulamein Bowling Club as an emergency evacuation centre, the consequences of failure reduce substantially and become very low.

This option was suggested by Council and the FRMC so as to provide confidence in the structural integrity of the town levee system, which is currently lacking.

11.2.1.2 Option FM02 – Upgrade to increase the height of existing town levee (northern levee only)

This option involved levee construction works on the northern levee system only. Similar to option FM01, this included remediation of the existing levee system and construction to increase the levee height to the 1% AEP riverine flood level plus a 0.5 m freeboard, where the existing level of protection is below this level.

The aim of this option was twofold:

1) to facilitate revisions to the emergency response plan (option RM01, discussed in Section 11.2.3.1); specifically to delist Moulamein Bowling Club as an emergency evacuation centre due to the high probability of inundation with a levee failure and to list an emergency evacuation centre within the northern levee where the probability of inundation with a levee failure is lower.
2) to decrease the risk of a levee failure in an area where the consequences of a levee failure are relatively high.

This option was investigated following discussions with Council about whether option FM01 could be constructed in two stages (Stage 1 being the northern levee upgrade and Stage 2 being the southern and western levee upgrade) due to potential funding constraints of the high cost total levee upgrade.

11.2.1.3 Option FM03 – Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)

This option involved levee construction works on the northern levee system between Moulamein Lake and Tchelery Road only. Similar to option FM01, this included remediation of the existing levee system and construction to increase the levee height to the 1% AEP riverine flood level plus a 0.5 m freeboard.

The aim of this option was similar to FM02, however it was specifically targeted towards an emergency response option (option RM01, discussed in Section 11.2.3.1) of listing an emergency evacuation centre at either the Moulamein Swimming Centre or Moulamein Lakeside Caravan Park (both located at the northern end of Brougham Road).

This option was suggested by Council, the SES and the FRMC to alleviate concerns regarding the flood risk of the Moulamein Bowling Club as an evacuation centre.

11.2.1.4 Option FM04 – Construct new levee around the water treatment plant

This option involved construction of an independent levee around the water treatment plant (which is located inside the southern levee area) and raising of the water intake pump located on the southern levee crest. This would also require remediation of the existing levee system below the water intake pump. Both the levee around the water treatment plant and the raised water intake pump would be constructed to the 1% AEP riverine flood level plus a 0.5 m freeboard.

The aim of this option was to protect the critical community infrastructure of the water treatment plant and the water intake pump in the event that the southern levee either breaches or overtops during a flood event (assuming that the southern levee is not remediated or raised).

11.2.1.5 Option FM05 – Install flap gates on culverts through town levees

This option involved the construction of flap gates on the culverts through the town levees, which currently do not have any reverse flow mechanisms attached. The aim of this option was to prevent riverine flooding from inundating the township within the levee system, whilst still facilitating the drainage of overland flooding from within the township when the river levels are lower.

This option was suggested by Council based upon observations during the October 2016 riverine flood event of backflow from the culverts through the town levee system.

11.2.2 Potential Property Modification Measures

11.2.2.1 Option PM01 – Update Development Controls

Development controls are often applied so as to protect future development from flood risk and flood damage. These are generally applied through the establishment of development controls within Council's Development Control Plan (DCP) and Section 10.7(2) Planning Certificates issued by Council for individual properties.

In reference to Moulamein, the following flood-related development controls are recommended:

- The adoption of a Flood Planning Level (FPL) based upon the 1% AEP riverine flood level plus a 0.5 m freeboard (as discussed in Section 9).
- The adoption of a Flood Planning Area (FPA) based upon the area below the 1% AEP riverine flood level plus a 0.5 m freeboard (as discussed in Section 9), as shown on Figure F 1.
- The incorporation of a map defining the FPA at Moulamein into the LEP.
- Prior to the consolidation of the former Murray DCP (2012) and Wakool DCP (2013), it is recommended that the application of the flood-related development controls for Moulamein be consistent with that recommended in the Murray Downs Local Flood Policy (discussed in Section 8.3).
- With the future Murray River Council DCP (currently pending), it is recommended that the Local Flood Policies be incorporated into the DCP.

11.2.2.2 Option PM02 – Voluntary Property Purchase

Voluntary purchase is a property modification measure where in council purchases land affected by high hazard areas. Buildings that are purchased are then demolished, and the land is rezoned to a more appropriate classification. This is seen as a last resort option, and is used only when other mitigation options are not feasible in the given area.

DPIE has made available guidelines for voluntary purchase schemes to assist in the determination of whether this modification option is suitable for the area (DPIE, 2020). These guidelines recommend that voluntary purchase is effective in areas where:

- there are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers.
- a property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function.
- purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset.

Highly hazardous flood conditions were defined using the 1% AEP riverine flood event. Of the residential properties identified within the Moulamein study area outside the northern town levee system, 4 were determined to have been subjected to highly hazardous flood conditions within the 1% AEP riverine flood event. Of these residential properties, 1 was found to have above floor level flooding of greater than 0.7 m, one other experienced above floor level flooding of greater than 0.15m, and the remaining two properties experienced below floor level flooding.

In order to implement this option, a voluntary purchase policy would need to be developed that would outline circumstances under which Council would acquire suitable properties. Council would then need to prepare a voluntary purchase scheme, which would detail:

- All properties subject to the scheme;
- The relative acquisition priority of the properties;
- The cost of the acquisition; and
- The anticipated acquisition schedule.

Importantly, resident participation in a scheme of this nature is entirely voluntary. It is expected that residents will likely not be amenable to such a scheme at the present time. However, support from the residents may change in the future, in the event of a large flood that may highlight the need for such a scheme. Should this option gain support in the future, it is recommended that priority be given to those properties with the most significant above floor level flooding.

11.2.3 Potential Response Modification Measures

11.2.3.1 Option RM01 – Update Emergency Response Plans

It is advisable that the current emergency response plans be updated to incorporate the flood risk information determined from the current Moulamein Flood Study and Floodplain Risk Management Study and Plan.

Of particular importance is the location of emergency evacuation centres. As one of the current emergency evacuation centres listed (Moulamein Bowling Club) is located in an area of high flood risk in the event of a levee breach on the western levee, it is recommended that this emergency evacuation centre be delisted.

As a replacement emergency evacuation centre, the Moulamein Swimming Centre or Moulamein Lakeside Caravan Park (both located at the northern end of Brougham Road) were considered. Both are located in an area that is subject to relatively low flood depths in the event of a levee breach and both are more accessible to the urban population of Moulamein as they are located within the same northern levee area.

Flood mitigation option FM03 was investigated to increase the level of flood protection provided to these possible emergency evacuation centres by upgrading the northern levee between Moulamein Lake and Tchelery Road. However, this option did not provide flood protection up to the PMF event as other sections of the northern levee were found to overtop in this event. Furthermore, it is inadvisable that the PMF protection required for an emergency evacuation centre be reliant on a levee system. Therefore, the option to relocate the emergency evacuation centre needed to consider the associated construction works to build a raised ground level area that was above the PMF flood level.

It was assumed that the raised ground level area would need to accommodate 305 people (based on the census data discussed in Section 4.1) and that each person would require 4 sq.m of area each. Therefore the raised ground level area that was assessed covered an area of 1216 sq.m in a the form of a 20 m by 61 m rectangle.

From this, it was found that the Moulamein Swimming Centre required less fill volume (due to the lower flood depths), and hence required a lower capital expenditure to undertake these associated works. Therefore, the Moulamein Swimming Centre is recommended as the replacement emergency evacuation centre.

Furthermore, it is recommended that the emergency response plans be updated to incorporate the findings of any future geotechnical study into the structural integrity of the town levees.

11.3 Option Assessment Process

The Floodplain Development Manual (NSW Government, 2005) and the Australian Emergency Management Handbook 7 (AEMI, 2017) recommend that a multi-criteria assessment (MCA) be carried out to assess each of the potential mitigation measures. An MCA considers the economic, social and environmental impacts of the potential mitigation measures. The multi-criteria matrix system that was used for the current assessment is detailed in Table 11-1.

Table 11-1: Multi-Criteria Matrix System

Category	Criteria	Score						
		-3	-2	-1	0	1	2	3
Flood Behaviour (Weighted 3)	Impact on Flood Behaviour	> 100 mm increase or newly flooded	50 to 100 mm increase	< 50 mm increase	No change	< 50 mm decrease	50 to 100 mm decrease	> 100 mm decrease or no longer flooded
Economic (Weighted 2)	Benefit Cost Ratio	< 0.15	0.15 to 0.5	0.5 to 1.0	1.0	1.0 - 1.2	1.2 - 1.5	> 1.5
	Average Annual Damages	>$20,000 increase	$10,000 to $20,000 increase	< $10,000 increase	No Change	< $10,000 decrease	$10,000 to $20,000 decrease	> $20,000 decrease
	Cost of initiating management measure	> $7,500,000	$7,500,000 to $5,000,000	$5,000,000 to $2,500,000	$2,500,000 to $1,000,000	$1,000,000 to $750,000	$750,000 to $500,000	> $500,000
Social (Weighted 1)	Social Disruption (during construction of measure)	Works within 10m of socially significant sites	Works within 20m of socially significant sites	Works within 30m of socially significant sites	No Impact	N/A	N/A	N/A
	Community Support	Strongly Disagree	Moderately Disagree	Minorly Disagree	Neutral	Minorly Agree	Moderately Agree	Strongly Agree
Environmental (Weighted 1)	Contaminated Land Impacts	Works within 10m of known contaminated land sites	Works within 20m of known contaminated land sites	Works within 30m of known contaminated land sites	No Impact	N/A	N/A	N/A
	Biodiversity Impacts	Works within 10m of known biodiversity sites	Works within 20m of known biodiversity sites	Works within 30m of known biodiversity sites	No Impact	N/A	N/A	N/A
	Heritage Impacts	Works within 10m of known heritage sites	Works within 20m of known heritage sites	Works within 30m of known heritage sites	No Impact	N/A	N/A	N/A

11.4 Option Assessment Results

11.4.1 Potential Flood Modification Measures

11.4.1.1 Option FM01 - Upgrade to increase the height of existing town levees (northern, southern and western levee)

Flood Behaviour Assessment

As a result of this mitigation option, the areas within the town levees were no longer flooded across the range of flood events. In the smaller magnitude events (such as the 10% AEP event), the decrease in flooding within the southern levee area resulted in a minor increase in flood levels upstream around Balpool Road. However in the larger magnitude events (such as the 1% AEP event), the increase in flood levels around Balpool Road shifted closer and resulted in a minor increase in flood levels adjacent to the southern levee's south-eastern boundary.

Economic Assessment

Table 11-2 details the economic assessment of mitigation option FM01. From this, it was found that there was a substantial decrease in properties affected by both above-ground flooding and above-floor flooding compared to no mitigation. This in turn, resulted in a substantial decrease in AAD and NPV. However, the cost to implement this mitigation option was conversely substantially high. Therefore, the B/C ratio was found to be relatively low.

Table 11-2: FM01 Economic Assessment (Riverine flooding inside and outside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	193	42	$7,489,752	$1,123,463	$8,613,214
	0.5% AEP	124	16	$4,200,349	$630,052	$4,830,401
	1% AEP	99	13	$3,301,645	$495,247	$3,796,892
	2% AEP	91	12	$2,950,837	$442,626	$3,393,463
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (before mitigation measure)					$298,261
	NPV (before mitigation measure)					$4,414,490
After Mitigation	PMF	115	26	$4,293,048	$643,957	$4,937,006
	0.5% AEP	103	11	$3,394,818	$509,223	$3,904,041
	1% AEP	88	10	$2,783,010	$417,451	$3,200,461
	2% AEP	80	7	$2,409,816	$361,472	$2,771,288
	5% AEP	55	5	$1,645,231	$246,785	$1,892,015
	10% AEP	26	5	$716,941	$107,541	$824,482

	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (after mitigation measure)					$232,499
	AAD Reduction					$65,763
	NPV (after mitigation measure)					$3,441,152
	NPV Reduction					$973,338
	Estimated Cost of Mitigation Measure					$5,493,000
	B/C Ratio					0.177

Social Assessment

When considering the works necessary to implement flood mitigation option FM01, the following social impacts were identified:

- Upgrade works to the town levees would come within 10 m of Moulamein Public School on Tallow Street and are highly likely to affect its operation.
- Upgrade works to the town levees would come within 20 m of the Moulamein Royal on Morago Street and have a moderate likelihood of affecting its operation.
- Upgrade works to the town levees would come within 30 m of Moulamein Lakeside Caravan Park on Brougham Street and have a low likelihood of affecting its operation.
- Upgrade works to the Northern levee would not affect any other structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM01, it was found that these works were not located within a 30 m radius of items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM01, the following environmental impacts were identified:

- Upgrade works to the town levees would happen directly within the floodplain wetlands along both the Edward River and Billabong Creek, as well as directly within the floodplain wetlands to the north of the Northern Levee, and are highly likely to impact the environment.
- Upgrade works to the town levees would come within 10-20 m of multiple sections of floodplain forest/woodland located along the Edward River, and have a moderate likelihood of impacting the environment.

11.4.1.2 Option FM02 – Upgrade to increase the height of existing town levee (northern levee only)

Flood Behaviour Assessment

As a result of this mitigation option, the area within the northern levee was no longer flooded in the larger magnitude flood events (such as the 1% AEP event). This decrease in flooding within the northern levee did not appear to result in increased flood levels elsewhere. This was due to the relatively low volume of flooding that is prevented from inundating the northern levee area with this mitigation option. In the smaller magnitude events (such as the 10% AEP event) there was little to no change in flood levels as the northern levee was only breached in larger flood events without this mitigation option.

Economic Assessment

Table 11-3 details the economic assessment of mitigation option FM02. From this, it was found that there was a substantial decrease in properties affected by both above-ground flooding and above-floor flooding compared to no mitigation. This in turn, resulted in a substantial decrease in AAD and NPV. However, the cost to implement this option was conversely substantially high. Therefore, the B/C ratio was found to be very low.

However when mitigation option FM02 is compared to mitigation option FM01, option FM01 resulted in a greater decrease in properties affected by flooding (particularly in the larger magnitude flood events) and a greater decrease in AAD and NPV. And although FM02 cost less to implement than FM01, the lower costs did not result in a relative similar difference in NPV. For this reason, the B/C ratio for option FM01 was greater than for option FM02.

Table 11-3: FM02 Economic Assessment (Riverine flooding inside and outside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	193	42	$7,489,752	$1,123,463	$8,613,214
	0.5% AEP	124	16	$4,200,349	$630,052	$4,830,401
	1% AEP	99	13	$3,301,645	$495,247	$3,796,892
	2% AEP	91	12	$2,950,837	$442,626	$3,393,463
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (before mitigation measure)					$298,261
	NPV (before mitigation measure)					$4,414,490
After Mitigation	PMF	115	27	$4,487,289	$673,093	$5,160,383
	0.5% AEP	105	15	$3,613,325	$541,999	$4,155,323
	1% AEP	97	13	$3,251,663	$487,750	$3,739,413
	2% AEP	90	12	$2,925,194	$438,779	$3,363,973
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (after mitigation measure)					$285,219
	AAD Reduction					$13,042
	NPV (after mitigation measure)					$4,221,455
	NPV Reduction					$193,035
	Estimated Cost of Mitigation Measure					$3,819,000
	B/C Ratio					0.051

Social Assessment

When considering the works necessary to implement flood mitigation option FM02, the following social impacts were identified:

- Upgrade works to the northern levee would come within 10 m of Moulamein Public School on Tallow Street and are highly likely to affect its operation.
- Upgrade works to the northern levee would come within 20 m of the Moulamein Royal on Morago Street and have a moderate likelihood of affecting its operation.
- Upgrade works to the northern levee would come within 30 m of Moulamein Lakeside Caravan Park on Brougham Street and have a low likelihood of affecting its operation.
- Upgrade works to the northern levee would not affect any other structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM02, it was found that these works were not located within a 30 m radius of items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM02, the following environmental impacts were identified:

- Upgrade works to the northern levee would happen directly within the floodplain wetlands along the Edward River, as well as directly within the floodplain wetlands to the North of the Northern levee, and are highly likely to impact the environment.
- Upgrade works to the northern levee would come within 10-20 m of multiple sections of floodplain forest/woodland located along the Edward River, and have a moderate likelihood of impacting the environment.

11.4.1.3 Option FM03 – Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)

Flood Behaviour Assessment

In the smaller magnitude flood events (such as the 10% AEP event) there was little to no change in flood levels as a result of this mitigation option as the northern levee was only breached in larger flood events without this mitigation option. In the larger magnitude flood events (such as the 1% AEP event), this mitigation option prevented inundation within the northern levee area with no increase in flood levels elsewhere. However, in extreme flood events (such as the 0.5% AEP event), the northern levee was found to overtop along the north-west boundary of the levee between Balranald Road and Moulamein Lake (which was not included in the construction works for this mitigation option). This resulted in backwatering into the northern levee area, however without the contribution of flow across the north-east levee boundary (between Moualmein Lake and Tchelery Road) this was reduced compared to the case without this mitigation option.

Economic Assessment

Table 11-4 details the economic assessment of mitigation option FM03. From this, it was found that there was a decrease in properties affected by both above-ground flooding and above-floor flooding compared to no mitigation. This in turn, resulted in a decrease in AAD and NPV. The cost to implement this option was also relatively low. Therefore the B/C ratio was found to be relatively low.

Table 11-4: FM03 Economic Assessment (Riverine flooding inside and outside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	193	42	$7,489,752	$1,123,463	$8,613,214
	0.5% AEP	124	16	$4,200,349	$630,052	$4,830,401
	1% AEP	99	13	$3,301,645	$495,247	$3,796,892
	2% AEP	91	12	$2,950,837	$442,626	$3,393,463
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (before mitigation measure)					$298,261
	NPV (before mitigation measure)					$4,414,490
After Mitigation	PMF	193	42	$7,459,320	$1,118,898	$8,578,218
	0.5% AEP	117	15	$3,994,259	$599,139	$4,593,398
	1% AEP	99	13	$3,301,645	$495,247	$3,796,892
	2% AEP	91	12	$2,949,533	$442,430	$3,391,963
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (after mitigation measure)					$296,960
	AAD Reduction					$1,302
	NPV (after mitigation measure)					$4,395,227
	NPV Reduction					$19,263
	Estimated Cost of Mitigation Measure					$172,000
	B/C Ratio					0.112

Social Assessment

When considering the works necessary to implement flood mitigation option FM03, it was found that upgrade works for the partial upgrade of the Northern levee would not affect any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM03, it was found that these works were not located within a 30 m radius of items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM03, it was found that upgrade works for the partial upgrade of the Northern levee would not affect any areas of environmental significance.

11.4.1.4 Option FM04 – Construct new levee around the water treatment plant

Flood Behaviour Assessment

As a result of this mitigation option, the water treatment plant and water intake pump were no longer flooded across the range of flood events. Furthermore, some areas within the southern levee area (to the south of Pretty Pine Road) were found to have a decrease in flood levels as a consequence of the work to raise the water intake pump (including remediating the southern levee located under the water intake pump).

Economic Assessment

Table 11-5 details the economic assessment of mitigation option FM04. From this, it was found that there was a minor decrease in properties affected by both above-ground flooding and above-floor flooding compared to no mitigation. This in turn, resulted in a minor decrease in AAD and NPV. However, the cost to implement this mitigation option was also substantially low. Therefore, the B/C ratio was found to be quite high.

Table 11-5: FM04 Economic Assessment (Riverine flooding inside and outside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	193	42	$7,489,752	$1,123,463	$8,613,214
	0.5% AEP	124	16	$4,200,349	$630,052	$4,830,401
	1% AEP	99	13	$3,301,645	$495,247	$3,796,892
	2% AEP	91	12	$2,950,837	$442,626	$3,393,463
	5% AEP	62	8	$1,973,877	$296,082	$2,269,959
	10% AEP	29	7	$947,575	$142,136	$1,089,712
	20% AEP	14	3	$283,745	$42,562	$326,306
	AAD (before mitigation measure)					$298,261
	NPV (before mitigation measure)					$4,414,490
After Mitigation	PMF	192	41	$7,485,347	$1,122,802	$8,608,149
	0.5% AEP	123	16	$4,193,620	$629,043	$4,822,663
	1% AEP	98	13	$3,298,281	$494,742	$3,793,023
	2% AEP	90	12	$2,912,372	$436,856	$3,349,228
	5% AEP	57	6	$1,761,202	$264,180	$2,025,383
	10% AEP	26	6	$803,355	$120,503	$923,858
	20% AEP	14	3	$283,745	$42,562	$326,306

	AAD (after mitigation measure)	$275,074
	AAD Reduction	$23,187
	NPV (after mitigation measure)	$4,071,303
	NPV Reduction	$343,187
	Estimated Cost of Mitigation Measure	$314,000
	B/C Ratio	1.093

Social Assessment

When considering the works necessary to implement flood mitigation option FM04, it was found whilst the critical community infrastructure of the water treatment plant was positively affected, the works would not adversely affect any other structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM04, it was found that these works were not located within a 30 m radius of items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM04, the following environmental impacts were identified:

- Upgrade works to the town levees would happen directly within the floodplain wetlands along the Edward River, and are highly likely to impact the environment.
- Upgrade works to the town levees would come within 10-20 m of multiple sections of floodplain forest/woodland located along the Edward River, and have a moderate likelihood of impacting the environment.

11.4.1.5 Option FM05 – Install flap gates on culverts through town levees

Flood Behaviour Assessment

In the smaller magnitude flood events (such as the 10% AEP event) there was little to no change in flood levels as a result of this mitigation option as the lower riverine flood levels were less influential compared to the overland (local rainfall) flood levels in determining the flood levels within the levee areas. In the larger magnitude flood events (such as the 1% AEP event), this mitigation option did reduce the flood levels within the northern levee area without increasing the flood levels elsewhere.

Economic Assessment

Table 11-6 details the economic assessment of mitigation option FM05. From this, it was found that the number of properties affected by above-ground flooding and above-floor flooding was relatively similar compared to no mitigation. However, the properties that were affected by flooding were affected by a lower flood level, which resulted in a slight decrease in AAD and NPV. As the cost to implement this option was also relatively low the B/C ratio was found to be mid-range.

Table 11-6: FM05 Economic Assessment (Riverine flooding inside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	172	29	$6,203,222	$930,483	$7,133,705
	0.5% AEP	102	9	$3,175,010	$476,252	$3,651,262
	1% AEP	77	7	$2,374,880	$356,232	$2,731,112
	2% AEP	71	6	$2,127,423	$319,113	$2,446,537
	5% AEP	46	3	$1,384,193	$207,629	$1,591,822
	10% AEP	16	2	$491,889	$73,783	$565,672
	20% AEP	6	0	$78,235	$11,735	$89,970
	AAD (before mitigation measure)					$207,122
	NPV (before mitigation measure)					$3,065,558
After Mitigation	PMF	172	29	$6,203,222	$930,483	$7,133,705
	0.5% AEP	81	9	$2,786,458	$417,969	$3,204,427
	1% AEP	29	7	$1,126,680	$169,002	$1,295,683
	2% AEP	25	6	$991,713	$148,757	$1,140,470
	5% AEP	15	3	$569,046	$85,357	$654,403
	10% AEP	13	2	$462,331	$69,350	$531,681
	20% AEP	5	0	$78,235	$11,735	$89,970
	AAD (after mitigation measure)					$127,957
	AAD Reduction					$79,165
	NPV (after mitigation measure)					$1,893,855
	NPV Reduction					$1,171,703
	FM05A (Flap gates with gate valves) Estimated Cost of Mitigation Measure					$318,000
	FM05A (Flap gates with gate valves) B/C Ratio					3.685
	FM05A (Flap gates with pen stocks) Estimated Cost of Mitigation Measure					$387,000
	FM05A (Flap gates with pen stocks) B/C Ratio					3.028

Social Assessment

When considering the works necessary to implement flood mitigation option FM05, the following social impacts were identified:

- Works to install flap gates would come within 10 m of Moulamein Royal on Morago Street and are highly likely to affect its operation.
- Works to install flap gates would come within 20 m of Moulamein Public School on Tallow Street and have a moderate likelihood of affecting its operation.
- Works to install flap gates would not affect any other structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM05, it was found that these works were not located within a 30 m radius of items of known heritage significance.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM05, the following environmental impacts were identified;

- Works to install flap gates would happen directly within both the floodplain wetlands and floodplain forest/woodlands along the Edward River, and are highly likely to impact these environments.

11.4.2 Potential Property Modification Measures

11.4.2.1 Option PM01 – Update Development Controls

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events.

Social Assessment

Implementation of this option would not affect locations of social importance to the wider community. However, it does have the potential to affect the community on an individual level, based upon their personal circumstances.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

11.4.2.2 Option PM02 – Voluntary Property Purchase

Flood Behaviour Assessment

As a result of this mitigation option, there was no change to the flood behaviour across the range of flood events as the building area was far exceeded by the flood area/volume experienced.

Economic Assessment

Table 11-7 details the economic assessment of mitigation option PM02. From this, it was found that the number of properties affected by above-ground flooding and above-floor flooding was slightly reduced across all flood events when compared to no mitigation. This in turn, resulted in a substantial decrease in AAD and NPV. Furthermore, the cost to implement this mitigation option was fairly low. Therefore, the B/C ratio was found to be relatively high.

Table 11-7: PM02 Economic Assessment (Riverine flooding outside the town levees)

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	21	13	$1,286,530	$192,979	$1,479,509
	0.5% AEP	22	7	$1,025,338	$153,801	$1,179,139
	1% AEP	22	6	$926,765	$139,015	$1,065,779
	2% AEP	20	6	$823,414	$123,512	$946,926
	5% AEP	16	5	$589,684	$88,453	$678,137
	10% AEP	13	5	$455,687	$68,353	$524,040
	20% AEP	8	3	$205,510	$30,827	$236,337
	AAD (before mitigation measure)					$91,139
	NPV (before mitigation measure)					$1,348,932
After Mitigation	PMF	19	11	$1,101,936	$165,290	$1,267,227
	0.5% AEP	20	5	$850,838	$127,626	$978,464
	1% AEP	20	4	$755,629	$113,344	$868,973
	2% AEP	18	4	$655,643	$98,346	$753,989
	5% AEP	14	4	$462,437	$69,366	$531,803
	10% AEP	11	4	$336,474	$50,471	$386,945
	20% AEP	6	3	$100,305	$15,046	$115,351
	AAD (after mitigation measure)					$74,184
	AAD Reduction					$16,955
	NPV (after mitigation measure)					$1,097,983
	NPV Reduction					$250,948
	Estimated Cost of Mitigation Measure					$296,000
	B/C Ratio					0.848

Social Assessment

Implementation of this option would not affect locations of social importance to the wider community. However, it does have the potential to affect the community on an individual level, based upon their personal circumstances.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

11.4.3 Potential Response Modification Measures

11.4.3.1 Option RM01 – Update Emergency Response Plans

Flood Behaviour Assessment

As a result of the construction works associated with this mitigation option, there was no change to the flood behaviour across the range of flood events as the raised evacuation area was far exceeded by the flood area/volume experienced.

Social Assessment

Implementation of this option would not affect locations of social importance to the wider community.

Heritage Assessment

Implementation of this option would not affect items of known heritage significance.

Environmental Assessment

Implementation of this option would not affect items of known environmental significance.

11.4.4 Summary of Modification Measures Results

Table 11-8 presents the preliminary results of the multi-criteria assessment for all of the above discussed mitigation options. Following consultation with the FRMC and the community, the relative community support factor for each option will be tabulated, and the overall weighted score and ranking calculated.

Table 11-8: Multi-Criteria Matrix Assessment

Option ID	Impact on flood behaviour	Benefit Cost Ratio	Average Annual Damages	Cost of initiating measure	Social disruption	Community support	Contaminated land impacts	Biodiversity impacts	Weighted score	Ranking
FM01	3	-3	3	-2	-3	0	0	-2	0	6
FM02	2	-3	2	-1	-3	0	0	-2	-3	7
FM03	2	-3	1	3	0	0	0	0	8	3
FM04	2	1	3	3	0	0	0	-2	18	2
FM05	3	3	3	3	-3	0	0	-3	21	1
PM01	0	N/A	N/A/	3	0	0	0	0	6	=5
PM02	0	-1	2	3	-1	0	0	0	7	4
RM01	0	N/A	N/A/	3	0	0	0	0	6	=5

12 Floodplain Maintenance Works

12.1 Overview

In addition to the flood mitigation measures investigated in Section 11, a couple of floodplain maintenance works were identified. However, as these works would be temporary in nature, these works are not suitable for NSW State Government funding and would therefore be the responsibility of Council to manage and fund.

12.2 Works Identified

12.2.1 Maintenance unblocking culverts

This work involves a regular maintenance schedule to unblock culverts that were reported to be subject to high levels of blockage. This work was suggested during the first round of community consultation for the Moulamein Flood Study in 2018. This was based upon both flood behaviour observations during the October 2016 riverine flood event as well as more regular observations of blockage of some of these culverts.

In the smaller magnitude flood events (such as the 10% AEP event), these works would result in an increase in flood levels between Pretty Pine Road and Billabong Creek as well as to the north of Maude Road. By comparison, smaller areas of decreased flood levels would be found south of Swan Hill Road and in localised spots between Pretty Pine Road and Maude Road. The increase in flood levels to the north of Maude Road and diversion of flood water to the north of Moulamein resulted in an increase in flood level within the northern town levee in larger flood events.

12.2.2 Sand-bagging of Town Levees

This work would be based upon the Moulamein Levee Owner's Manual (discussed in Section 4.5.6). It involves the use of sandbags to reinforce and temporarily increase the levee crest of the northern town levee in the lead up to a flood event occurring.

The aim of this work would be to reduce the risk of flooding due to the levee overtopping. However, as it does not address the structural integrity concerns of the town levees, it is likely that flood evacuation will still be recommended, though perhaps with a higher flood level threshold.

13 Floodplain Risk Management Plan

13.1 Recommended Measures

Based upon the multi-criteria assessment of the flood mitigation options, the following options are recommended for implementation:

- FM05 - Install flap gates on culverts through the town levees
- FM04 – Construct new levee around the water treatment plant
- FM03 – Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)
- PM01 – Update development controls
- RM01 – Update emergency response plans

Furthermore, the following options are recommended for further investigation:

- PM02 – Voluntary property purchase. Discussion would need to be had with the relevant landholders to evaluate the level of interest in a voluntary property purchase scheme.
- A detailed geotechnical report to assess the structural integrity of the town levees. Pending the recommendations of the geotechnical report, further investigation of the town levee upgrades can be undertaken.

13.2 Implementation

Implementing the aforementioned recommended measures requires information on the following details:

- The agency or organisation primarily responsible for project managing the implementation of the measure;
- The financial requirements to implement the measure; and
- The priority for implementation of the measure.

Table 13-1 lists the implementation plan with consideration given to the aforementioned details. The measures identified would require a total capital expenditure of approximately $1.315 million. However, the measures given high priority would require a total capital expenditure of $944,000.

The plan is expected to be executed over a five to ten year timeframe. The scheduling of the works proposed will be dependent upon the financial commitments of the agencies or organisations responsible.

13.3 Maintenance

A floodplain risk management plan is an ongoing procedure, and is not over at the completion of the report.

A management plan should be based on the best knowledge currently available. Therefore, due to key factors of the study area changing over time, such as social, economic, and catchment conditions that may affect flooding behaviours, the management plan should be reassessed periodically. It is advised that plan reassessment take place every five years or following a significant flood event.

Table 13-1: Moulamein Floodplain Risk Management Implementation Plan

Measure ID	Measure Description	Responsibility	Cost	Timeframe (Budget Dependent)	Priority
PM01	Update development controls	Council	$10,000	1 years	High
FM05	Install flap gates on culverts through town levees	Council / DPIE	$387,000	1 years	High
RM01	Update emergency response plans	Council / SES	$80,000	2 years	High
FM03	Upgrade to increase the height of existing town levee (northern levee between Moulamein Lake and Tchelery Road only)	Council / DPIE	$153,000	2 years	High
FM04	Construct new levee around the water treatment plant	Council / DPIE	$314,000	3 years	High
PM02	Further investigation of voluntary property purchase	Council / DPIE	$296,000	5 years	Medium
	Further investigation of the structural integrity of the town levees via a detailed geotechnical report	Council / DPIE	$75,000	5 years	Medium

14 References

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Ref 2: Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Ref 3: BMT WBM (2016), *TUFLOW User Manual*

Ref 4: Boyd, M., Rigby, E., VanDrie, R. (2017), *Watershed Bounded Network Model (WBNM) User Guide*

Ref 5: Chow, V.T. (1959), *Open Channel Hydraulics*, McGraw-Hill, New York

Ref 6: GHD (2017), *Barham Floodplain Risk Management Study and Plan*, Murray River Council

Ref 7: GHD (2017), *Murray Downs Floodplain Risk Management Study and Plan*, Murray River Council

Ref 8: GHD (2017), *Tooleybuc Floodplain Risk Management Study and Plan*, Murray River Council

Ref 9: Henderson, F.M. (1966), *Open Channel Flow*, MacMillan, New York

Ref 10: HydroSpatial (2019), *Moulamein Flood Study*, Murray River Council

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Ref 14: NSW Government (2005), *Floodplain Development Manual: The management of flood liable land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, Sydney

Ref 15: NSW Government (2007), *Residential Flood Damages*, Department of Environment and Climate Change, Sydney

Ref 16: NSW Government (2007), *Flood Emergency Response Planning Classification of Communities*, Department of Environment and Climate Change, Sydney

Ref 17: NSW Government (2013), *Aspects of Quaternary geology, geomorphic history, stratigraphy, soils and hydrogeology in the Edward-Wakool channel system, with particular reference to the distribution of sulfidic channel sediment*, Office of Environment and Heritage (now the Department of Planning, Industry and Environment), prepared for Southern Cross GeoScience, Southern Cross University and Murray-Darling Basin Authority

Ref 18: NSW Government (2013), *Visual Audit of Moulamein Levee*, Public Works

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Ref 20: NSW Government (2018), *Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in Studies*, Office of Environment and Heritage (now the Department of Planning, Industry and Environment)

Ref 21: Patterson Britton & Partners Pty Ltd (2006), *Moulamein Levee Upgrade Flood Study*, Wakool Shire Council

Ref 22: NSW SES (2018), *Murray River Council Flood Emergency Sub Plan*, Murray River Council Local Emergency Management Committee

Ref 23: SMEC Australia Pty Ltd (2004), *Edward/Wakool Rivers Rural Floodplain Management Plan*, Department of Infrastructure, Planning and Natural Resources

Ref 24: WMAwater Pty Ltd (2014), *Edward River at Deniliquin Flood Study*, Deniliquin City Council

APPENDIX A
GLOSSARY

The following glossary has been extracted from the Australian Emergency Management Institute Handbook 7 (AEMI, 2017).

Annual Exceedance Probability (AEP)	The likelihood of the occurrence 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 flow of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is, a one-in-20 chance) of a flow of 500 m3/s or larger occurring in any one year (see also average recurrence interval, flood risk, likelihood of occurrence, probability).
Australian Height Datum (AHD)	A common national survey height datum as a reference level for defining reduced levels; 0.0 m AHD corresponds approximately to 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. If the damage associated with various annual events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence-probability curve. AAD provides a basis for comparing the economic effectiveness of different management measures (i.e. their ability to reduce the AAD).
Average Recurrence Interval (ARI)	A statistical estimate of the average number of years between the occurrence of a flood of a given size or larger than the selected event. For example, floods with a flow as great as or greater than the 20-year ARI (5% AEP) flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see also annual exceedance probability).
Catchment	The area of land draining to a particular site. It is related to a specific location, and includes the catchment of the main waterway as well as any tributary streams.
Catchment flooding	Flooding due to prolonged or intense rainfall (e.g. severe thunderstorms, monsoonal rains in the tropics, tropical cyclones). Types of catchment flooding include riverine, local overland and groundwater flooding.
Chance	The likelihood of something happening that will have beneficial consequences (e.g. the chance of a win in a lottery). Chance is often thought of as the 'upside of a gamble' (Rowe 1990) (see also risk).
Consent authority	The authority or agency with the legislative power to determine the outcome of development and building applications.
Consequence	The outcome of an event or situation affecting objectives, expressed qualitatively or quantitatively. Consequences can be adverse (e.g. death or injury to people, damage to property and disruption of the community) or beneficial.

Defined Flood Event (DFE)	The flood event selected for the management of flood hazard to new development. This is generally determined in floodplain management studies and incorporated in floodplain management plans. Selection of DFEs should be based on an understanding of flood behaviour, and the associated likelihood and consequences of flooding. It should also take into account the social, economic, environmental and cultural consequences associated with floods of different severities. Different DFEs may be chosen for the basis for reducing flood risk to different types of development. DFEs do not define the extent of the floodplain, which is defined by the PMF (see also design flood, floodplain and probable maximum flood).
Design flood	The flood event selected for the treatment of existing risk through the implementation of structural mitigation works such as levees. It is the flood event for which the impacts on the community are designed to be limited by the mitigation work. For example, a levee may be designed to exclude a 2% AEP flood, which means that floods rarer than this may breech the structure and impact upon the protected area. In this case, the 2% AEP flood would not equate to the crest level of the levee, because this generally has a freeboard allowance, but it may be the level of the spillway to allow for controlled levee overtopping (see also annual exceedance probability, defined flood event, floodplain, freeboard and probable maximum flood).
Development	Development may be defined in jurisdictional legislation or regulation. This may include erecting a building or carrying out of work, including the placement of fill; the use of land, or a building or work; or the subdivision of land. Infill development refers to the development of vacant blocks of land within an existing subdivision 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 is intensification of use with development of a completely different nature to that associated with the former land use or zoning (e.g. the urban subdivision of an area previously used for rural purposes). New developments generally involve rezoning, and associated consents and approvals. It may require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. Redevelopment refers to rebuilding in an existing developed 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.

Effective warning time	The effective warning time available to a floodprone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. The effective warning time is typically used for people to self-evacuate, to move farm equipment, move stock, raise furniture, and transport their possessions.
Existing flood risk	The risk a community is exposed to as a result of its location on the floodplain.
Flood	Flooding is a natural phenomenon that occurs when water covers land that is normally dry. It may result from coastal or catchment flooding, or a combination of both (see also catchment flooding and coastal flooding).
Flood awareness	An appreciation of the likely effects of flooding, and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, the response to flood warnings is prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.
Flood damage	The tangible (direct and indirect) and intangible costs (financial, opportunity costs, clean-up) of flooding. Tangible costs are quantified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people that are attributed to a flooding episode.
Flood education	Education that raises awareness of the flood problem, to help individuals understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood emergency response plan	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. The objective is to ensure a coordinated response by all agencies having responsibilities and functions in emergencies.
Flood emergency management	Emergency management is 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.
Flood fringe areas	The part of the floodplain where development could be permitted, provided the development is compatible with flood hazard and appropriate building measures to provide an adequate level of flood protection to the development. This is the remaining area affected by flooding after flow

	conveyance paths and flood storage areas have been defined for a particular event (see also flow conveyance areas and flood storage areas).
Flood hazard	Potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management.
Floodplain	An area of land that is subject to inundation by floods up to and including the probable maximum flood event – that is, flood-prone land.
Floodplain management entity (FME)	The authority or agency with the primary responsibility for directly managing flood risk at a local level.
Floodplain management plan	A management plan developed in accordance with the principles and guidelines in this handbook, usually includes both written and diagrammatic information describing how particular areas of flood-prone land are to be used and managed to achieve defined objectives. It outlines the recommended ways to manage the flood risk associated with the use of the floodplain for various purposes. It represents the considered opinion of the local community and the floodplain management entity on how best to manage the floodplain, including consideration of flood risk in strategic land-use planning to facilitate development of the community. It fosters flood warning, response, evacuation, clean-up and recovery in the onset and aftermath of a flood, and suggests an organisational structure for the integrated management for existing, future and residual flood risks. Plans need to be reviewed regularly to assess progress and to consider the consequences of any changed circumstances that have arisen since the last review.
Flood Planning Area (FPA)	The area of land below the flood planning level, and is thus subject to flood-related development controls.
Flood Planning Level (FPL)	The FPL is a combination of the defined flood levels (derived from significant historical flood events or floods of specific annual exceedance probabilities) and freeboards selected for floodplain management purposes, as determined in management studies and incorporated in management plans.
Flood-prone land	Land susceptible to flooding by the probably maximum flood event. Flood-prone land is synonymous with the floodplain. Floodplain management plans should encompass all flood-prone land rather than being restricted to areas affected by defined flood events.
Flood proofing of buildings	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures that are subject to flooding, to reduce structural

	damage and potentially, in some cases, reduce contents damage.
Flood readiness	An ability to react within the effective warning time (see also flood awareness and flood education).
Flood risk	The potential risk of flooding to people, their social setting, and their built and natural environment. The degree of risk varies with circumstances across the full range of floods. Flood risk is divided into three types – existing, future and residual.
Flood severity	A qualitative indication of the 'size' of a flood and its hazard potential. Severity varies inversely with likelihood of occurrence (i.e. the greater the likelihood of occurrence, the more frequently an event will occur, but the less severe it will be). Reference is often made to major, moderate and minor flooding (see also minor, moderate and major flooding).
Flood storage areas	The parts of the floodplain that are important for temporary storage of floodwaters during a flood passage. 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 (see also flow conveyance areas and flood fringe areas).
Flood study	A comprehensive technical investigation of flood behaviour. It defines the nature of flood hazard across the floodplain by providing information on the extent, level and velocity of floodwaters, and on the distribution of flood flows. The flood study forms the basis for subsequent management studies and needs to take into account a full range of flood events up to and including the probable maximum flood.
Flow	The rate of flow of water measured in volume per unit time – for example, cubic metres per second (m3/s). Flow 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).
Flow conveyance areas	Those areas of the floodplain where a significant flow of water occurs during floods. They are often aligned with naturally defined channels. Flow conveyance paths are areas that, even if only partially blocked, would cause a significant redistribution of flood flow or a significant increase in flood levels. They are often, but not necessarily, areas of deeper flow or areas where higher velocities occur, and can also include areas where significant storage of floodwater occurs. Each flood has a flow conveyance area, and the extent and flood behaviour within flow conveyance areas may change with flood severity. This is because areas that are benign for small floods may experience much greater and more

	hazardous flows during larger floods (see also flood fringe areas and flood storage areas).
Freeboard	The height above the DFE or design flood used, in consideration of local and design factors, to provide reasonable certainty that the risk exposure selected in deciding on a particular DFE or design flood is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels and so on. Freeboard compensates for a range of factors, including wave action, localised hydraulic behaviour and levee settlement, all of which increase water levels or reduce the level of protection provided by levees. Freeboard should not be relied upon to provide protection for flood events larger than the relevant defined flood event of a design flood. Freeboard is included in the flood planning level and therefore used in the derivation of the flood planning area (see also defined flood event, design flood, flood planning area and flood planning level).
Frequency	The measure of likelihood expressed as the number of occurrences of a specified event in a given time. For example, the frequency of occurrence of a 20% annual exceedance probability or five-year average recurrence interval flood event is once every five years on average (see also annual exceedance probability, annual recurrence interval, likelihood and probability).
Future flood risk	The risk that new development within a community is exposed to as a result of developing on the floodplain.
Gauge height	The height of a flood level at a particular gauge site related to a specified datum. The datum may or may not be the AHD (see also Australian height datum).
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this handbook, the hazard is flooding, which has the potential to cause damage to the community.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level, extent and velocity.
Hydrograph	A graph that shows how the flow or stage (flood level) at any particular location varies with time during a flood.
Hydrologic analysis	The study of the rainfall and runoff process, including the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Intolerable risk	A risk that, following understanding of the likelihood and consequences of flooding, is so high that it requires consideration of implementation of treatments or actions to improve understanding, avoid, transfer or reduce the risk.
Life-cycle costing	All of the costs associated with the project from the cradle to the grave. This usually includes investigation, design,

	construction, monitoring, maintenance, asset and performance management and, in some cases, decommissioning of a management measure.
Likelihood	A qualitative description of probability and frequency (see also frequency and probability).
Likelihood of occurrence	The likelihood that a specified event will occur. (With respect to flooding, see also annual exceedance probability and average recurrence interval).
Local overland flooding	Inundation by local runoff on its way to a waterway, rather than overbank flow from a stream, river, estuary, lake or dam. Can be considered synonymous with stormwater flooding.
Loss	Any negative consequence or adverse effect, financial or otherwise.
Mathematical and 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 wellbeing of rivers and floodplains. This approach operates at two levels. At the strategic level, it allows for the consideration of flood hazard and associated social, economic, ecological and cultural issues in formulating statutory planning instruments, and development control plans and policies. At a site specific level, it involves consideration of the best way of developing land in consideration of the zonings in a statutory planning instruments, and development control plans and policies.
Minor, moderate and major flooding	These terms are often used in flood warnings to give a general indication of the types of problems expected with a flood.
Probability	A statistical measure of the expected chance of flooding. It is the likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage. For example, the probability of 'throwing a six' on a single roll of a die is one in six, or 0.167 or 16.7% (see also annual exceedance probability).
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from PMP 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 (WMO 1986). It is the primary input to probable maximum flood estimation.
Rainfall intensity	The rate at which rain falls, typically measured in millimetres per hour (mm/h). Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see also temporal pattern).
Residual flood risk	The risk a community is exposed to that is not being remedied through established risk treatment processes. In simple terms, for a community, it is the total risk to that community, less any measure in place to reduce that risk. The risk a community is exposed to after treatment measures have been implemented. For a town protected by a levee, the residual flood risk is the consequences of the levee being overtopped by floods larger than the design flood. For an area where flood risk is managed by land-use planning controls, the residual flood risk is the risk associated with the consequences of floods larger than the DFE on the community.
Risk	'The effect of uncertainty on objectives' (ISO31000:2009). NOTE 4 of the definition in ISO31000:2009 also states that 'risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence'. Risk is based upon the consideration of the consequences of the full range of flood behaviour on communities and their social settings, and the natural and built environment (see also likelihood and consequence).
Risk analysis	The systematic use of available information to determine how often specified (flood) events occur and the magnitude of their likely consequences. Flood risk analysis is normally undertaken as part of a floodplain management study, and involves an assessment of flood levels and hazard associated with a range of flood events (see also flood study).
Risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk.

	Flood risk management is undertaken as part of a floodplain management plan. The floodplain management plan reflects the adopted means of managing flood risk (see also floodplain management plan).
Riverine flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. Riverine flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Runoff	The amount of rainfall that drains into the surface drainage network to become stream flow; also known as rainfall excess.
Stage	Equivalent to water level. Both stage and water level are measured with reference to a specified datum (e.g. the Australian height datum).
Stormwater flooding	Is inundation by local runoff caused by heavier than usual rainfall. It can be caused by local runoff exceeding the capacity of an urban stormwater drainage systems, flow overland on the way to waterways or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (see also local overland flooding).
Temporal pattern	The variation of rainfall intensity with time during a rainfall event.
Treatment options	The measures that might be feasible for the treatment of existing, future and residual flood risk at particular locations within the floodplain. Preparation of a treatment plan requires a detailed evaluation of floodplain management options (see also floodplain management plan).
Velocity of floodwater	The speed of floodwaters, measured in metres per second (m/s).
Vulnerability	The degree of susceptibility and resilience of a community, its social setting, and the natural and built environments to flood hazards. Vulnerability is assessed in terms of ability of the community and environment to anticipate, cope and recover from flood events. Flood awareness is an important indicator of vulnerability (see also flood awareness).

APPENDIX B
EXISTING CATCHMENT CHARACTERISTICS

Please refer to the Moulamein Floodplain Risk Management Report Volume 2.

APPENDIX C
POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES

Please refer to the Moulamein Floodplain Risk Management Report Volume 2.

APPENDIX D
ESTIMATE OF BENEFITS

Please refer to the Moulamein Floodplain Risk Management Report Volume 2.

APPENDIX E
ESTIMATE OF COSTS

Please refer to the Moulamein Floodplain Risk Management Report Volume 2.

APPENDIX F
DRAFT LOCAL FLOOD POLICY FOR MOULAMEIN

F.1 Land to which these Development Controls Apply

The development controls in this Local Flood Policy apply to the Flood Planning Area at Moulamein as defined by Figure F 1.

F.2 Objectives

The floodplain development controls are intended to:

- Guide the development of flood prone land, applying balanced strategies to economically, socially and environmentally manage the potential flood risk to life and property.
- Ensure that sufficient land is set aside to convey and/or store floodwaters and to protect and enhance the riparian zone.
- Ensure that development, when considered both individually and in the context of cumulative development trends, will not cause unreasonable adverse flooding impacts in other locations.

F.3 Definitions

Floodway	Those parts of the floodplain where a significant discharge of water occurs during floods. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage	Those parts of the floodplain important for the temporary storage of floodwaters during the passage of a flood.
Flood Fringe	The remaining area of land affected by flooding, after floodway and flood storage areas have been defined.
Low Flood Hazard	Those parts of the floodplain where able bodied adults would generally have little difficulty wading and trucks could evacuate people and their possessions should it be necessary.
High Flood Hazard	Those parts of the floodplain where there would be a possible danger to personal safety, able bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be potential for significant structure damage to buildings.
Flood Planning Area (FPA)	Represents the area below the FPL and thus subject to flood related development controls.
Flood Planning Levels (FPLs)	This is the combination of flood levels and freeboards selected for floodplain risk management purposes.
Flood Prone Land	Land susceptible to flooding by the Probable Maximum Flood event. Flood prone land is synonymous with flood liable land.
Freeboard	Refers to a designated height above the design flood which is stipulated to incorporate a suitable factor of safety into development.

F.4 Site Classifications

- Flood Planning Area means land as defined by the attached Figure F 1, coinciding with the area below the 100 year ARI flood level plus a freeboard of 0.5 metres.
- Flood Planning Levels coincide with the 100 year ARI flood level plus 0.5 metre as determined by this FRMS&P. The 100 year ARI flood levels coincide with levee breach conditions (i.e. as per Figure B 10 of this FRMS&P).
- Low Hazard and High Hazard Areas means land as defined by the attached Figure F 2.
- Floodway, Flood Storage and Flood Fringe Areas means land as defined by the attached Figure F 3.

F.5 General – Development within the Flood Planning Area

General Development Standards applicable to the Flood Planning Area are as follows:

a. All development within the Flood Planning Area requires the consent of Council.
b. All development shall be generally assessed in accordance with the latest edition of the NSW Floodplain Development Manual as issued by the NSW Government.
c. Development will not be permitted unless Council is satisfied that the proposed development will not increase the flood hazard rating or likely flood damage to any other property.

F.6 Development within Floodway Areas

Development Standards applicable to Floodway Areas are as follows.

High Hazard Floodway Areas

Development within High Hazard Floodway areas is generally discouraged. Council may consider granting permission to minor developments including extensions provided the requirements for Low Hazard Floodway areas can be met.

Low Hazard Floodway Areas

a. No alteration in ground levels by more than 100 mm will be permitted, whether by excavation or filling, without the submission of a local hydraulic study and prior development consent.
b. The erection of any new habitable structure on land within Floodway Areas will only be permitted if the land is outside the High Hazard area and supported by a local hydraulic impact study demonstrating that the works will have no adverse flooding effect on any other property.
c. Extensions to existing residential buildings:
    i. Where the area of the extension is less than 50% of the existing floor area, the floor level of the extension may be constructed to the same level as the existing floor level.
    ii. Where the extension is greater than 50% of the existing floor area, the minimum floor level of the extension is to be at the FPL.
d. Fencing. Fences of a continuous (impermeable) design, such as metal cladding, shall not be permissible. Post and rail fences will be permitted providing they are designed to permit the unimpeded flow of floodwater.

F.7 Development within Flood Storage Areas and Flood Fringe Areas

Development Standards applicable to Flood Storage Areas and Flood Fringe Areas are as follows.

High Hazard Flood Storage and Flood Fringe Areas

The same requirements as those listed under Low Hazard Floodway Areas apply.

Low Hazard Flood Storage and Flood Fringe Areas

a. Development consent is required to be obtained prior to any work or building activity being carried out within the Flood Planning Area. A hydraulic study may be required to be submitted with any Development Application at the discretion of Council.
b. The minimum floor level of any new residential building is to be at the FPL (i.e. 0.5 metres above the 100 year ARI flood level).
c. Commercial and industrial development. At Council's discretion, the minimum floor level is to be at the FPL or the building is to be flood proofed to at least the FPL.
d. Extensions to existing residential buildings.
    i. Where the area of the extension is less than 50% of the existing floor area, the floor level of the extension may be constructed to the same level as the existing floor level.
    ii. Where the extension is greater than 50% of the existing floor area, the minimum floor level of the extension is to be at the FPL.
e. Extensions to existing non-residential buildings. Extensions to existing non-residential buildings may be constructed at the same level as the existing building. At Council's discretion, the complete building is to be flood proofed to the FPL.
f. Carports and open sheds. Carports and open sheds may be constructed at existing ground levels. They must be constructed from flood compatible materials.
g. Fencing. Fencing of a continuous design (e.g. metal cladding) shall be permissible.

F.8 Development Application Requirements

A development application lodged for development within the Flood Planning Area is to be accompanied by:

a. Existing ground levels of the subject site certified by a registered surveyor.
b. Floodway and High Hazard Areas only:
    i. A report from an accredited Consulting Engineer detailing any adverse effects of the proposed development on potential flood damages to the subject property and any other property as a result of the development.
    ii. An evacuation plan for the development accompanied by evidence that the local division of the SES has been consulted in the formulation of the plan.

APPENDIX G
SES FLOOD DATA OUTPUTS

G.1 Emergency Response Classification of Communities

G.1.1 Definitions

The *Flood Emergency Response Planning Classification of Communities* (NSW Government, 2007) definitions have been used for Moulamein to maintain consistency with previous studies undertaken for Council (such as the Murray Downs Floodplain Risk Management Study and Plan (GHD, 2017)); as described below:

- **Areas with rising road access** – those areas where access roads rise steadily uphill and away from the rising floodwaters.
- **Areas with overland escape route** – those areas where access roads to flood free land cross lower lying flood prone land or where escape to flood free land is possible by walking overland to flood free land.
- **High flood island** – the flood island includes enough land above the PMF level to cope with the people in the area.
- **Low flood island** – the flood island is either lower than the limit of flooding or cannot cope with the number of people in the area.
- **Low trapped perimeter** – similar to a low flood island, except that the accessible area will eventually be completely covered with floodwater, with higher ground unable to be reached due to topography or impassable structures.
- **High trapped perimeter** – those areas above the PMF level, but access out via road or foot is cut during a flood.
- **Indirectly affected areas** – those areas above the PMF level but are indirectly affected as a result of flooding (e.g. loss of power, isolation doe to damages road).

G.1.2 Response Required for ERP Classified Areas

Classification	Response Required		
	Resupply	Rescue / Medivac	Evacuation
Areas with rising road access	No	Possibly	Yes
Areas with overland escape routes	No	Possibly	Yes
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

G.2 Consequences Relative to Gauge Height at Moulamein

Moulamein gauge height (m)	ARI (years)	Description	Consequences – number of buildings affected	
			Residential	Other
5.48	5	Some inundation inside the Southern Town Levee and the Western Town Levee is possible due to breaching of the levee. Balranald Road, Moulamein Road and Morton Road become inaccessible due to flooding.	0	3
5.91	20	Some inundation inside the Northern Town Levee is possible due backwatering of the culverts through the levee. Pretty Pine Road, Nacurrie Road North and Balpool Road become inaccessible due to flooding. Consider evacuating: • Mooloomoon tourist accommodation on Hay Street.	4	4
6.08	100	Some inundation inside the Northern Town Levee is possible due to either backwatering of culverts, breaching or overtopping of the levee.	8	5

6.12	200	Town Levees (northern, southern and western) overtopping is inevitable. Swan Hill Road, Tchelery Road and Maude Road become inaccessible due to flooding. Consider evacuating: • Moulamein Preschool on Turora Street; • Moulamein Public School on Tallow Street; • Moulamein Lakeside Caravan Park on Brougham Street; and • Moulamein Retirement Village on Turora Street.	11	5

Note: The Moulamein gauge is located 140 meters upstream of Moulamein Road Bridge. Gauge zero datum is 64.324 m AHD.

APPENDIX H
COMMUNITY CONSULTATION

H.1 First Round of Community Consultation

The distribution material from the first round of the FRMS community consultation process is shown in the following.

Moulamein Floodplain Risk Management Study and Plan

COMMUNITY CONSULTATION

Moulamein Floodplain Risk Management Committee will deliver a PowerPoint Presentation on the Draft Floodplain Risk Management Study and Floodplain Risk Management Plan and community input will be sought so that community views are captured in the drafting of these important documents.

Tuesday 4 February, 2020

5pm-7pm at the Moulamein Bowling Club.

Enquiries to Council's Manager Design Capital Works and Projects
admin@murrayriver.nsw.gov.au or 1300 087 004

Murray River Council, with the support of the NSW Department of Planning Industry and Environment is undertaking the Moulamein Flood Study and Floodplain Risk Management Study and Plan (FS&FRMS&P). At the Ordinary Council Meeting held on 26 November 2019, Council adopted Moulamein Flood Study. The Flood Study provides modelling tools which are now being used to identify and assess flood risks for the township of Moulamein in the Floodplain Risk Management Study.

The Floodplain Risk Management Study will provide information and tools for strategic assessment of the impact of management options for existing and future flood risks for Moulamein. The output of the project is the Floodplain Risk Management Plan which will comprise of the mix of options to manage the full range of flood risks for the town. The Floodplain Risk Management Plan will have sufficient flood information that is capable of being used by a variety of stakeholders including authorities and community for land use planning, flood management planning, emergency response and flooding education.

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H.2 Second Round of Community Consultation

The distribution material from the second round of the FRMS community consultation process is shown in the following. Furthermore, the results of the questionnaire from this round of community consultation is also shown in the following.

Moulamein Floodplain Risk Management Study

Management Options

Overview

Murray River Council, with funding support from NSW Government Floodplain Management Grant Program and assistance from Department of Planning, Industry and Environment is delivering the Floodplain Risk Management Study and Plan for Moulamein.

Modelling tools have been used to identify and assess flood risks for the town. Management options outlined in the following pages have been proposed for consideration in mitigating existing and future flood risks for the town.

Council is requesting the community to review the proposed management options and complete the short community survey so that it can gauge the level of support for each proposed option.

You are also invited to attend a community consultation session on Wednesday 17 March, 5pm at Moulamein Bowling Club to discuss the community's preferred floodplain mitigation options.

Further information

Please access the survey and more information at:
yoursay.murrayriver.nsw.gov.au

Or by contacting Council's Manager Design, Capital Works and Projects on 1300 087 004 or by e-mail:
omukodi@murrayriver.nsw.gov.au.

Council's consultant Erika Taylor of Hydrospatial on 0423 624 696 or by e-mail: erika.taylor@hydrospatial.com.au

HYDRO SPATIAL

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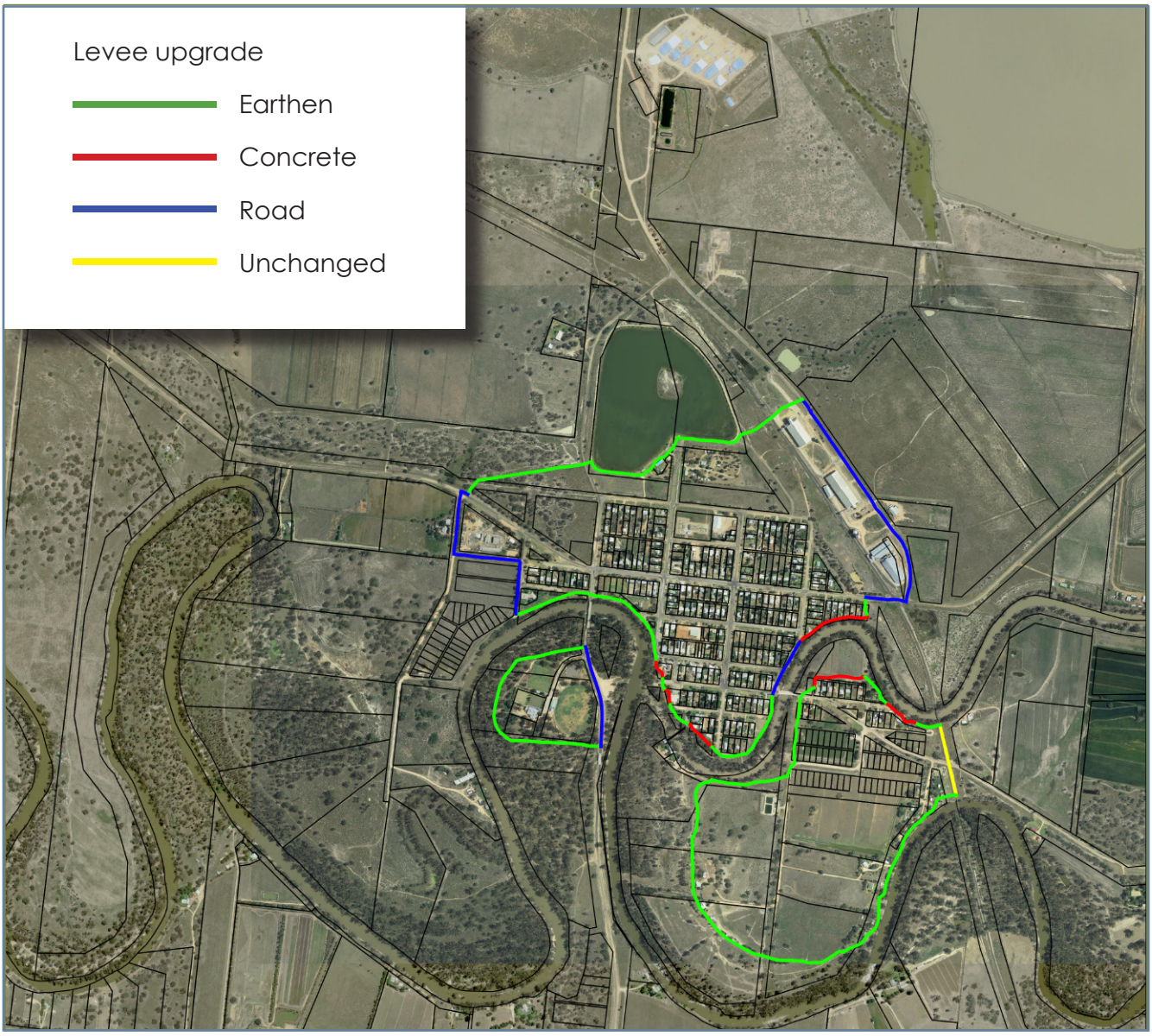
Moulamein Floodplain Risk Management Options

FM01



FM01 overview: Full remediation for Northern, Southern and Western Levees, with levee upgrade works where the existing levees are not at the 1% AEP riverine flood level plus a 0.5m freeboard.

Approximate cost to implement: $5,493,000

Approximate reduction in average annual damages: $66,000

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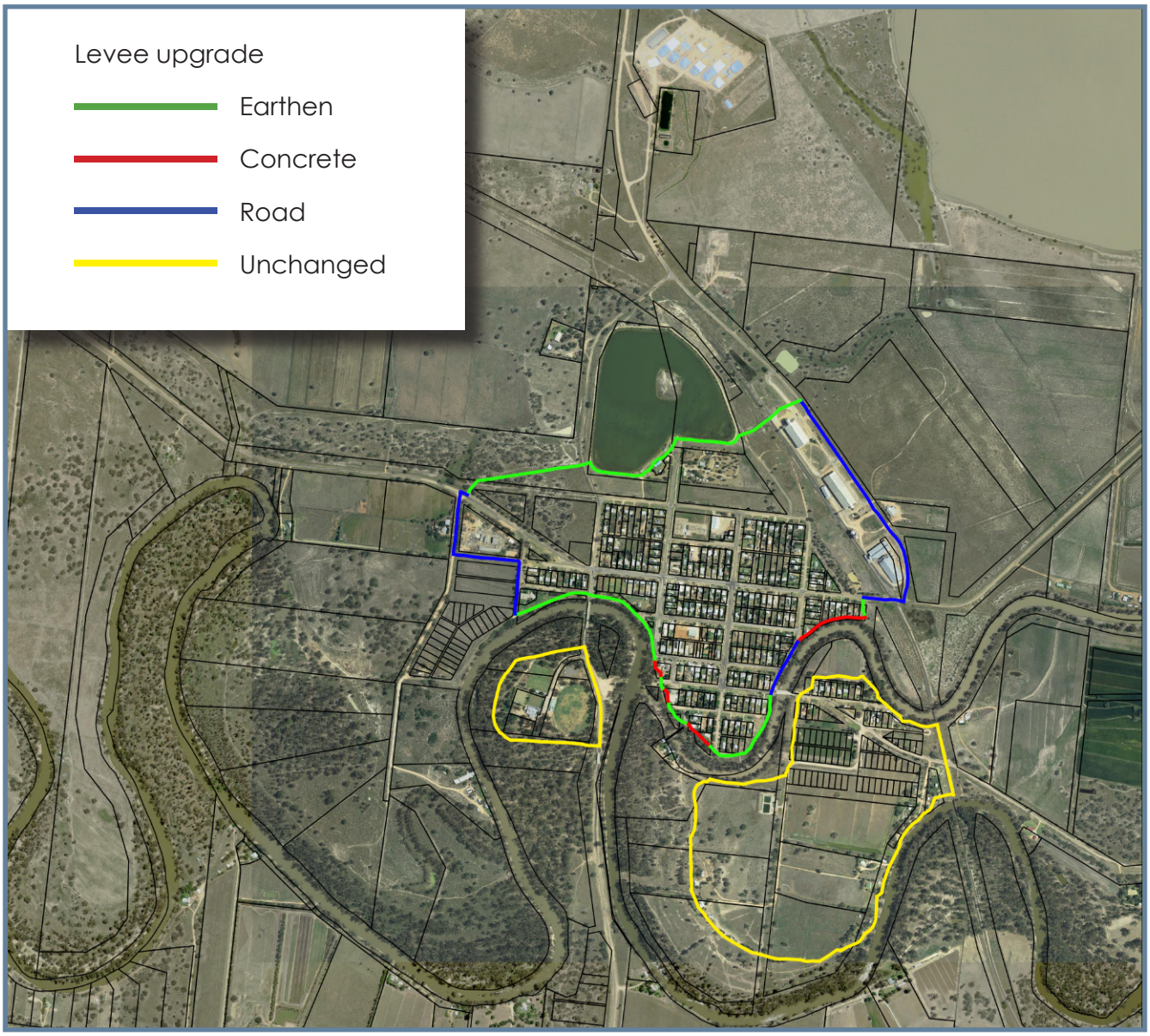
Moulamein Floodplain Risk Management Options

FM02



FM02 overview: Full remediation for Northern levee, with levee upgrade works where the existing levee is not at the 1% AEP riverine flood level plus a 0.5m freeboard.

Approximate cost to implement: $3,819,000

Approximate reduction in average annual damages: $14,000

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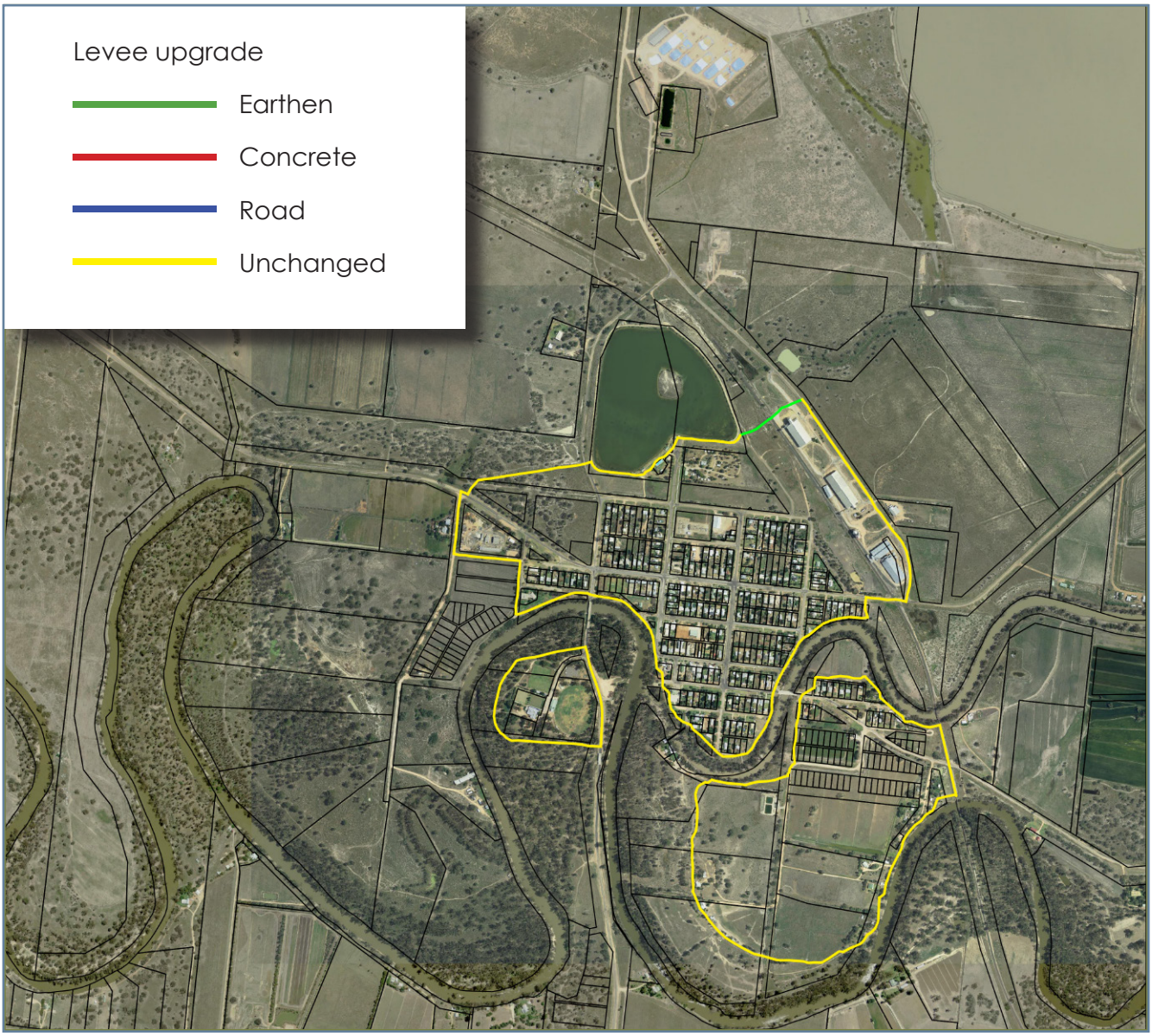
Moulamein Floodplain Risk Management Options

FM03



FM03 overview: Remediation and upgrade of the Northern Levee between Moulamein Lake and Tchelery Road to the 1% AEP riverine flood level plus a 0.5m freeboard.

Approximate cost to implement: $172,000

Approximate reduction in average annual damages: $2,000

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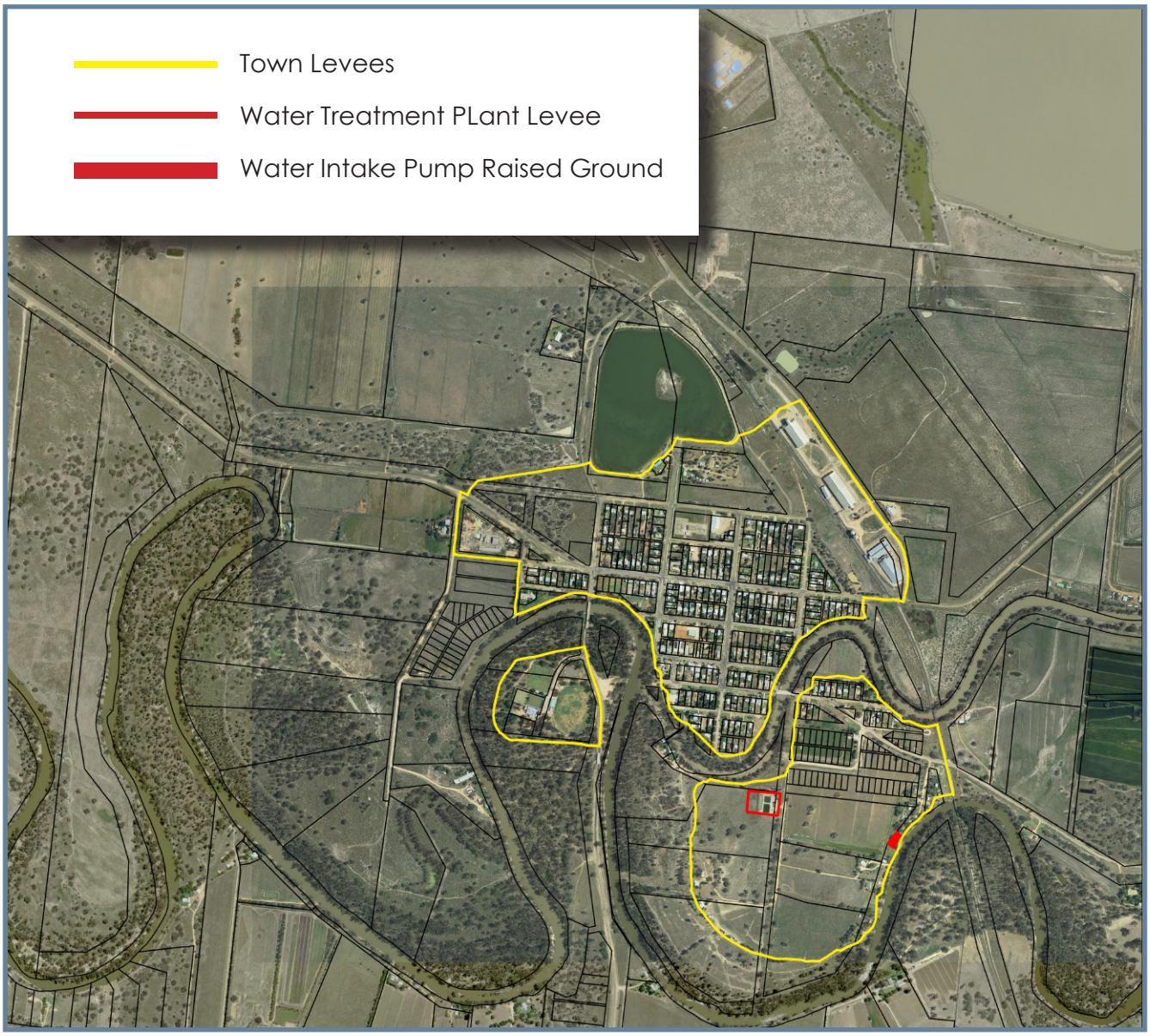
Moulamein Floodplain Risk Management Options

FM04



FM04 overview: Construction of an additional levee around the water treatment plant, and the raising of the ground level at the water intake pump located on the southern levee crest.

Approximate cost to implement: $314,000

Approximate reduction in average annual damages: $24,000

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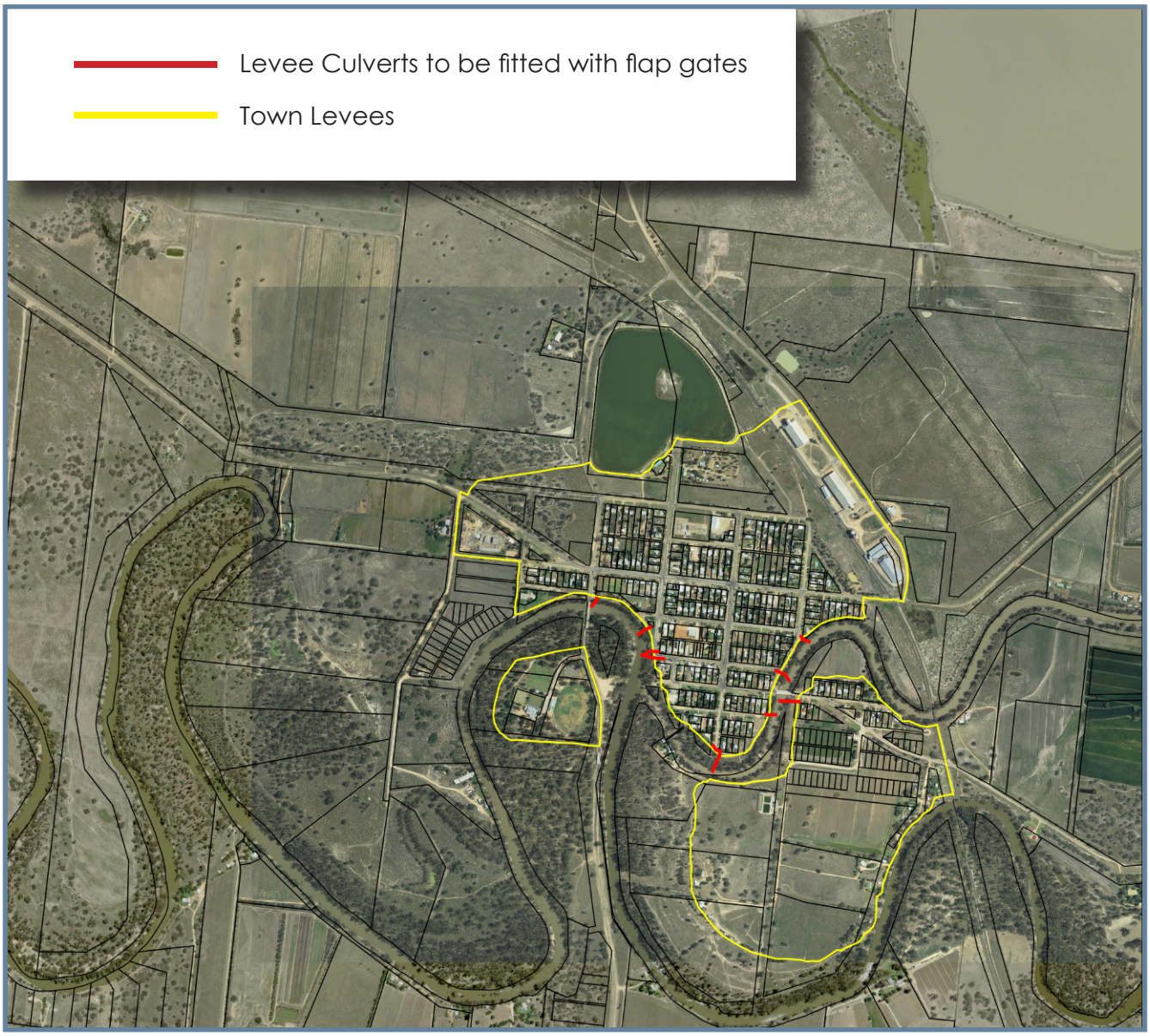
Moulamein Floodplain Risk Management Options

FM05



FM05 overview: Installation of flap gates and gate valves on culverts along the town levees to prevent riverine flooding inundation of the town, while still allowing overland drainage.

Approximate cost to implement: $318,000

Approximate reduction in average annual damages: $80,000

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Moulamein Floodplain Risk Management Options

PM01

PM01 overview: Update Council's Development Control Plan to include Flood Planning Areas and Flood Planning Levels for new developments.

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Moulamein Floodplain Risk Management Options

PM02

PM02 overview: Voluntary purchase and rezoning of residential lots affected by highly hazardous flood conditions in the 1% AEP riverine flood event.

Approximate cost to implement: $296,000

Approximate reduction in average annual damages: $17,000

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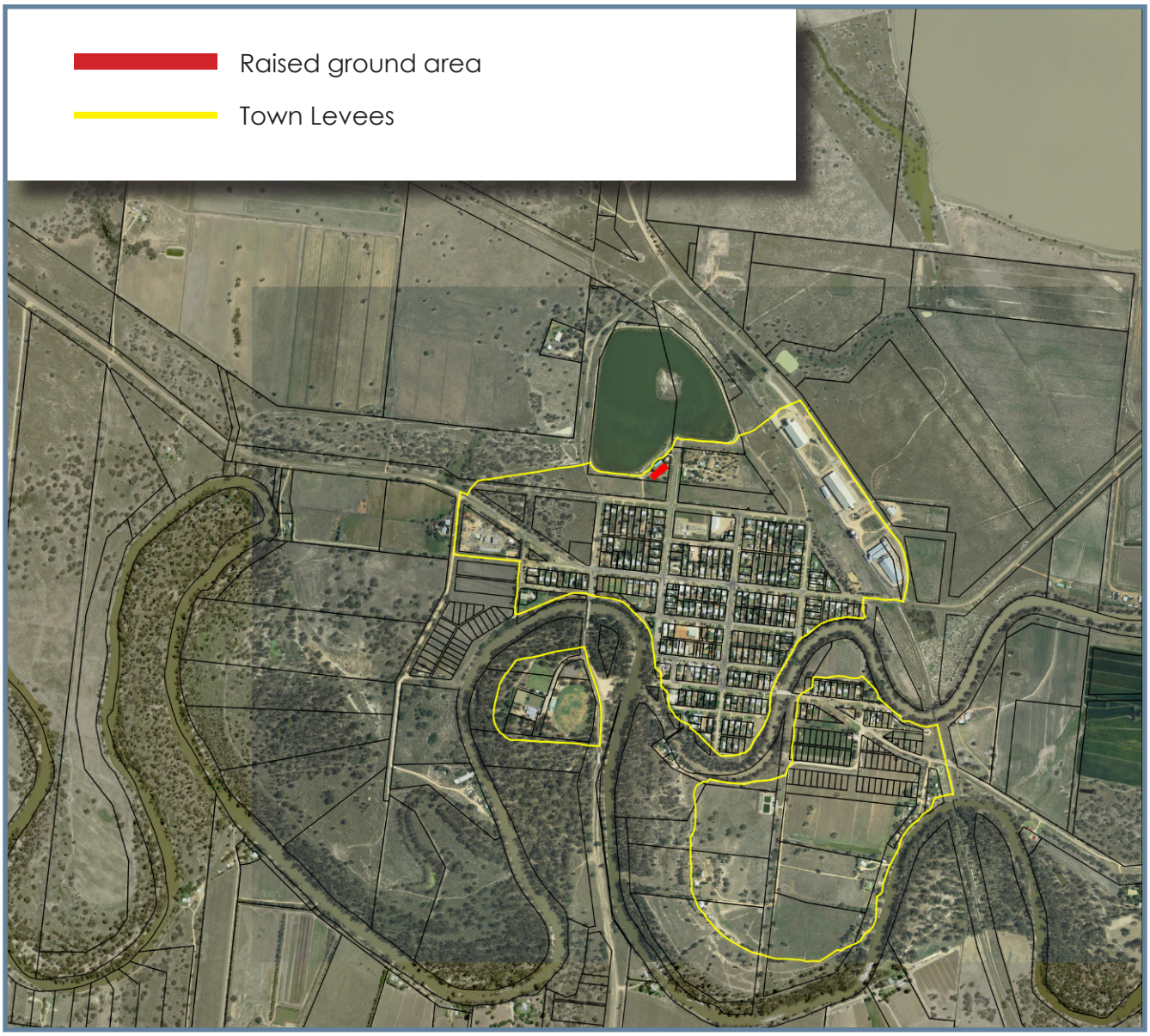
Moulamein Floodplain Risk Management Options

RM01



RM01 overview: Updating the emergency response plans and raising of a section of land at the Moulamein Swimming Centre above the PMF riverine flood level (to establish the area as a replacement emergency evacuation centre instead of Moulamein Bowling Club).

Approximate cost to implement: $87,000

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Survey Responses

29 March 2020 - 14 March 2021

Moulamein Floodplain Risk Management Study- management options survey

Your Say Murray River

Project: Moulamein Floodplain Risk Management Study

BANG THE TABLE engagementHQ

VISITORS					
8					
CONTRIBUTORS			RESPONSES		
3			3		
0 Registered	0 Unverified	3 Anonymous	0 Registered	0 Unverified	3 Anonymous

Respondent No: 1
Login: Anonymous
Email: n/a

Responded At: Feb 08, 2021 14:45:22 pm
Last Seen: Feb 08, 2021 14:45:22 pm
IP Address: n/a

Q1. **How would you describe your impression of option FM01: Increase height of Northern, Southern and Western Levees?** Negative

Q2. **Please include any comments regarding option FM01. (if none write 'nil')**

Not worth worrying when the town hasn't flooded before the current level banks were built.

Q3. **How would you describe your impression of option FM02: Increase height of Northern Levee?** Neutral

Q4. **Please include any comments regarding option FM02. (if none write 'nil')**

Nil

Q5. **How would you describe your impression of option FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only)?** Negative

Q6. **Please include any comments regarding option FM03. (if none write 'nil')**

Nil

Q7. **How would you describe your impression of option FM04: Construct Water Treatment Plant Levee?** Neutral

Q8. **Please include any comments regarding option FM04. (if none write 'nil')**

Nil

Q9. **How would you describe your impression of option FM05: Install flap gates on culverts through town levees?** Positive

Q10. **Please include any comments regarding option FM05. (if none write 'nil')**

About bloody time was proposed in,early 1990's, and money obtained to do it .

Q11. **How would you describe your impression of option PM01: Update Development Controls?** Neutral

Q12. **Please include any comments regarding option PM01. (if none write 'nil')**

Nil

Q13.	**How would you describe your impression of option PM02: Voluntary property purchase?**	Neutral

Q14. **Please include any comments regarding option PM02. (if none write 'nil')**

Nil

Q15.	**How would you describe your impression of option RM01: Update Emergency Response Plans (including construction of a raised evacuation area)?**	Neutral

Q16. **Please include any comments regarding option RM01. (if none write 'nil')**

Not needed. Town doesn't flood. Check all previous records ,back to town inception.

Q17.	**Which flood mitigation measures would you like to see implemented? (please rank your preferences for the following; with 1 being the most preferred)**	1. FM05: Install flap gates on culverts through town levees 2. FM01: Increase height of Northern, Southern and Western Levees 3. FM04: Construct Water Treatment Plant Levee 4. FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only) 5. RM01: Update Emergency Response Plans (including construction of a raised evacuation area) 6. FM02: Increase height of Northern Levee 7. PM01: Update Development Controls 8. PM02: Voluntary property purchase

Respondent No: 2
Login: Anonymous
Email: n/a

Responded At: Feb 08, 2021 15:49:49 pm
Last Seen: Feb 08, 2021 15:49:49 pm
IP Address: n/a

Q1. **How would you describe your impression of option FM01: Increase height of Northern, Southern and Western Levees?** Positive

Q2. **Please include any comments regarding option FM01. (if none write 'nil')**

I believe placing intermittent concrete levee's will not work due to erosion.

Q3. **How would you describe your impression of option FM02: Increase height of Northern Levee?** Neutral

Q4. **Please include any comments regarding option FM02. (if none write 'nil')**

Nil

Q5. **How would you describe your impression of option FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only)?** Negative

Q6. **Please include any comments regarding option FM03. (if none write 'nil')**

Won't make any difference. The town will not flood to the north due to farmers changing the path of where the water goes.

Q7. **How would you describe your impression of option FM04: Construct Water Treatment Plant Levee?** Positive

Q8. **Please include any comments regarding option FM04. (if none write 'nil')**

I believe this should be implemented along side of upgrading existing levees.

Q9. **How would you describe your impression of option FM05: Install flap gates on culverts through town levees?** Neutral

Q10. **Please include any comments regarding option FM05. (if none write 'nil')**

If we are already looking at flooding where is this water going to go from the culverts?

Q11. **How would you describe your impression of option PM01: Update Development Controls?** Neutral

Q12. **Please include any comments regarding option PM01. (if none write 'nil')**

Nil

Q13.	**How would you describe your impression of option PM02: Voluntary property purchase?**	Neutral

Q14. **Please include any comments regarding option PM02. (if none write 'nil')**

The map is difficult to understand.

Q15.	**How would you describe your impression of option RM01: Update Emergency Response Plans (including construction of a raised evacuation area)?**	Positive

Q16. **Please include any comments regarding option RM01. (if none write 'nil')**

This should be included in align with levee upgrade.

Q17.	**Which flood mitigation measures would you like to see implemented? (please rank your preferences for the following; with 1 being the most preferred)**	1. FM01: Increase height of Northern, Southern and Western Levees 2. FM04: Construct Water Treatment Plant Levee 3. RM01: Update Emergency Response Plans (including construction of a raised evacuation area) 4. FM05: Install flap gates on culverts through town levees 5. PM02: Voluntary property purchase 6. PM01: Update Development Controls 7. FM02: Increase height of Northern Levee 8. FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only)

Respondent No: 3
Login: Anonymous
Email: n/a

Responded At: Feb 10, 2021 20:50:57 pm
Last Seen: Feb 10, 2021 20:50:57 pm
IP Address: n/a

Q1. **How would you describe your impression of option FM01: Increase height of Northern, Southern and Western Levees?** Neutral

Q2. **Please include any comments regarding option FM01. (if none write 'nil')**

What's with the concrete

Q3. **How would you describe your impression of option FM02: Increase height of Northern Levee?** Positive

Q4. **Please include any comments regarding option FM02. (if none write 'nil')**

Nil

Q5. **How would you describe your impression of option FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only)?** Positive

Q6. **Please include any comments regarding option FM03. (if none write 'nil')**

Nil

Q7. **How would you describe your impression of option FM04: Construct Water Treatment Plant Levee?** Positive

Q8. **Please include any comments regarding option FM04. (if none write 'nil')**

Nil

Q9. **How would you describe your impression of option FM05: Install flap gates on culverts through town levees?** Positive

Q10. **Please include any comments regarding option FM05. (if none write 'nil')**

Nil

Q11. **How would you describe your impression of option PM01: Update Development Controls?** Neutral

Q12. **Please include any comments regarding option PM01. (if none write 'nil')**

Nil

Q13.	**How would you describe your impression of option PM02: Voluntary property purchase?**	Negative

Q14. **Please include any comments regarding option PM02. (if none write 'nil')**

Nil

Q15.	**How would you describe your impression of option RM01: Update Emergency Response Plans (including construction of a raised evacuation area)?**	Negative

Q16. **Please include any comments regarding option RM01. (if none write 'nil')**

Nil

Q17.	**Which flood mitigation measures would you like to see implemented? (please rank your preferences for the following; with 1 being the most preferred)**	1. FM02: Increase height of Northern Levee 2. FM03: Increase height of Northern Levee (between Moulamein Lake and Tchelery Road only) 3. FM04: Construct Water Treatment Plant Levee 4. FM05: Install flap gates on culverts through town levees 5. PM02: Voluntary property purchase 6. FM01: Increase height of Northern, Southern and Western Levees 7. PM01: Update Development Controls 8. RM01: Update Emergency Response Plans (including construction of a raised evacuation area)