Bimbi Village Flood Risk Management Study and Plan

Final Report

Volume 1

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Prepared for
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Table of Abbreviations

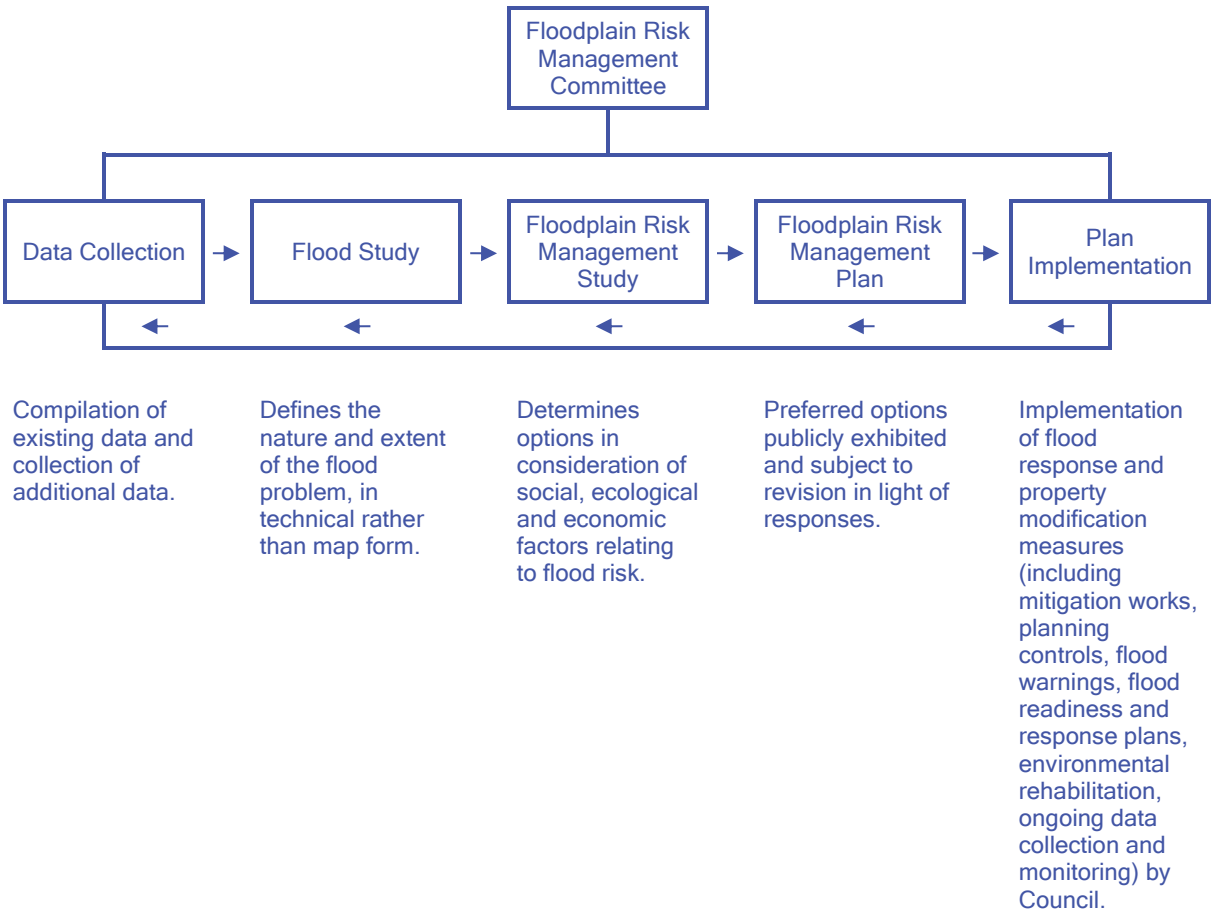
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AAD	Average Annual Damage
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DEM	Digital Elevation Model
DPE	Department of Planning and Environment
EY	Exceedances per Year
FMC	Floodplain Management Committee
FPA	Flood Planning Area
FPL	Flood Planning Level
LGA	Local Government Area
LiDAR	Light Detection and Ranging
NSW	New South Wales
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
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 and Environment (DPE) (formerly the Office of Environment and Heritage (OEH)), 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 (with an earlier draft version in 2016).

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

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 0-1, which has been extracted from Section 2.2.5., Chapter 2, Book 1 of ARR 2019.

Table 0-1: 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 and Environment (DPE), 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, Weddin Shire Council and DPE commissioned the Bimbi Village Flood Study and the Bimbi Village Floodplain Risk Management Study and Plan. HydroSpatial Pty Ltd were engaged to undertake both studies.

Bimbi is located in the Central West NSW with a population of 114 people, according to the 2016 Australian Bureau of Statistics Census. It predominately consists of rural residential properties, with the exception of the Rural Fire Service (RFS) building on the corner of Caldwell Street and Young Street. The closest service town to Bimbi is Grenfell, located approximately 30 km north-east via Mary Gilmore Way.

Burrangong Creek runs through Bimbi in an east-to-west direction. It is located to the south of (and runs approximately parallel to) Mary Gilmore Way. This creek system extends as far upstream as the town of Young, approximately 50 km to the south-east of Bimbi.

Existing Flood Damages

Direct flood damages within the study area were estimated to have an Average Annual Damage (AAD) value of $338,906 and a Net Present Value (NPV) of $5,016,063.

Identifying Options

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

- Potential flood modification measures:
  - FM01 – Removal of Burrangong Creek TSR fence
  - FM02 – Clearing of Burrangong Creek
  - FM03 – Detention basin on Burrangong Creek
  - FM04 – Road bridge along Mary Gilmore Way
  - FM05 – Road levee along Mary Gilmore Way
  - FM06 – Road levee east of Bimbi
  - FM07 – Road levee along Mary Gilmore Way and road levee east of Bimbi
  - FM08 – Individual residential earthen levees
  - FM09 – Single span bridge at Mary Gilmore Way
  - FM10 – Mound levelling at Mary Gilmore Way
- Potential property modification measures:
  - PM01 – Update development controls
  - PM02 – Voluntary property purchase
  - PM03 – Voluntary house raising
  - PM04 – Voluntary house raising and road levee along Mary Gilmore Way and road levee east of Bimbi
- Potential response modification measures
  - RM01 - Update emergency response plans
  - RM02 – Early warning system

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. This is summarised in Table 0-1.

Table 0-1: Summary of recommended measures

Measure ID	Measure Description	Cost	Timeframe (Budget Dependent)	Priority
PM01	Update development controls	$10,000	1 year	High
RM01	Update emergency response plans	$10,000	1 year	High
RM02	Early warning system	$75,000	5 years	Medium

1 Introduction

1.1 Overview

Weddin Shire Council, with the support of the NSW DPIE, has commissioned HydroSpatial Pty Ltd to prepare the following Bimbi Village Floodplain Risk Management Study and Plan.

1.2 Study Objectives

The objectives of the FRMS&P were to utilise the hydrologic and hydraulic models, developed as part of the Bimbi Village Flood Study (HydroSpatial, 2021) 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

Bimbi is located in the Weddin Shire Council Local Government Area (LGA) in Central West NSW. According to the 2016 Australian Bureau of Statistics Census, the suburb of Bimbi has a population of 114 people. It predominately consists of rural residential properties, with the exception of the Rural Fire Service (RFS) building on the corner of Caldwell Street and Young Street. The closest service town to Bimbi is Grenfell, located approximately 30 km north-east via Mary Gilmore Way.

Burrangong Creek runs through Bimbi in an east-to-west direction. It is located to the south of (and runs approximately parallel to) Mary Gilmore Way. This creek system extends as far upstream as the town of Young, approximately 50 km to the south-east of Bimbi.

2 Study Methodology

The following tasks were undertaken as part of the Bimbi 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 0.

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. 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 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. Additionally, the Local Environmental Plans and Development Control Plans for Weddin Shire Council 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 Bimbi Village Flood Study (HydroSpatial, 2021) process, two community consultation sessions were held at different stages of the study.

3.2.1.1 First Round

A community consultation process was undertaken during the data collection stage of the study through the August 2020 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 conducting a mail-out, which included a newsletter and questionnaire. The newsletter contained information about the flood study process and where it fits into the wider floodplain risk management process. The questionnaire was provided in paper form as well as online and asked questions about the community's experience of flooding in the past.

There were 5 responses to the community consultation questionnaire. Of the respondents that listed how long they had been living in the area, most had been at their current addresses for an average of 10 years. All respondents expressed that they had been affected by the September-October 2016 flood event, and 2 respondents mentioned themselves or family members being affected by other historical flood events. Over 40 photographs have been submitted displaying the effects of historical flooding in Bimbi.

3.2.1.2 Second Round

A community information session was held at the Bimbi RFS Shed on the 16 March 2021 between 4pm and 7pm. The information session was attended by representatives from HydroSpatial, the SES, Council, and two Councillors. Approximately a dozen community members attended the information session.

At the information session, a discussion was held regarding the results of computational modelling of historical events, as well as possible mitigation measures to be investigated at the next stage of the process.

The key notes from the community meeting were:

- Community members generally felt that the results of computational modelling of historical events presented were largely accurate to their recollection of the events.
- Several community members felt strongly that the Burrangong Creek Travelling Stock Reserve (TSR) fence erected by Local Land Services (LLS) in 2014 has significantly impacted flood behaviours in the town, and requested that its impact be investigated.
- One resident noted that shortly after the flood events in 2016, a private aerial photography company captured images of the receding flood waters in the area. The resident has provided the images he purchased from the aerial photography company to HydroSpatial.
- One resident brought up concerns that any mitigation measures that would aim to divert flood waters away from the town may negatively impact the efficacy of the aquifer recharge areas near town.
- One resident mentioned that they requested assistance to evacuate a mobility impaired family member during the 2016 flood event and that this was not provided.

3.2.2 Floodplain Risk Management Study and Plan

A community consultation process was undertaken during the public exhibition phase through the July/August 2022 period. The purpose of this community consultation work was to gather feedback from the community on their preferences for various mitigation measures and any feedback on refinement of the mitigation measures. This community consultation consisted of a community meeting hosted by Council, alongside a community submission portal for written responses.

The community meeting was held at Grenfell Hub on the 3 August 2022 between 2pm and 4pm. The community meeting was attended by representatives from HydroSpatial, Council and Councillors. Approximately half a dozen community members attended this community meeting.

At this consultation, HydroSpatial discussed the general concept and preliminary results of several mitigation measures, including:

- Option PM01 – Updated development controls
- Option PM03 – Voluntary house raising
- Option PM04 – Voluntary house raising and road levee along Mary Gilmore Way and road levee east of Bimbi

The key notes from the community meeting were:

- The community seemed to generally favour mitigation measures that avoided diverting flood waters onto surrounding agricultural lands.
- While the community were receptive to voluntary house raising due to the reason above, several members worried that the older houses in town would be either very expensive or impossible to raise.
- Residents wondered if individual levees would be a viable option for flood affected houses that aren't raiseable.
- Community members were largely in agreement that Burrangong Creek required a more frequent maintenance schedule, particularly near the Mary Gilmore Way bridge.
- The community seemed generally receptive to updating development controls to regulate floor levels of new builds.
- One resident suggested either extending the Hunter's Lane causeway, or constructing a series of levees and channels around Bimbi town to divert flood water directly into the Burrangong Creek.

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. 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)

	Bimbi	NSW
Population		
Total Population	114	7,480,228
< 4 years	5.3%	6.2%
5 - 14 years	16.7%	12.3%
15 - 64 years	58.7%	65.1%
> 65 years	19.3%	16.2%
Assistance		
Core activity need for assistance	15.8%	5.4%
Volunteering		
Provided unpaid assistance to a person with a disability (last two weeks)	22.0%	11.6%
Did volunteer work through an organisation or group (last 12 months)	28.6%	18.1%
Language		
English only spoken at home	100%	68.5%
Language top responses (other than English)	N/A	N/A
Internet Access		
Internet not accessed from dwelling	20.0%	14.7%
Internet accessed from dwelling	80.0%	82.5%
Not stated	0.0%	2.8%
Registered Motor Vehicles		
None	0.0%	9.2%
1 or more motor vehicles in occupied private dwellings	90.0%	87.4%
Not stated	10.0%	3.7%
Housing Density		
Average number of people per household	3.0	2.6
Median Weekly Income		
Personal	$665	$664

Family	$1,625	$1,780
Household	$1,562	$1,486
Property Tenure		
Owned outright	42.9%	32.2%
Owned with a mortgage	32.1%	32.3%
Rented	25.0%	31.8%
Not stated	0.0%	2.8%

According to the 2016 Census, Bimbi has a population of 114 people with a median age of 43. Of this population, the proportion of the people aged under 4 was relatively similar to the NSW average, with the proportion of people aged over 65 being notably higher. Additionally, the proportion of people aged between 5 and 14 years of age was also moderately 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 15.8% of the population. These vulnerable community members are likely to require additional assistance during a flood event.

The proportion of the population that were involved in volunteer work and had provided unpaid assistance to a person with a disability was greater within the Bimbi community compared to 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 Bimbi is extremely low, with the entire population of the area speaking English exclusively at home. This proportion was far greater than the NSW average. As such, it is highly unlikely that translation services will be required to disseminate flood preparation material and flood warnings in the lead up to a flood event.

Within Bimbi, the proportion of the population with internet access within their homes was less than the NSW average. Therefore, it is advisable that any flood preparation initiatives and flood warnings provide information across a range of different media forms to communicate with a wider breadth of the community.

The number of homes with a registered motor vehicle in Bimbi was higher than the NSW average and accounted for a large proportion of the population. Therefore, the community have a greater ability to self-evacuate and are less likely to require assistance during a flood event.

The median family/household income in Bimbi is relatively similar to the NSW average. However, the number of properties that are owned outright was higher than the NSW average. Therefore, the community are somewhat likely to be relatively financially resilient and able to recover after a flood event.

The proportion of properties within Bimbi 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 60.7% of the population). As such, the population of Bimbi could be considered relatively stable. This increases the likelihood that community flood preparation and/or flood awareness initiatives will be retained.

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 centres, SES centres 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 4-2 and the location of these sensitive land use sites is shown on Figure B 2.

Table 4-2: Sensitive Land Uses

Type	Name	Address	Population*
Critical Community Facilities			
Fire Service	Bimbi RFS Shed	Cnr Caldwell Street and Young Street, Bimbi	

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. To identify the cultural and heritage characteristics of the study area the following searches have been undertaken.

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 July 2021. From this, 6 potential Aboriginal heritage sites were found in the study area. Three of these were potential archaeological deposits that were determined to not be Aboriginal sites. Of the three remaining sites, the heritage feature type of these sites included:

- 1 was the site of an artefact; and
- 2 were modified trees (either carved or scarred).

The location of these 3 sites ranged from:

- 2 were on Freehold land that was privately-owned; and
- 1 was within the Weddin Mountains National Park.

Of the three sites that were identified, all of these sites were located east of the Bimbi township, mostly located around Burrangong Creek. The traditional indigenous community within the Bimbi area are the Wiradjuri People.

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 Weddin Shire Local Environmental Plan (LEP) 2011.

- 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 non-Indigenous Australian cultural heritage sites within the study area were found to be:

- Bimbi Police Station and Lock-Up;
- Rammed earth cottage on Grenfell Street;
- Bimbi Post Office; and
- Weddin Mountains National Park.

4.4 Environmental Characteristics

The preservation of the environmental characteristics of an area needs 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 Bimbi catchment. No known sites were discovered in the catchment.

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.

4.4.3 Flora and Fauna

A search was conducted using the NSW Bionet Wildlife Atlas in July 2021 for sighted flora and fauna in a 35 km by 28 km area including the catchment. This search returned a total of 192 species of fauna, most of which were vulnerable, protected, or endangered, and 478 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
    - Grey Box (Eucalyptus microcarpa) Grassy Woodlands and Derived Native Grassylands of South-Eastern Australia
    - Poplar Box Grassy Woodlands on Alluvial Plains
    - Weeping Myall Woodlands
    - White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grasslands
- 24 threatened species

- 11 migratory species

Table 4-3: Flora and Fauna

Name	Status
Birds	
Anthochaera Phrygia Regent Honeyeater [82338]	Critically Endangered
Botaurus Poiciloptilus Australasian Bittern [1001]	Endangered
Calidris Ferruginea Curlew Sandpiper [856]	Critically Endangered
Flaco Hypoleucos Grey Falcon [929]	Vulnerable
Grantiella Picta Painted Honeyeater [470]	Vulnerable
Hirundapus Caudacutus White-throated Needletail [682]	Vulnerable
Lathamus Discolor Swift Parrot [744]	Critically Endangered
Leipoa Ocellata Malleefowl [934]	Vulnerable
Numenius Madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered
Polytelis Swainsonii Superb Parrot [738]	Vulnerable
Rostratula Australis Australian Painted Snipe [77037]	Endangered
Fish	
Maccullochella Macquariensis Trout Cod [26171]	Endangered
Macquaria Australasica Macquarie Perch [66632]	Endangered
Mammals	
Chalinolobus Dwyeri Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable
Dasyurus Maculatus Maculatus (SE mainland population)	Endangered

Name	Status
Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	
Nyctophilus Corbeni Corben's Long-eared Bat, South-eastern Long-eared Bat [83395]	Vulnerable
Phascolarctos Cinereus Koala [85104]	Vulnerable
Pteropus Poliocephalus Grey-headed Flying-fox [186]	Vulnerable
Plants	
Austrostipa Metatoris [66704]	Vulnerable
Austrostipa Wakoolica [66623]	Endangered
Lepidium Monoplocoides Winged Pepper-cress [9190]	Endangered
Swainsona Murrayana Slender Darling-Pea, Slender Swainson, Murray Swainson-Pea [6765]	Vulnerable
Tylophora Linearis [55231]	Endangered
Reptiles	
Aprasia Parapulchella Pink-tailed Worm-lizard, Pink-tailed Legless Lizard [1665]	Vulnerable

5 Computational Modelling

The previous Bimbi Village Flood Study (HydroSpatial, 2021) included computational hydrologic and hydraulic modelling of the study area under existing conditions. This model was reviewed and discussed below.

5.1 Review Hydrologic Modelling

The hydrologic model developed in the flood study used the WBNM 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 hydrologic 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.

5.2 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.

6 Assessment of Existing Flood Behaviour

6.1 Introduction

The study area is subject to creek flooding and overland flooding. Both flood mechanisms have been investigated as part of the previous Bimbi Village Flood Study (HydroSpatial, 2021) and as part of this current study.

6.2 Assessment of Bridge and Culvert Capacity

The magnitude of event that results in the bridges and culverts reaching capacity is shown on Figure B 5.

From this, it was found that the majority of culverts through road embankments reach capacity in events greater than and equal to the 20% AEP event, with culverts along major roads such as Mary Gilmore Way being the most likely to reach capacity in the 20% AEP event.

6.3 Assessment of Time to Peak

The time between the rainfall commencing and the flood level reaching its peak is shown on Figure B 6. It should be noted that this time to peak was dependent upon the storm duration and that the critical storm duration was the one that produced the highest average flood flow. Therefore, there could be storm events that have a shorter time to peak but a lower flood level/flow than the critical storm.

For the 0.2% AEP event (with a 540 minute storm duration), the time to peak across the urban properties was generally between 75-90 minutes. Along Wah Way Creek, through the rural properties, the time to peak was generally in a similar range of 60-90 minutes.

For the 1% AEP event (with a 540 minute storm duration), the time to peak across the urban properties was generally between 75-90 minutes. Along Wah Way Creek, through the rural properties, the time to peak was generally in a similar range of 75-105 minutes.

For the 5% AEP event (with a 540 minute storm duration), the time to peak across the urban properties was generally between 90-105 minutes, with the time to peak for a number of urban properties at the southern end of town being between 30-45 minutes. Along Wah Way Creek, through the rural properties, the time to peak was generally in the same range of 90-105 minutes downstream of Bimbi, and slightly shorter in the range of 75-80 minutes upstream of Bimbi.

For the 20% AEP event (with a 540 minute storm duration), the time to peak across the urban properties was generally between 90-105 minutes, with the time to peak for a number of urban properties at the southern end of town being between 30-45 minutes. Along Wah Way Creek, through the rural properties, the time to peak was generally in the slightly longer range of 105-120 minutes.

6.4 Assessment of Duration of Inundation

The duration of time between the beginning and end of inundation with flood depths greater than 0.3 m is shown in Figure B 7. It should be noted that this duration of inundation was dependent upon the storm duration and that the critical storm duration was the one that produced the highest average flood level (for the overland, urban area of the catchment). Therefore, there could be storm events that have a longer duration of inundation but a lower flood level than the critical storm.

For the 1% event (with a 540 minute storm duration), the duration of inundation across the rural properties was generally less than 2 hours. Along Burrangong Creek, the Wah Way Creek and Red Creek, the duration of inundation was longer and in the range of 16-24 hours.

For the 5% event (with a 540 minute storm duration), the duration of inundation across the rural properties was generally less than 2 hours. Along Burrangong Creek, the Wah Way Creek and Red Creek, the duration of inundation was longer and in the range of 14-24 hours.

For the 20% event (with a 540 minute storm duration), the duration of inundation across the rural properties was generally less than 2 hours. Along Burrangong Creek, the Wah Way Creek and Red Creek, the duration of inundation was longer and in the range of 12-24 hours.

6.5 Assessment of Road Access

Road accessibility was assessed using the ARR 2019 vehicle stability criteria, detailed in Table 6-1. From this, the time to inaccessibility and duration of road inaccessibility was assessed for a range of flood events for a number of access roads into Bimbi, detailed in Table 6-2 and Table 6-3 respectively. From this, seven roads out of the sixteen were inaccessible to a large 4WD vehicle in the 20% AEP flood event, with this number increasing to eight in the 5% AEP event, and nine in the 1% AEP event. Of the roads rendered inaccessible in the 1% AEP event, there was a period of 1.3 to 11.5 hours between the beginning of the event and the time at which the roads became inaccessible. 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: Time between the rainfall event commencing and road inaccessibility occurring

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
20% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	18.0 hours	N/A	N/A
Nowlans Road	10.2 hours	15.1 hours	15.2 hours
Bimbi Caragabal Road	11.1 hours	11.3 hours	11.4 hours
Grimms Lane	6.5 hours	13.3 hours	13.4 hours
Blayneys Road	1.4 hours	1.6 hours	1.7 hours
Heathcotes Lane	5.9 hours	6.0 hours	6.1 hours
Mary Gilmore Way (west of Heathcotes Lane)	5.6 hours	6.3 hours	7.3 hours
Mary Gilmore Way (east of Heathcotes Lane	9.6 hours	10.2 hours	10.8 hours
5% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	13.7 hours	13.8 hours	13.9 hours
Nowlans Road	7.9 hours	8.0 hours	12.1 hours
Bimbi Caragabal Road	6.7 hours	8.7 hours	8.8 hours
Grimms Lane	4.9 hours	5.9 hours	10.5 hours

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
Blayneys Road	1.0 hours	1.8 hours	1.9 hours
Heathcotes Lane	4.8 hours	5.0 hours	5.1 hours
Mary Gilmore Way (west of Heathcotes Lane)	3.6 hours	4.6 hours	4.9 hours
Mary Gilmore Way (east of Heathcotes Lane	5.5 hours	7.0 hours	7.3 hours
1% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	11.3 hours	11.4 hours	11.5 hours
Nowlans Road	6.1 hours	6.2 hours	7.2 hours
Bimbi Caragabal Road	5.5 hours	6.9 hours	7.0 hours
Grimms Lane	2.3 hours	5.0 hours	8.7 hours
Blayneys Road	0.9 hours	1.2 hours	1.3 hours
Heathcotes Lane	3.5 hours	3.7 hours	3.8 hours
Mary Gilmore Way (west of Heathcotes Lane)	1.6 hours	2.4 hours	3.3 hours
Mary Gilmore Way (east of Heathcotes Lane	3.5 hours	5.4 hours	5.7 hours
Nowlan Street	13.3 hours	N/A	N/A
Arramagong Street	12.9 hours	N/A	N/A
Young Street	12.9 hours	N/A	N/A
Bland Street	12.6 hours	N/A	N/A
Billicott Road	9.4 hours	10.0 hours	11.4 hours
0.2% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	7.0 hours	9.3 hours	9.4 hours
Nowlans Road	5.0 hours	5.1 hours	5.4 hours
Bimbi Caragabal Road	3.3 hours	5.8 hours	5.9 hours
Grimms Lane	1.4 hours	2.4 hours	4.1 hours
Blayneys Road	0.5 hours	0.7 hours	0.9 hours
Heathcotes Lane	2.9 hours	3.0 hours	3.1 hours
Mary Gilmore Way (west of Heathcotes Lane)	1.1 hours	1.5 hours	1.9 hours
Mary Gilmore Way (east of Heathcotes Lane	2.0 hours	2.5 hours	4.4 hours
Nowlan Street	10.1 hours	10.4 hours	10.9 hours
Arramagong Street	10.0 hours	10.5 hours	11.3 hours
Young Street	10.0 hours	10.3 hours	10.9 hours

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
Bland Street	10.0 hours	10.3 hours	10.7 hours
Billicott Road	7.3 hours	7.5 hours	7.8 hours
Caldwell Street	10.3 hours	11.4 hours	N/A
Khartoum Road	10.3 hours	11.0 hours	N/A
Bimbi-Quandialla Road	10.2 hours	11.4 hours	N/A

Table 6-3: Duration of road inaccessibility

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
20% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	6.4 hours	N/A	N/A
Nowlans Road	22.9 hours	17.9 hours	17.8 hours
Bimbi Caragabal Road	21.9 hours	21.8 hours	21.6 hours
Grimms Lane	21.1 hours	19.8 hours	17.0 hours
Blayneys Road	31.6 hours	31.4 hours	31.3 hours
Heathcotes Lane	27.1 hours	27.0 hours	26.9 hours
Mary Gilmore Way (west of Heathcotes Lane)	27.4 hours	26.7 hours	25.7 hours
Mary Gilmore Way (east of Heathcotes Lane	9.6 hours	7.0 hours	3.9 hours
5% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	12.4 hours	8.6 hours	5.6 hours
Nowlans Road	25.1 hours	25.0 hours	20.9 hours
Bimbi Caragabal Road	25.6 hours	24.2 hours	24.2 hours
Grimms Lane	26.9 hours	23.7 hours	21.0 hours
Blayneys Road	32.0 hours	31.2 hours	31.1 hours
Heathcotes Lane	28.1 hours	28.0 hours	27.9 hours
Mary Gilmore Way (west of Heathcotes Lane)	29.3 hours	28.4 hours	28.1 hours
Mary Gilmore Way (east of Heathcotes Lane	14.9 hours	11.5 hours	8.9 hours
1% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	16.6 hours	13.0 hours	10.5 hours
Nowlans Road	26.9 hours	26.8 hours	25.8 hours
Bimbi Caragabal Road	27.5 hours	26.0 hours	26.0 hours
Grimms Lane	30.7 hours	27.5 hours	24.3 hours

Location	Small passenger vehicle	Large passenger vehicle	Large 4WD vehicle
Blayneys Road	32.1 hours	31.8 hours	31.7 hours
Heathcotes Lane	29.5 hours	29.3 hours	29.2 hours
Mary Gilmore Way (west of Heathcotes Lane)	31.4 hours	30.6 hours	29.7 hours
Mary Gilmore Way (east of Heathcotes Lane	18.4 hours	15.0 hours	12.5 hours
Nowlan Street	2.6 hours	N/A	N/A
Arramagong Street	4.4 hours	N/A	N/A
Young Street	3.8 hours	N/A	N/A
Bland Street	5.6 hours	N/A	N/A
Billicott Road	7.1 hours	4.7 hours	1.1 hours
0.2% AEP event (with a 540 minute storm duration)			
Bimbi Thuddungra Road	22.1 hours	17.0 hours	14.6 hours
Nowlans Road	27.9 hours	27.9 hours	27.7 hours
Bimbi Caragabal Road	29.7 hours	27.2 hours	27.1 hours
Grimms Lane	31.7 hours	30.7 hours	28.9 hours
Blayneys Road	32.5 hours	32.3 hours	32.1 hours
Heathcotes Lane	30.1 hours	30.0 hours	30.0 hours
Mary Gilmore Way (west of Heathcotes Lane)	31.9 hours	31.6 hours	31.1 hours
Mary Gilmore Way (east of Heathcotes Lane	22.1 hours	19.4 hours	15.8 hours
Nowlan Street	9.2 hours	7.0 hours	4.9 hours
Arramagong Street	10.2 hours	6.9 hours	3.9 hours
Young Street	9.7 hours	7.3 hours	5.1 hours
Bland Street	11.0 hours	8.0 hours	5.9 hours
Billicott Road	11.5 hours	9.9 hours	8.6 hours
Caldwell Street	6.4 hours	3.2 hours	N/A
Khartoum Road	6.4 hours	3.8 hours	N/A
Bimbi-Quandialla Road	8.4 hours	4.3 hours	N/A

6.6 Flood Hazard

There are two standard industry methods for determining the flood hazard categories as defined by the 2005 Floodplain Development Manual (Ref 9) and 2019 Australian Rainfall and Runoff (Ref 2). Both methods use the depth and velocity product, however they differ in the thresholds applied and the categories denoted.

6.6.1 Floodplain Development Manual Categorisation

The FDM method denotes hazard categories as low hazard or high hazard, with each described as follows:

- High hazard – possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings.
- Low hazard – should it be necessary, truck could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The high hazard category is particularly significant as it is a criteria in regulating complying development as per the State Environmental Planning Policy (SEPP) (Exempt and Complying Development Codes) 2008 (discussed in Section 8.1.5), as well as a criteria in determining voluntary property purchase (discussed in Section 11.2.2.2).

6.6.1.1 Provisional Flood Hazard Methodology

Provisional flood hazard categorisation is based upon the depth-velocity curves shown in Chart 6-1. The provisional flood hazard categorisation for the study area was undertaken as part of the Bimbi Village Flood Study (HydroSpatial, 2021).

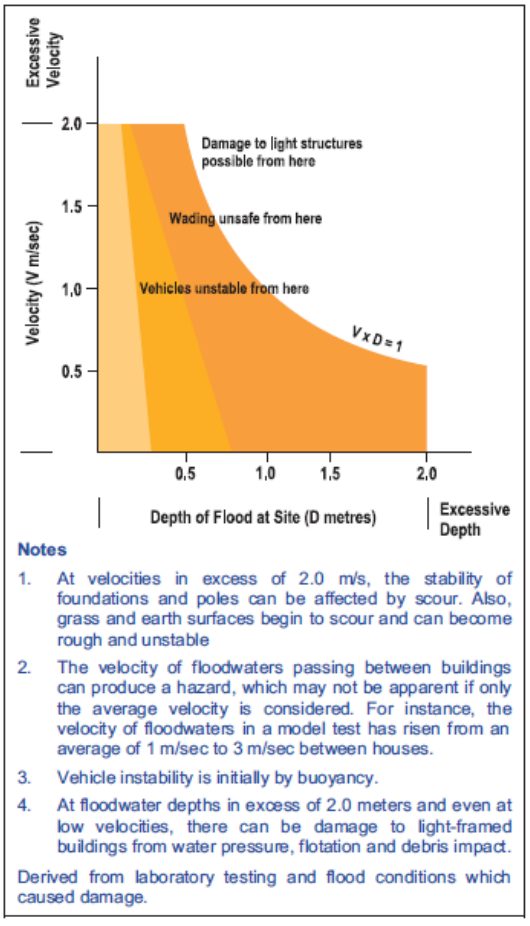


FIGURE L1 - Velocity & Depth Relationships

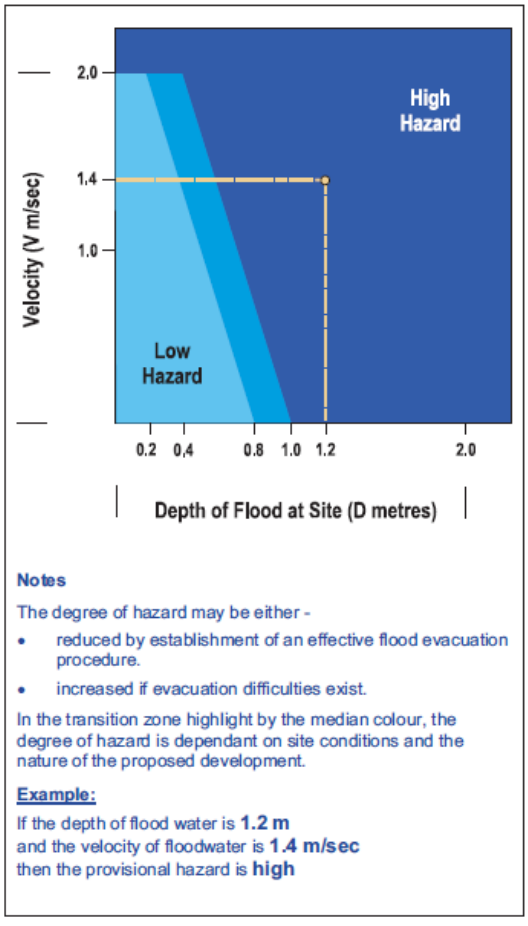


FIGURE L2 - Provisional Hydraulic Hazard Categories

Chart 6-1: Flood hazard curves (FDM, 2005)

6.6.1.2 True Flood Hazard Methodology

True flood hazard categorisation is based upon the provisional flood hazard categorisations with further refinement to take into consideration the following factors:

- Size of flood;
- Effective warning time;
- Flood readiness;
- Rate of rise of floodwaters;
- Depth and velocity of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Effective flood access; and
- Type of development.

The true flood hazard categorisation for the study area has been undertaken for the 1% AEP event, shown on Figure B 9.

6.6.1.3 Building and Property Affectation

Table 6-4 summarises the number of buildings affected by high flood hazard using the true flood hazard methodology. From this, it was found that multiple residential buildings experiences highly hazardous conditions in all flood events.

Table 6-4: FDM flood hazard – building affectation

Design Event	Number of buildings affected by high hazard (using the true flood hazard methodology)
20% AEP	20
10% AEP	40
5% AEP	59
2% AEP	81
1% AEP	90
0.5% AEP	123
0.2% AEP	155
PMF	260

6.6.2 Australian Rainfall and Runoff Categorisation

This method is defined in both the Australian Rainfall and Runoff Guidelines (Ref 2) and also in the Australian Emergency Management Handbook 7 Guidelines (Ref 1). This method denotes hazard categories as H1, H2, H3, H4, H5 and H6; with the greater risk attributed to the highest category (i.e. H6). These hazard categories are described as follows:

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

6.6.2.1 Methodology

The ARR flood hazard categorisation is based upon the depth-velocity curves shown in Chart 6-2. This flood hazard categorisation was undertaken as part of the Bimbi Village Flood Study

(HydroSpatial, 2021), with the 1% AEP flood hazard categorisation using this method shown on Figure B 10.

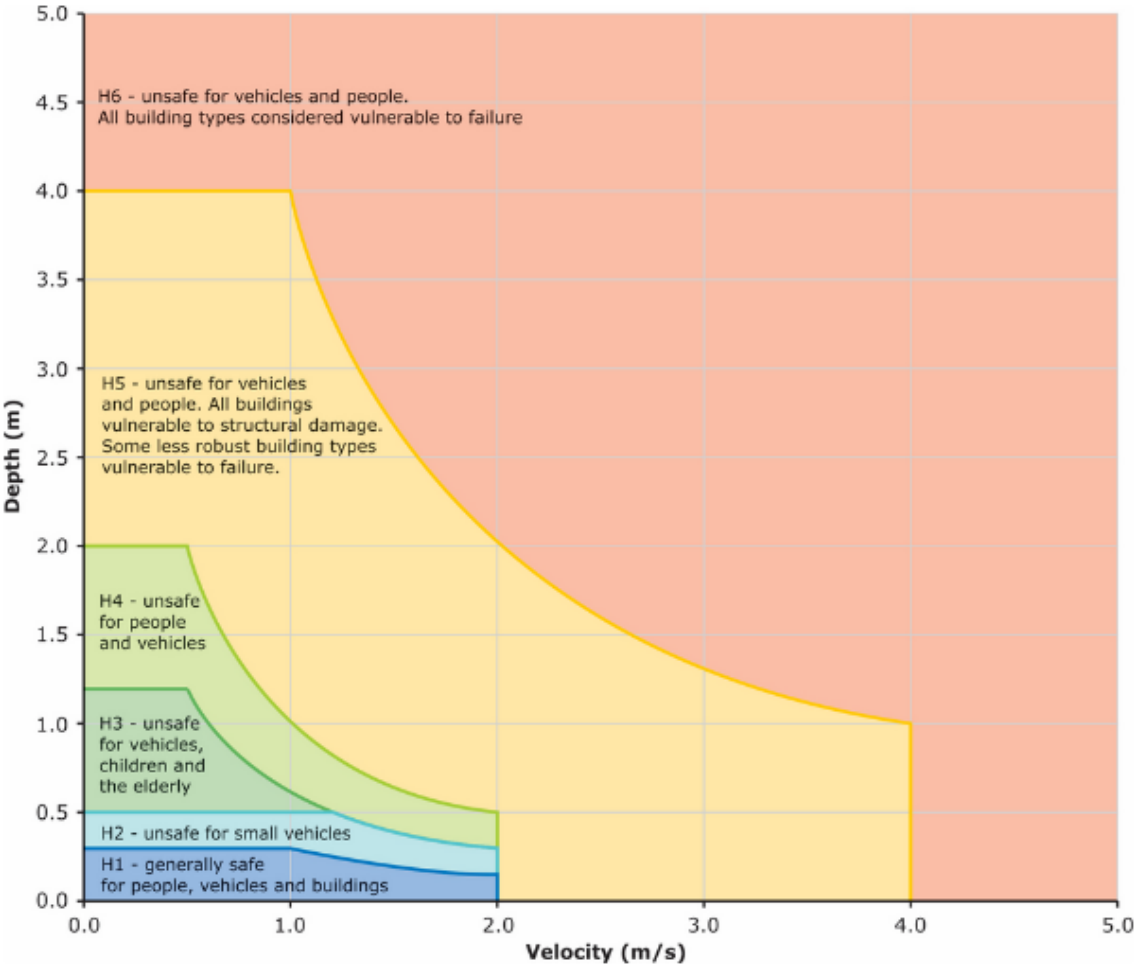


Chart 6-2: Flood hazard curves (ARR, 2019)

6.6.2.1 Building and Property Affectation

The number of buildings and properties affected by the various categories of flood hazard have been investigated for each design event. In the case of the building affectation, this was determined based upon the highest flood hazard category immediately adjacent to the building extent. In the case of the property affectation, this was determined based upon the highest flood hazard category that affected greater than 10% of the property area. Table 6-5 and Table 6-6 summarises the number of buildings and properties affected, respectively.

Table 6-5: ARR flood hazard - building affectation

Design Flood	Number of existing buildings affected					
	H1	H2	H3	H4	H5	H6
20% AEP	81	28	12	12	3	0
10% AEP	76	32	24	13	10	0
5% AEP	83	36	26	21	17	0

2% AEP	98	33	28	31	28	0
1% AEP	109	34	33	37	38	0
0.5% AEP	95	52	29	43	60	0
0.2% AEP	95	52	29	43	60	0
PMF	30	30	35	39	169	25

Table 6-6: ARR flood hazard - property affectation

Design Flood	Number of existing properties affected by >10%					
	H1	H2	H3	H4	H5	H6
20% AEP	139	43	31	20	33	2
10% AEP	144	36	36	20	49	3
5% AEP	131	45	42	21	57	3
2% AEP	117	65	60	25	68	4
1% AEP	88	91	60	27	80	7
0.5% AEP	49	89	105	18	106	10
0.2% AEP	39	47	132	35	115	23
PMF	31	11	32	57	233	59

6.7 Flood Risk

6.7.1 Categorisation

Flood risk is a function of the level of consequence and the likelihood of the consequence occurring. This is illustrated in Chart 6-3 (extracted from the Australian Emergency Management Handbook 7 Guidelines (Ref 1)), which provides a qualitative risk matrix.

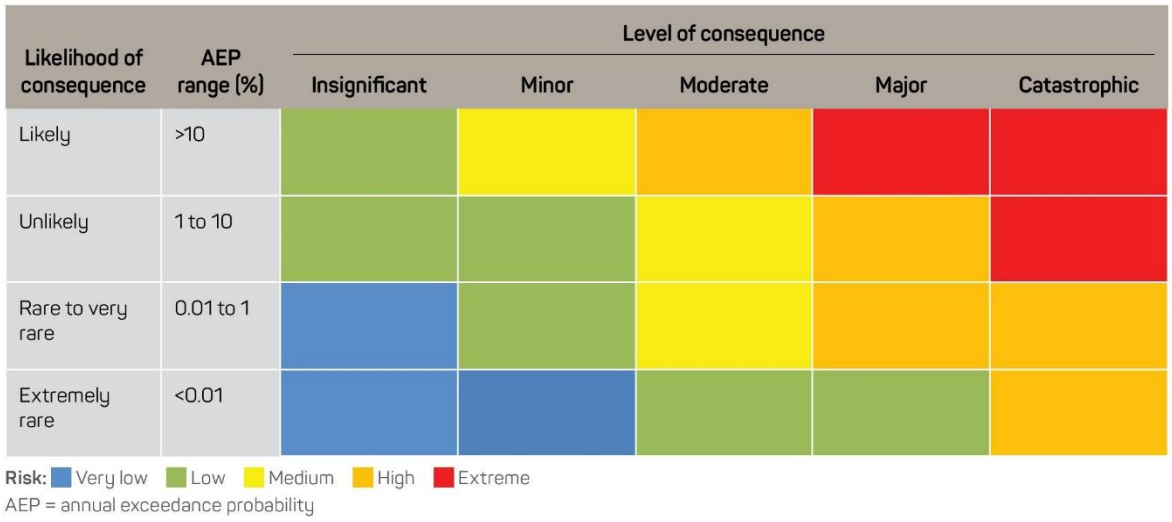


Chart 6-3: Example qualitative risk matrix

This example risk matrix was used in conjunction with the ARR hazard categories (discussed in Section 6.6.2) to define the qualitative flood risk matrix for the study area. This is shown in Table 6-7, whereby the flood risk categories were denoted as:

- Z6 – Extreme risk
- Z5 – High risk
- Z4 – Medium risk
- Z3 – Low risk
- Z2 – Very low risk
- Z1 – Flood free

Table 6-7: Flood risk matrix

Design Flood	Flood risk per hydraulic hazard category					
	H1	H2	H3	H4	H5	H6
20% AEP	Z4	Z5	Z5	Z6	Z6	Z6
10% AEP	Z4	Z5	Z5	Z6	Z6	Z6
5% AEP	Z3	Z4	Z4	Z5	Z6	Z6
2% AEP	Z3	Z3	Z4	Z5	Z5	Z6
1% AEP	Z2	Z3	Z3	Z4	Z5	Z6
0.5% AEP	Z2	Z2	Z3	Z4	Z5	Z6
0.2% AEP	Z2	Z2	Z2	Z3	Z4	Z5
PMF	Z2	Z2	Z2	Z3	Z3	Z4

6.7.2 Building and Property Affectation

The number of buildings and properties affected by the various categories of flood risk have been investigated. In the case of the building affectation, this was determined based upon the highest flood risk category immediately adjacent to the building extent. In the case of the property affectation, this was determined based upon the highest flood risk category that affected greater than 10% of the property area.

Figure B 11 shows the flood risk relative to the property affectation; and Table 6-8 summarises the number of properties affected, the number of the affected properties that contained a building, and the current land zoning of the affected properties.

From this, it was found that Z4 (medium) flood risk category affected the largest number of properties in the study area. There were also a large number of properties affected by both Z5 (High Risk) and Z6 (Extreme Risk) flood risk categories, with more than 20 properties affected by each of these categories containing an existing building.

Table 6-8: Flood risk affectation

Flood Risk	Number of Properties Affected (total)	Number of Properties Affected (that contain an existing building)	Current Land Zoning of Affected Properties
Z2	40	8	RU1 = 40

Z3	65	16	RU1 = 59 RU5 = 6
Z4	139	37	RU1 = 101 RU3 = 2 RU5 = 36
Z5	93	22	RU1 = 83 RU5 = 10
Z6	81	22	RU1 = 81

7 Assessment of Existing Flood Response Arrangements

7.1 Flood Emergency Response Documents

7.1.1 Local Emergency Management Plan

The Weddin Shire Local Emergency Management Plan (Weddin Shire EMPLAN) (Weddin Shire Council, 2017) governs a range of potential hazards across the Weddin Shire Council area; including flood hazards, fire hazards, and earthquake hazards, etc. The Weddin Shire EMPLAN was prepared in accordance with the *State Emergency & Rescue Management Act 1989* by the Weddin Shire Council Local Emergency Management Committee (Weddin Shire 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 Weddin Shire Local Flood 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 Weddin Shire Council area. Across the council area, the NSW SES unit available is the NSW SES Grenfell Unit.

7.1.2 Flood Emergency Sub Plan

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

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

7.2 Evacuation Centres

The Weddin Shire Flood Emergency Sub Plan provides details for two evacuation centres across the council area. Of the two evacuation centres listed in the Flood Emergency Sub Plan, both were located within Grenfell and were therefore outside of the study area.

8 Assessment of Existing Flood Planning Policies

8.1 State Government Planning Policies

The role of state government legislation is to provide a robust framework for all local legislation and planning policies to be based upon. Local floodplain management policies must be developed in accordance with relevant state legislation. This section discusses relevant state government legislation regarding flood planning.

8.1.1 NSW Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 governs the use, development and protection of land in NSW, and is the framework upon which various relevant local government and SES plans are based. The objects of this Act are:

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)

As per Section 9.1 of the Environmental Planning and Assessment Act, the Minister for Planning issued direction 4.3 in July of 2009 to local governments requiring they implement the NSW Flood Prone Land Policy into their Local Environmental Plans.

The objectives of the direction and obligations of relevant planning authorities in relation to the direction are:

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 Floodplain Development Manual supports the NSW the NSW Government's Flood Prone Land Policy in its goal of developing sustainable strategies for human occupation and use of floodplains. The manual was primarily written for the use of local governments, providing guidance for the undertaking of flood studies and floodplain risk management plans.

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.*

8.1.4 Planning Circular PS 07-003

Planning Circular PS 07-003 (31 January 2007) acts as an overview of a new guideline to the Floodplain Development Manual, as well as changes made to the Environmental Planning and Assessment Regulation and Section 9.1 (previously Section 117) Direction on flood prone land. These changes relate to the flood-related development controls on residential development 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 exemption may be relevant for areas that may wish to prohibit specific land use under 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 development that complies with specified development standards by providing exempt and complying development codes that have State-wide application. Developments that pose minimal environmental impact do not require development consent.

Part 3A Division 3 Subdivision 9 Section 3A.38 of the SEPP relates to Complying Development n "flood control lots", which must satisfy the following criteria:

1) *Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the complying development certificate, as not being any of the following—*
    a) *A flood storage area,*
    b) *A floodway area,*
    c) *A flow path,*
    d) *A high hazard area,*
    e) *A high risk area.*
2) *Development that is carried out under this code on any part of a flood control lot must meet the following requirements—*
    a) *if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*
    b) *any part of the dwelling house or any ancillary development that is erected at or below the flood planning level is constructed of flood compatible material,*
    c) *any part of the dwelling house or any ancillary development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),*
    d) *the development must not result in increased flooding elsewhere in the floodplain,*
    e) *the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,*
    f) *vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,*
    g) *the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.*
3) *The requirements under subclause (2)(c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*

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 Weddin Shire Local Environmental Plan 2011

The Weddin Shire Local Environmental Plan was adopted in December 2011. In this, the flood controls are stated in Clause 6.5 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 impact 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, published in 2005 by the NSW Government, unless it is otherwise defined in this clause.*
5) *In this clause–*
    a. ***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.*

8.2.2 Weddin Shire Development Control Plan 2014

The Weddin Shire Development Control Plan was adopted in November 2014 and applies to land which is part of the Weddin Shire Council area. It includes the town of Grenfell, as well as the Caragabal, Greenethorpe, Quandialla and Bimbi towns.

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

Chapter 4 of the DCP relates to flooding and flood affected land, and applies to all R1, RU1, R5, B2, IN1, RE1, RE2, SP2 and E3 zoned lots within the extent of the Flood Planning Area. The objectives of this part of the DCP are to:

a) *To provide detailed flood related development controls for the assessment of applications on land affected by floods in accordance with the provisions of Weddin LEP 2011 (and as amended in future editions) and the findings of the Emu Creek Floodplain Risk Management Study and Plan, 2012.*
b) *To alert the community to the hazard and extent of land affected by floods.*
c) *To inform the community of Council's policy in relation to the use and development of land affected by the potential floods in Grenfell.*
d) *To reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by floods.*
e) *To ensure new development is consistent with the flood response strategy set out in the Weddin Shire Local Flood Plan, 2009 published by the State Emergency Service (SES) and does not impose additional burdens on, or risk to, SES personnel during flood emergencies.*

To determine the development controls to be applied to a development application under the DCP, the following process is undertaken:

i) Determine which part of the floodplain the development is located in. This is divided into four categories; being High Hazard Floodway, Low Hazard Floodway; Intermediate Floodplain and Outer Floodplain. The Intermediate Floodplain was defined as areas between the Floodway extent (both High Hazard Floodway and Low Hazard Floodway) and the Flood Planning Area (FPA) the extent of the 1% AEP peak flood level plus 0.5 m freeboard. The Outer Floodplain was defined as areas between the Intermediate Floodplain extent and the PMF extent.
ii) Identify the category of the development. This is divided into eight categories; being essential community facilities, critical utilities and uses, flood vulnerable residential, residential, business and commercial or industrial, non-urban and outbuildings, subdivision and filling, and minor residential additions.
iii) Determine the appropriate Flood Planning Level and flood related development controls from the Development Control Matrix (provided in Chapter 4, Annexure 2 of the Weddin Shire DCP and shown in the following).
iv) Determine the flood level at the site.

DEVELOPMENT CONTROLS MATRIX

Not Relevant Unsuitable Land Use **See Notes over page**

Planning Consideration	OUTER FLOODPLAIN							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level	1	1	1	1	1		1	
Building Components	2	2						
Structural Soundness	2	2						
Flood Affectation Evacuation								
Evacuation/ Access	1	1	1					
Management & Design	2,3	2,3	5					

Planning Consideration	INTERMEDIATE FLOODPLAIN							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level	1	1	1	1	1		1	1
Building Components	2	2	1	1	1		1	1
Structural Soundness	2	2	1	1	1		1	1
Flood Affectation								
Evacuation/ Access	1	1	1					
Management & Design	2,3	2,3	5		4			6

Planning Consideration	LOW HAZARD FLOODWAY							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level	1	1	1	1	1		1	1
Building Components	2	2	1	1	1		1	1
Structural Soundness	2	2	1	1	1		1	1
Flood Affectation Evacuation	1	1	1	1	1		1	1
Evacuation/ Access	1	1	1					
Management & Design	2,3,7	2,3,7	5,7	6	4,7		1,7	6

Planning Consideration	HIGH HAZARD FLOODWAY							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level								1
Building Components								1
Structural Soundness								1
Flood Affectation						1		1
Evacuation/ Access								
Management & Design						3,8		6,8

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.

9.2 Methodology

The FPA was determined by applying a 0.5 m freeboard to the 1% AEP peak flood levels in Burrangong Creek. The DCP flood categories were then determined using the same method as was applied to the Emu Creek study area so as to maintain consistency in flood-related planning controls across the Council area.

10 Consequences of Flooding

10.1 Introduction

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.

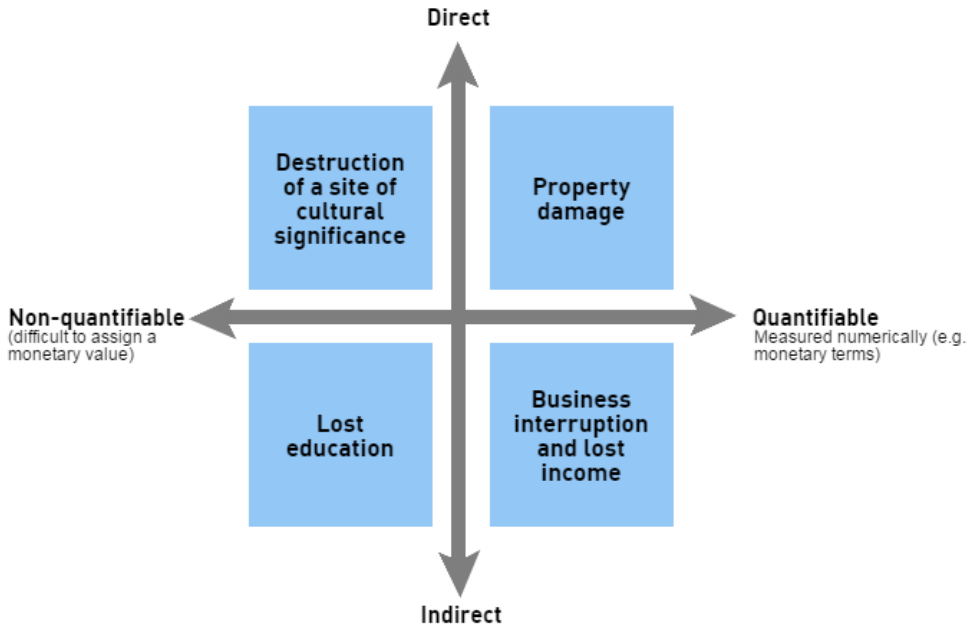


Chart 10-1: Flood Damage Representation (Source - UNISDR: Prevention Web, Direct and Indirect Losses, 2014)

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

10.2 Property 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 to be the maximum flood level from

within a 3m radius of the building for each flood event was then assigned to each building) 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	1.1	Costs adjusted based on Rawlinsons (2019) for Forbes.
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	320 m^2	Based upon the digital schematisation of buildings in the study area from the aerial photography.
Typical Duration of Immersion	9 hours	
Building Damage Repair Limitation Factor	0.9	Based on a moderate duration flood event.
Average Contents Value	$80,000	Based upon the typical house size in the study area.
Contents Damage Repair Limitation Factor	0.9	Based on a moderate 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 1999 and 2016 floods, a classification of 'High' was

		deemed appropriate for the study area.
Effective Warning Time	3 hours	Given the moderate duration and rate at which road access is cut during the storm events that cause flooding in the study area, an effective warning time of 3 hours was deemed appropriate.

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

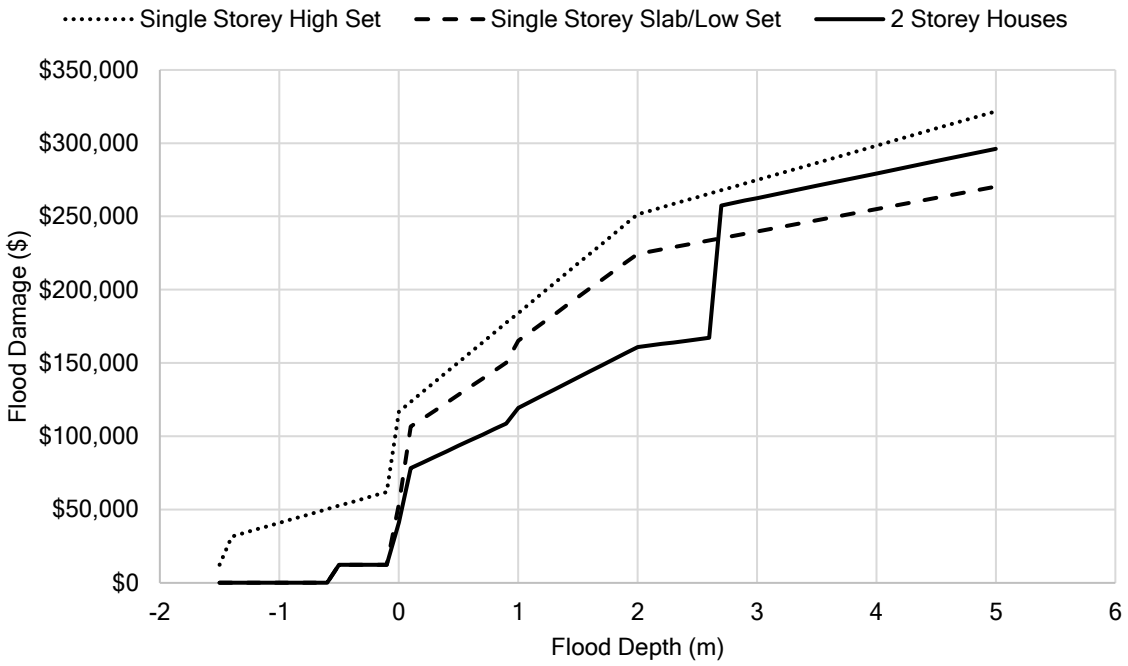
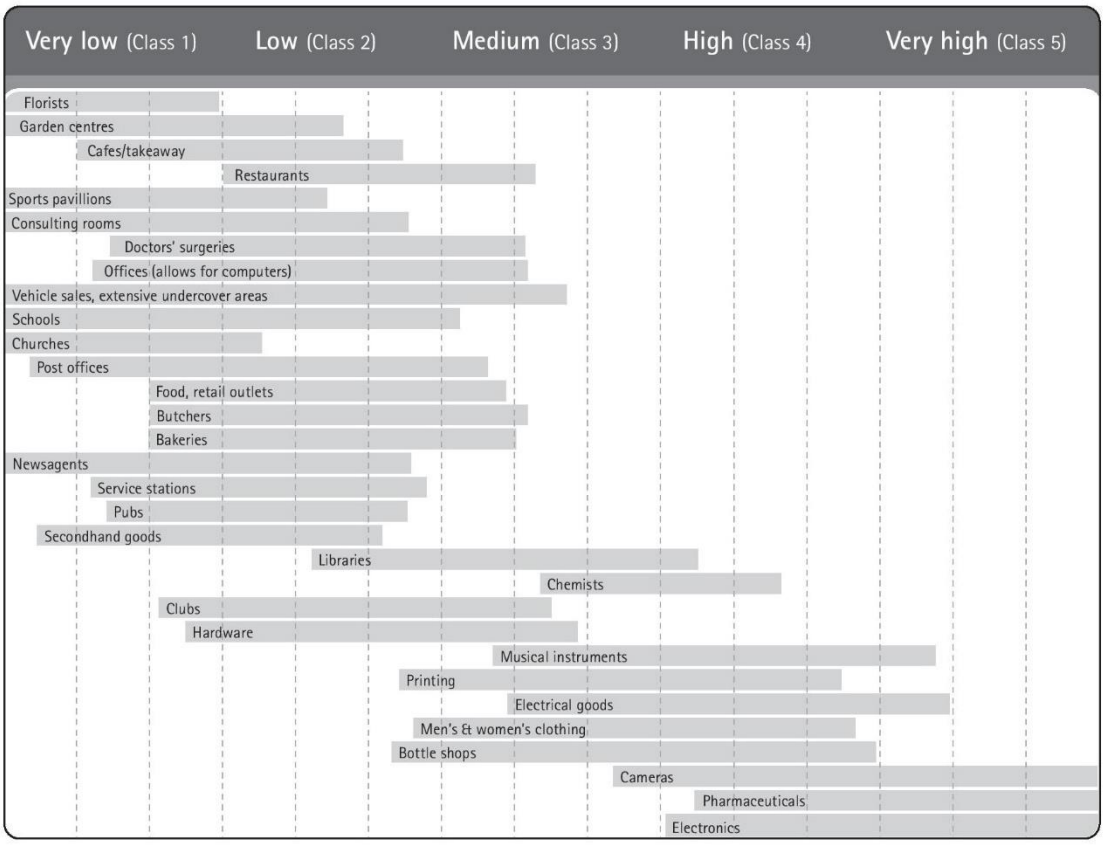


Chart 10-2: Residential depth-damage curves

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 Bimbi study area, it was found that all the commercial properties were within the Class 2 category. This resulted in the following commercial depth-damage curves.

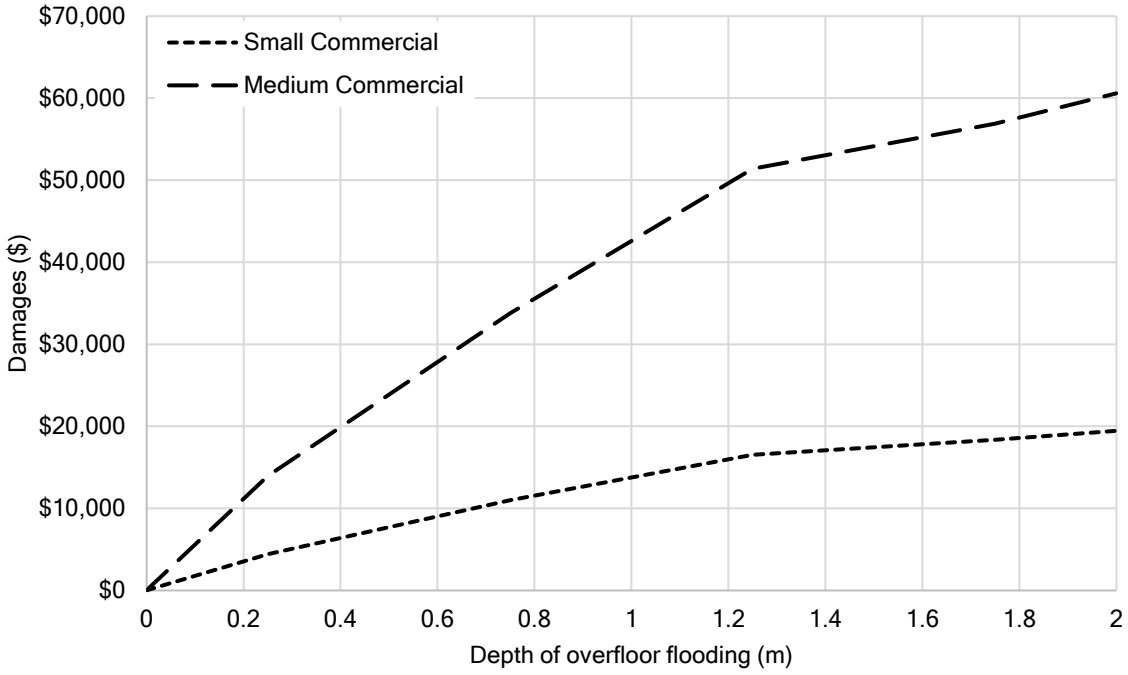


Chart 10-4: Commercial depth-damage curves

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.

10.2.2 Residential and Non-Residential Damage 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 flooding within the study area. From this, the AAD was $338,906 and the NPV was $5,016,063.

Table 10-2: Direct flood damages

Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
PMF					
Residential	49	47	$8,354,904	$1,253,236	$9,608,139
Commercial	1	1	$16,518	$2,478	$18,996
Sub-Total	50	48	$8,371,422	$1,255,713	$9,627,135
0.2% AEP					
Residential	44	35	$5,855,324	$878,299	$6,733,623
Commercial	1	1	$11,011	$1,652	$12,663
Sub-Total	45	36	$5,866,335	$879,950	$6,746,285
0.5% AEP					
Residential	42	33	$5,199,055	$779,858	$5,978,913
Commercial	1	1	$4,405	$661	$5,066
Sub-Total	43	34	$5,203,460	$780,519	$5,983,979
1% AEP					
Residential	38	22	$4,306,707	$646,006	$4,952,713
Commercial	1	1	$4,405	$661	$5,066
Sub-Total	39	23	$4,311,112	$646,667	$4,957,779
2% AEP					
Residential	35	16	$3,561,199	$534,180	$4,095,379
Commercial	1	1	$4,405	$661	$5,066
Sub-Total	36	17	$3,565,604	$534,841	$4,100,445
5% AEP					
Residential	31	10	$2,853,322	$427,998	$3,281,320
Commercial	1	-	$ -	$ -	$ -
Sub-Total	32	10	$2,853,322	$427,998	$3,281,320
10% AEP					
Residential	26	9	$2,366,397	$354,960	$2,721,356
Commercial	1	-	$-	$-	$-
Sub-Total	27	9	$2,366,397	$354,960	$2,721,356
20% AEP					
Residential	24	7	$2,004,312	$300,647	$2,304,959
Commercial	1	-	$ -	$ -	$ -
Sub-Total	25	7	$2,004,312	$300,647	$2,304,959

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 Bimbi RFS Shed experiences partial flooding of less than 0.15 m in the 5% AEP event, with depths reaching up to 0.3 m in the 1% AEP event and between 1 m and 2 m in the PMF event.

10.4 Heritage Impacts

Through analysing flood behaviours in relation to non-Indigenous Australian cultural heritage sites, it was found that:

- Bimbi Police Station and Lock-Up, and Bimbi Post Office experience partial flooding of less than 0.15 m in the 5% AEP event, and is fully inundated in the 1% AEP event.
- The Rammed Earth Cottage on Grenfell Street experiences partial flooding of less than 0.15 m in the 20% AEP event, and is fully inundated in the 1% AEP event.
- Bimbi Police Station and Lock-Up, Bimbi Post Office and The Rammed Earth Cottage on Grenfell Street all experience flooding of up to 0.5 m in the 0.2% AEP event.

Similarly, the flood behaviours in relation to the Indigenous Australian cultural heritage sites was analysed, and it was found that:

- A modified tree near the intersection of Mary Gilmore Way and Blayneys Road experiences flooding of up to 1 m in the 20% AEP event.
- A modified tree near the intersection of Mary Gilmore Way and Grimms Lane experiences flood depths of less than 0.15 m in the 1% AEP event, with the same tree experiencing depths of up to 1 m in the PMF event.
- An artefact site located within Weddin Mountains National Park does not appear to experience significant flood depths.

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 Identification

11.2.1 Potential Flood Modification Measures

11.2.1.1 Option FM01 – Removal of Burrangong Creek TSR fence

This option involved the removal of the current Burrangong Creek Travelling Stock Reserve fence erected by Local Land Services in 2014. This option was investigated following the second round of community consultation as part of the previous Bimbi Flood Study, where several community members requested the impact of the fence on flood behaviours in town. Figure C 1 shows the location and schematisation of the fence.

11.2.1.2 Option FM02 - Clearing of Burrangong Creek

This option involved the clearing of vegetation from a section of Burrangong Creek. This section of creek extended from the Mary Gilmore Way bridge south of town, to a point approximately 8.7 km upstream where the flow from Burrangong Creek typically spills over to the northern side of Mary Gilmore Way. Figure C 2 shows the location and schematisation of the creek clearing.

11.2.1.3 Option FM03 – Detention basin on Burrangong Creek

This option involved the construction of an in-line detention basin along Burrangong Creek, near Heathcotes Lane, as well as the construction of a small earthen levee along the northern side of the basin. This included the purchase of private property covered by the detention basin, excavation of the grounds (with battered sides to the base of the detention basin), and re-grassing and landscaping the grounds. This property was selected as it is located upstream of where overflow from Burrangong Creek crosses Mary Gilmore Way to flow into Wah Way Creek, as well as being a property that is eligible for voluntary house purchase (discussed in Section 11.2.2.2). Figure C 3 shows the location and schematisation of this detention basin and levee.

11.2.1.4 Option FM04 – Road bridge along Mary Gilmore Way

This option involved the construction of a road bridge along a section of Mary Gilmore Way between Grimms Lane and Heathcotes Lane. This included the raising of the road surface to above the 1% AEP flood level, while allowing flood waters to flow below the bridge unobstructed. The aim of this option was to flood-proof the primary evacuation route for Bimbi. Figure C 4 shows the location and schematisation of this road bridge.

11.2.1.5 Option FM05 – Road levee along Mary Gilmore Way

This option involved the raising of a section of Mary Gilmore Way between Grenfell Street and Khartoum Road to above the 1% AEP flood level. This road raising also acted as a levee to

prevent flood water from crossing the roadway. Figure C 5 shows the location and schematisation of this raised road section.

11.2.1.6 Option FM06 – Road levee east of Bimbi

This option involved the raising of an unnamed road to the east of Bimbi, located between Arramagong Street and Khartoum Road. This included the raising of the road surface to above the 1% AEP flood level in order to act as a levee for the town. Figure C 6 shows the location and schematisation of this raised road section.

11.2.1.7 Option FM07 – Road levee along Mary Gilmore Way and road levee east of Bimbi

This option involved the raising of two sections of road, one being a section of Mary Gilmore Way between Grenfell Street and Khartoum Road, and the other a section of an unnamed road to the east of Bimbi, located between Arramagong Street and Khartoum Road. Both sections would be raised to above the 1% AEP flood level in order to act as a levee system for the town. Figure C 7 shows the location and schematisation of these raised road sections.

11.2.1.8 Option FM08 – Individual residential earthen levees

This option involved the construction of a series of earthen levees around each residence within Bimbi town. These levees would be constructed to meet the 1% AEP flood level, plus a 0.5 m freeboard. Figure C 8 shows the location and schematisation of these individual levees.

11.2.1.9 Option FM09 – Single span bridge at Mary Gilmore Way

This option involves the upgrading of the current bridge on the Mary Gilmore Way, west of Bimbi to a single span bridge. This option was investigated to determine the impact of the current bridge's piers on blockages within the Burrangong Creek. Figure C 9 shows the location and schematisation of this bridge.

11.2.1.10 Option FM10 – Mound levelling at Mary Gilmore Way bridge

This option involves the levelling of an earthen mound located near the intersection of Mary Gilmore Way and Bimbi-Thuddungra Road, just west of Burrangong Creek. Figure C 10 shows the location and schematisation of this option.

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.

This option is to adopt the FPA and FPL determined from this study (discussed in Section 9) into Council's LEP and DCP. This would also involve updating individual property's Section 10.7(2) Planning Certificates accordingly.

11.2.2.2 Option PM02 – Voluntary property purchase

Voluntary purchase is a property modification measure where in council purchases land affected by high flood hazard. 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 flood event. Of the residential properties identified within the study area, 10 were determined to have been subjected to highly hazardous flood conditions within the 1% AEP flood event. Of these residential properties, 2 was found to have above floor level flooding of greater than 1 m, 5 others experienced above floor level flooding of greater than 0.5 m, and the remaining 3 properties experienced above floor level flooding of less than 0.5 m.

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.

11.2.2.3 Option PM03 – Voluntary house raising

Voluntary house raising is a property modification measure wherein council would raise individual residences within Bimbi to above the 1% AEP flood level, plus a 0.5 m freeboard. Houses eligible to be raised were determined by identifying residences within Bimbi town that would be affected by above floor flooding in the 1% AEP flood event. From this, 5 houses were identified as fitting this criteria.

11.2.2.4 Option PM04 – Voluntary house raising and road levee along Mary Gilmore Way and road levee east of Bimbi

This option involved the raising of two sections of road, one being a section of Mary Gilmore Way between Grenfell Street and Khartoum Road, and the other a section of an unnamed road to the east of Bimbi, located between Arramagong Street and Khartoum Road. Both sections would be raised to above the 1% AEP flood level in order to act as a levee system for the town. Figure C 7 shows the location and schematisation of these raised road sections.

Voluntary house raising is a property modification measure wherein council would raise individual residences within Bimbi to above the 1% AEP flood level, plus a 0.5 m freeboard. Houses eligible to be raised were determined by identifying residences within Bimbi town that would be affected by above floor flooding in the 1% AEP flood event after the implementation of the above road levees. From this, 2 houses were identified as fitting this criteria.

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 study.

11.2.3.2 Option RM02 – Early Warning System

This option involved the installation of a stream gauge within Burrangong Creek upstream of Bimbi with the data from this gauge automatically input into a flood early warning software. The flood early warning software would be used to estimate if a minor, moderate or major flood level is likely to be reached or exceeded at Bimbi as a result of the flows being recorded at the gauge. A flood warning would then be issued via a geo-targeted emergency alert, with a pre-recorded telephone voice message to landline phones and text messages to mobile phones within the defined area of Bimbi.

11.3 Options 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 Options Assessment Results

11.4.1 Potential Flood Modification Measures

11.4.1.1 Option FM01 - Removal of Burrangong Creek TSR fence

Flood Behaviour Assessment

Figure D 1 to Figure D 3 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels throughout most of the town in smaller events, with a slight increase in flood levels within the creek and at the southern end of town. However, in larger events there is a smaller area of decreased flood levels, with a larger area at the southern end of town that experiences increased flood levels.

Economic Assessment

Table 11-2 details the economic assessment of this option. From this it was found that there was a marginal increase in damages across all events.

Table 11-2: FM01 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,391,619	$1,258,743	$9,650,362
	0.2% AEP	45	36	$5,886,533	$882,980	$6,769,513
	0.5% AEP	43	34	$5,223,658	$783,549	$6,007,207
	1% AEP	39	24	$4,365,901	$654,885	$5,020,786
	2% AEP	36	17	$3,613,371	$542,006	$4,155,376
	5% AEP	32	10	$2,791,512	$418,727	$3,210,239
	10% AEP	28	9	$2,428,401	$364,260	$2,792,661
	20% AEP	24	7	$1,944,649	$291,697	$2,236,346
	AAD (after mitigation measure)					$345,585
	AAD Reduction					-$6,679
	NPV (after mitigation measure)					$5,114,915

	NPV Reduction	-$98,852
	Estimated Cost of Mitigation Measure	$100,000
	B/C Ratio	-0.989

Social 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 any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM01, it was found that these works would come within 30 m of the Bimbi Police Station & Lock-Up, and have a low likelihood of affecting the heritage structure.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM01, it was found that construction would occur directly within an area of high biodiverse sensitivity along Burrangong Creek, and is highly likely to impact the environment.

11.4.1.2 Option FM02 - Clearing of Burrangong Creek

Flood Behaviour Assessment

Figure D 4 to Figure D 6 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreases flood levels to the east and north of town, while increasing levels within the town and further downstream. The flood level impact (both the decrease and the increase in flood levels) was found to lessen in the larger flood events.

Economic Assessment

Table 11-3 details the economic assessment of this option. From this it was found that there was a marginal increase in flood damages across all events due to the increase flows through the town.

Table 11-3: FM02 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959

	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,398,352	$1,259,753	$9,658,105
	0.2% AEP	45	36	$5,886,533	$882,980	$6,769,513
	0.5% AEP	43	34	$5,225,998	$783,900	$6,009,898
	1% AEP	39	25	$4,425,371	$663,806	$5,089,176
	2% AEP	36	17	$3,745,775	$561,866	$4,307,642
	5% AEP	33	11	$3,089,054	$463,358	$3,552,413
	10% AEP	31	9	$2,653,108	$397,966	$3,051,074
	20% AEP	28	7	$2,233,700	$335,055	$2,568,755
	AAD (after mitigation measure)					$362,997
	AAD Reduction					-$24,091
	NPV (after mitigation measure)					$5,372,631
	NPV Reduction					-$356,568
	Estimated Cost of Mitigation Measure					$5,620,000
	B/C Ratio					-0.063

Social 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 any 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, it was found that construction would occur directly within an area of high biodiverse sensitivity along Burrangong Creek, and is highly likely to impact the environment.

11.4.1.3 Option FM03 - Detention basin on Burrangong Creek

Flood Behaviour Assessment

Figure D 7 to Figure D 9 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels around the detention basin and along Red Creek. However, in smaller events this option increased flood levels long Burrangong creek and, in larger events, also increased flood levels in and around town and further downstream.

Economic Assessment

Table 11-4 details the economic assessment of this option. From this it was found that there was a marginal increase in flood damages in events larger than the 10% AEP due to the increase flows in and around town and further downstream.

Table 11-4: FM03 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,429,964	$1,264,495	$9,694,459
	0.2% AEP	45	36	$5,913,464	$887,020	$6,800,483
	0.5% AEP	43	33	$5,252,929	$787,939	$6,040,868
	1% AEP	38	23	$4,317,651	$647,648	$4,965,299
	2% AEP	35	17	$3,565,121	$534,768	$4,099,889
	5% AEP	32	10	$2,910,451	$436,568	$3,347,019
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (after mitigation measure)					$341,605
	AAD Reduction					-$2,699
	NPV (after mitigation measure)					$5,056,008
	NPV Reduction					-$39,945
	Estimated Cost of Mitigation Measure					$61,650,000
	B/C Ratio					-0.001

Social 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 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 construction would occur directly within an area of high biodiverse sensitivity between Burrangong Creek and Mary Gilmore Way, and is highly likely to impact the environment.

11.4.1.4 Option FM04 - Road bridge along Mary Gilmore Way

Flood Behaviour Assessment

Figure D 10 to Figure D 12 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option had very little effect in smaller events, with only small areas of slight flood level decrease to the north of the bridge and increase to the south of the bridge in events of a 1% AEP magnitude or larger.

Economic Assessment

Table 11-5 details the economic assessment of this option. From this it was found that there was a marginal decrease in decrease in flood damages in the smaller events, however there was a marginal increase in damages in events larger than the 1% AEP.

Table 11-5: FM04 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,384,887	$1,257,733	$9,642,620
	0.2% AEP	45	36	$5,873,068	$880,960	$6,754,028
	0.5% AEP	43	34	$5,210,193	$781,529	$5,991,721
	1% AEP	39	23	$4,304,380	$645,657	$4,950,037
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	31	10	$2,741,211	$411,182	$3,152,392
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	24	7	$1,944,649	$291,697	$2,236,346
	AAD (after mitigation measure)					$338,883

	AAD Reduction	$23
	NPV (after mitigation measure)	$5,015,714
	NPV Reduction	$349
	Estimated Cost of Mitigation Measure	$13,280,000
	B/C Ratio	0.000

Social 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 any 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, it was found that construction would occur directly within an area of high biodiverse sensitivity along Mary Gilmore Way, and is highly likely to impact the environment.

11.4.1.5 Option FM05 - Road levee along Mary Gilmore Way

Flood Behaviour Assessment

Figure D 13 to Figure D 15 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels within and to the west of town, while also increasing flood levels in and around Burrangong Creek downstream of the road raising location. The flood level impact (both the decrease and the increase in flood levels) was found to significantly lessen in the larger flood events.

Economic Assessment

Table 11-6 details the economic assessment of this option. From this it was found that there was a decrease in flood damages across all but the smallest of events. However, the decrease in flood damages was most noticeable in the 1% AEP event.

Table 11-6: FM05 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320

	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,324,293	$1,248,644	$9,572,937
	0.2% AEP	45	30	$5,542,564	$831,385	$6,373,949
	0.5% AEP	43	26	$4,788,665	$718,300	$5,506,965
	1% AEP	39	20	$3,939,054	$590,858	$4,529,912
	2% AEP	34	14	$3,418,465	$512,770	$3,931,235
	5% AEP	30	10	$2,733,995	$410,099	$3,144,094
	10% AEP	26	9	$2,313,755	$347,063	$2,660,818
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (after mitigation measure)					$321,937
	AAD Reduction					$16,969
	NPV (after mitigation measure)					$4,764,912
	NPV Reduction					$251,151
	Estimated Cost of Mitigation Measure					$1,390,000
	B/C Ratio					0.181

Social 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 any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM05, it was found that these works would come within 20 m of the Bimbi Police Station & Lock-Up, and have a moderate likelihood of affecting the heritage structure.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM05, it was found that construction would occur directly within an area of high biodiverse sensitivity along Mary Gilmore Way, and is highly likely to impact the environment.

11.4.1.6 Option FM06 - Road levee east of Bimbi

Flood Behaviour Assessment

Figure D 16 to Figure D 18 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels within and to the west of town along Bimbi-Quandialla Road, while increasing flood levels east of the road levee and directly north of town. In larger events there was a greater increase in flood levels east of the road levee and directly north of town, as well as a smaller area than saw a decrease in flood levels.

Economic Assessment

Table 11-7 details the economic assessment of this option. From this it was found that there was a decrease in flood damages in the smaller events, however there was a marginal increase in damages in larger events.

Table 11-7: FM06 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,378,154	$1,256,723	$9,634,877
	0.2% AEP	45	36	$5,859,602	$878,940	$6,738,543
	0.5% AEP	43	33	$5,201,119	$780,168	$5,981,287
	1% AEP	39	23	$4,313,453	$647,018	$4,960,471
	2% AEP	36	14	$3,554,190	$533.129	$4,087,319
	5% AEP	28	10	$2,512,112	$376,817	$2,888,929
	10% AEP	21	9	$2,008,414	$301,262	$2,309,676
	20% AEP	20	7	$1,703,653	$255,548	$1,959,201
	AAD (after mitigation measure)					$313,212
	AAD Reduction					$25,694
	NPV (after mitigation measure)					$4,635,769
	NPV Reduction					$380,294
	Estimated Cost of Mitigation Measure					$310,000
	B/C Ratio					1.227

Social Assessment

When considering the works necessary to implement flood mitigation option FM06, it was found that these works were not located within a 30 m radius of any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM06, 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 FM06, it was found that construction would occur directly within an area of high biodiverse sensitivity along the unnamed road, and is highly likely to impact the environment.

11.4.1.7 Option FM07 - Road levee along Mary Gilmore Way and road levee east of Bimbi

Flood Behaviour Assessment

Figure D 19 to Figure D 21 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels within and to the west of town, while also increasing flood levels in and around Burrangong Creek downstream of the road raising location, as well as east of the road levee and directly north of town. The flood level impact (both the decrease and the increase in flood levels) was found to lessen in intensity, but increase in area of effect in the larger flood events.

Economic Assessment

Table 11-8 details the economic assessment of this option. From this it was found that there was a decrease in flood damages across all events.

Table 11-8: FM07 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,324,293	$1,248,644	$9,572,937
	0.2% AEP	45	29	$5,529,099	$829,365	$6,358,464
	0.5% AEP	43	26	$4,727,144	$709,072	$5,436,215
	1% AEP	39	19	$3,929,980	$589,497	$4,519,477
	2% AEP	34	12	$3,297,474	$494,621	$3,792,096
	5% AEP	26	10	$2,392,785	$358,918	$2,751,702

	10% AEP	21	9	$2,008,414	$301,262	$2,309,676
	20% AEP	20	7	$1,703,653	$255,548	$1,959,201
	AAD (after mitigation measure)					$297,654
	AAD Reduction					$41,252
	NPV (after mitigation measure)					$4,405,497
	NPV Reduction					$610,566
	Estimated Cost of Mitigation Measure					$1,690,000
	B/C Ratio					0.361

Social Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that these works were not located within a 30 m radius of any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that these works would come within 20 m of the Bimbi Police Station & Lock-Up, and have a moderate likelihood of affecting the heritage structure.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that construction would occur directly within an area of high biodiverse sensitivity along Mary Gilmore Way and the unnamed road, and is highly likely to impact the environment.

11.4.1.8 Option FM08 - Individual residential earthen levees

Flood Behaviour Assessment

Figure D 22 to Figure D 24 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels within the individual residential levees, while also increasing flood levels in and around town. The flood level impact (both the decrease and the increase in flood levels) was found increase in the larger flood events.

Economic Assessment

Table 11-9 details the economic assessment of this option. From this it was found that there was a decrease in flood damages in the smaller events, however there was a marginal increase in damages in the 2% AEP event and all larger flood events.

Table 11-9: FM08 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigatio	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979

	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,405,085	$1,260,763	$9,665,847
	0.2% AEP	45	35	$5,813,598	$872,040	$6,685,638
	0.5% AEP	43	33	$5,209,903	$781,485	$5,991,389
	1% AEP	39	23	$4,256,324	$638,449	$4,894,773
	2% AEP	36	16	$3,567,655	$535,148	$4,102,804
	5% AEP	32	10	$2,850,982	$427,647	$3,278,629
	10% AEP	26	9	$2,309,074	$346,361	$2,655,435
	20% AEP	23	7	$1,887,325	$283,099	$2,170,424
	AAD (after mitigation measure)					$339,921
	AAD Reduction					-$1,015
	NPV (after mitigation measure)					$5,031,080
	NPV Reduction					-$15,017
	Estimated Cost of Mitigation Measure					$270,000
	B/C Ratio					-0.056

Social Assessment

When considering the works necessary to implement flood mitigation option FM08, it was found that these works would come within 10 m of the Bimbi RFS Shed, and have a high likelihood of affecting the structure.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM08, it was found that these works would come within 10 m of the following heritage structures, and have a moderate likelihood of affecting the heritage structure:

- Rammed Earth Cottage
- Bimbi Post Office
- Bimbi Police Station & Lock-Up

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM08, the following environmental impacts were identified:

- Construction of one of the individual levees would occur directly within an area of high biodiverse sensitivity, and is highly likely to impact the environment.
- Construction of one of the individual levees would occur within 10 m of an area of high biodiverse sensitivity, and is highly likely to impact the environment.

11.4.1.9 Option FM09 - Single span bridge at Mary Gilmore Way

Flood Behaviour Assessment

Figure D 25 to Figure D 27 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option resulted in a slight decrease in flood levels in a small area directly upstream of the bridge across all event sizes.

Economic Assessment

Table 11-10 details the economic assessment of this option. From this it was found that there was a marginal decrease in flood damages in the 1% and 2% AEP flood events, with no change in flood damages in any other flood events.

Table 11-10: FM09 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,256,324	$638,449	$4,894,773
	2% AEP	36	17	$3,563,263	$534,490	$4,097,753
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (after mitigation measure)					$338,448
	AAD Reduction					$458
	NPV (after mitigation measure)					$5,009,288
	NPV Reduction					$6,775
	Estimated Cost of Mitigation Measure					$5,010,000

	B/C Ratio	0.001

Social Assessment

When considering the works necessary to implement flood mitigation option FM09, it was found that these works were not located within a 30 m radius of any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM09, 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 FM07, it was found that construction would occur directly within an area of high biodiverse sensitivity along Mary Gilmore Way, and is highly likely to impact the environment.

11.4.1.10 Option FM10 - Mound levelling at Mary Gilmore Way bridge

Flood Behaviour Assessment

Figure D 28 to Figure D 30 shows the flood level impact of this option over a range of flood event magnitudes. From this it was found that this option decreased flood levels at the site of the levelling, while also increasing flood levels in a small area between the levelled area and Mary Gilmore Way. The flood level impact (both the decrease and the increase in flood levels) was found to decrease in the larger flood events.

Economic Assessment

Table 11-11 details the economic assessment of this option. From this it was found that there was a marginal increase in flood damages in the 0.5% AEP flood event, with no change in flood damages in any other flood events.

Table 11-11: FM10 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063

After Mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,210,193	$781,529	$5,991,721
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (after mitigation measure)					$338,933
	AAD Reduction					-$27
	NPV (after mitigation measure)					$5,016,461
	NPV Reduction					-$398
	Estimated Cost of Mitigation Measure					$210,000
	B/C Ratio					-0.002

Social Assessment

When considering the works necessary to implement flood mitigation option FM10A, it was found that these works were not located within a 30 m radius of any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM10A, 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 FM07, it was found that construction would occur directly within an area of high biodiverse sensitivity between Bimbi-Thunddungra Road and Burrangong Creek, and is highly likely to impact the environment.

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.

Economic Assessment

Table 11-12 details the economic assessment of this option. From this it was found that there was a significant decrease in damages across all flood events due to the decreased number of residences experiencing above floor flooding.

Table 11-12: PM02 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	40	38	$6,171,953	$925,793	$7,097,746
	0.2% AEP	35	26	$4,004,945	$600,742	$4,605,686
	0.5% AEP	33	24	$3,456,524	$518,479	$3,975,003
	1% AEP	29	13	$2,671,899	$400,785	$3,072,684
	2% AEP	26	9	$2,000,450	$300,067	$2,300,517
	5% AEP	22	2	$1,485,558	$222,834	$1,708,392
	10% AEP	17	1	$1,066,249	$159,937	$1,226,186
	20% AEP	15	-	$876,037	$131,406	$1,007,443
	AAD (after mitigation measure)					$185,659
	AAD Reduction					$153,247
	NPV (after mitigation measure)					$2,747,886
	NPV Reduction					$2,268,177

	Estimated Cost of Mitigation Measure	$7,370,000
	B/C Ratio	0.308

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.

11.4.2.3 Option PM03 – Voluntary house raising

Flood Behaviour Assessment

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

Economic Assessment

Table 11-13 details the economic assessment of this option. From this it was found that there was a decrease in damages across all flood events due to the decreased number of residences experiencing above floor flooding.

Table 11-13: PM03 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445
	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,162,710	$1,224,406	$9,387,116
	0.2% AEP	45	31	$5,443,696	$816,554	$6,260,251
	0.5% AEP	43	29	$4,827,082	$724,062	$5,551,144
	1% AEP	39	18	$3,956,694	$593,504	$4,550,198

	2% AEP	36	13	$3,281,202	$492,180	$3,773,382
	5% AEP	32	10	$2,675,867	$401,380	$3,077,247
	10% AEP	27	9	$2,307,881	$346,182	$2,654,063
	20% AEP	25	7	$1,945,796	$291,869	$2,237,666
	AAD (after mitigation measure)					$319,229
	AAD Reduction					$19,677
	NPV (after mitigation measure)					$4,724,828
	NPV Reduction					$291,235
	Estimated Cost of Mitigation Measure					$290,000
	B/C Ratio					1.004

Social Assessment

Implementation of this option would occur within 30 m of the Bimbi RFS Shed, and have a low likelihood of affecting the structure. Additionally, 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 come within 10 m of the Bimbi Police Station & Lock-Up, and is highly likely to affect the heritage structure.

Environmental Assessment

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

11.4.2.4 Option PM04 - Voluntary house raising and road levee along Mary Gilmore Way and road levee east of Bimbi

Flood Behaviour Assessment

As the road levee portion of this option is the same as option FM07, the flood level impact of this option over the range of flood event magnitudes was also the same.

Economic Assessment

Table 11-14 details the economic assessment of this option. From this it was found that there was a decrease in damages across all flood events due to the decreased number of residences experiencing above floor flooding.

Table 11-14: PM04 Economic Assessment

	Event (AEP)	Affected by Above Ground Flooding	Affected by Above Floor Flooding	Tangible, Direct Damages	Intangible, Direct Damages	Total Direct Damages
Before mitigation	PMF	50	48	$8,371,422	$1,255,713	$9,627,135
	0.2% AEP	45	36	$5,866,335	$879,950	$6,746,285
	0.5% AEP	43	34	$5,203,460	$780,519	$5,983,979
	1% AEP	39	23	$4,311,112	$646,667	$4,957,779
	2% AEP	36	17	$3,565,604	$534,841	$4,100,445

	5% AEP	32	10	$2,853,322	$427,998	$3,281,320
	10% AEP	27	9	$2,366,397	$354,960	$2,721,356
	20% AEP	25	7	$2,004,312	$300,647	$2,304,959
	AAD (before mitigation measure)					$338,906
	NPV (before mitigation measure)					$5,016,063
After Mitigation	PMF	50	48	$8,256,967	$1,238,545	$9,495,512
	0.2% AEP	45	27	$5,372,105	$805,816	$6,177,920
	0.5% AEP	43	24	$4,583,325	$687,499	$5,270,824
	1% AEP	39	17	$3,794,946	$569,242	$4,364,188
	2% AEP	34	12	$3,164,491	$474,674	$3,639,165
	5% AEP	26	10	$2,364,697	$354,705	$2,719,401
	10% AEP	21	9	$1,996,711	$299,507	$2,296,218
	20% AEP	20	7	$1,689,609	$253,441	$1,943,050
	AAD (after mitigation measure)					$291,648
	AAD Reduction					$47,258
	NPV (after mitigation measure)					$4,316,602
	NPV Reduction					$699,461
	Estimated Cost of Mitigation Measure					$1,880,000
	B/C Ratio					0.372

Social Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that these works were not located within a 30 m radius of any structures of social importance.

Heritage Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that these works would come within 20 m of the Bimbi Police Station & Lock-Up, and have a moderate likelihood of affecting the heritage structure.

Environmental Assessment

When considering the works necessary to implement flood mitigation option FM07, it was found that construction would occur directly within an area of high biodiverse sensitivity along Mary Gilmore Way and the unnamed road, and is highly likely to impact the environment.

11.4.3 Potential Response Modification Measures

11.4.3.1 Option RM01 – Update emergency response plans

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.

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.

11.4.3.2 Option RM02 – Early Warning System

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.

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 11-15 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 11-15: 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	1	-3	-1	3	-1	0	0	-3	-3	=6
FM02	0	-3	-3	-2	0	0	0	-3	-19	13
FM03	0	-3	-1	-3	0	-1	0	-3	-18	12
FM04	0	-3	1	-3	0	0	0	-3	-13	11
FM05	1	-2	2	0	-2	-1	0	-3	-3	=6
FM06	1	2	3	3	0	-1	0	-3	15	1
FM07	1	-2	3	0	-2	-1	0	-3	-1	=5
FM08	-1	-3	-1	3	-3	1	0	-3	-10	10
FM09	0	-3	1	-1	0	0	0	-3	-9	9
FM10	0	-3	-1	3	0	0	0	-3	-5	7
PM01	0	N/A	0	N/A	0	0	0	0	0	=4
PM02	0	-2	0	-2	0	0	0	0	-8	8
PM03	0	1	2	3	-3	0	0	0	9	2
PM04	1	-2	3	0	-2	-1	0	-3	-1	=5
RM01	0	N/A	0	N/A	0	1	0	0	1	=4
RM02	0	N/A	0	3	0	2	0	0	8	3

12 Floodplain Risk Management Plan

12.1 Recommended Measures

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

- RM01 – Update Emergency Response Plans
- RM02 – Early Warning System
- PM01 – Update Development Controls

12.2 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 12-1 lists the implementation plan with consideration given to the aforementioned details. The measures identified would require a total capital expenditure of approximately $95,000.

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

12.3 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 12-1: Implementation plan

Measure ID	Measure Description	Responsibility	Cost	Timeframe (Budget Dependent)	Priority
PM01	Update development controls	Council	$10,000	1 year	High
RM01	Update emergency response plans	Council / SES	$10,000	1 year	High
RM02	Early warning system	Council	$75,000	5 years	Medium

13 References

Ref 1: Australian Emergency Management Institute (2017), *Australian Emergency Management Handbook 7: Managing the Floodplain Best Practice in Flood Risk Management in Australia*, AEMI, Canberra

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 (2018), *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: Henderson, F.M. (1966), *Open Channel Flow*, MacMillan, New York

Ref 7: HydroSpatial Pty Ltd (2021), Bimbi Village Flood Study, Weddin Shire Council

Ref 8: Institute of Engineers, Australia (1987), *Australian Rainfall and Runoff: A Guide to Flood Estimation, Vol. 1*, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted 1998), Barton, ACT

Ref 9: NSW Government (2005), *Floodplain Development Manual: The management of flood liable land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, Sydney

Ref 10: NSW Office of Environment and Heritage (2019), *Floodplain Risk Management Guide: Incorporating 2016 Australian Rainfall and Runoff in Studies*, NSW Government

APPENDIX A
GLOSSARY

The following glossary has been extracted from the Australian Emergency Management Handbook 7 (Ref 1).

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).
Astronomical tide	The variation in sea level caused by the gravitational effects of (principally) the moon and sun. It includes highest and lowest astronomical tides (HAT and LAT) occur when relative alignment and distance of the sun and moon from the earth are 'optimal'. Water levels approach to within 20 cm of HAT and LAT twice per year around mid-summer and mid-winter 'king tides'.
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).
Coastal flooding	Flooding due to tidal or storm-driven coastal events, including storm surges in lower coastal waterways. This can

	be exacerbated by wind-wave generation from storm events.
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.
Ecologically sustainable development	Using, conserving and improving natural resources so that ecological processes on which life depends are maintained, and the total quality of life – now and in the future – can be maintained or increased.
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.
Flash flood	Flood that is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. It is generally not possible to issue detailed flood warnings for flash flooding. However, generalised warnings may be possible. It is often defined as flooding that peaks within six hours of the causative rain.
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).
Habitable room	In a residential situation, a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial or commercial situation, it refers to an area used for offices or to store valuable

	possessions susceptible to flood damage in the event of a flood.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this 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).
Storm surge	The increases in coastal water levels above predicted astronomical tide level (i.e. tidal anomaly) resulting from a range of location dependent factors including the inverted barometer effect, wind and wave setup and astronomical tidal waves, together with any other factors that increase tidal water level (see also astronomical tide, wind set-up and wave set-up).
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.

Tidal anomaly	The difference between recorded storm surge levels and predicted astronomical tide level.
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).
Wave set-up	The increase in water levels in coastal waters (within the breaker zone) caused by waves transporting water shorewards. The zone of wave set-up against the shore is balanced by a zone of wave 'set-down' (i.e. reduced water levels) seawards of the breaker zone. Wave setups of 2-4 m could occur during tropical cyclones.
Wind set-up	The increase in water levels in coastal waters caused by the wind driving the water shorewards and 'piling it up' against the shore. Wind set-up can be as high as 10 m in an extreme case, and often exceeds 2-3 m in typical tropical cyclones.

APPENDIX B
EXISTING CATCHMENT CHARACTERISTICS

Please refer to the Bimbi Village Floodplain Risk Management Study and Plan Report Volume 2.

APPENDIX C
POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES

Please refer to the Bimbi Village Floodplain Risk Management Study and Plan Report Volume 2.

APPENDIX D
ESTIMATE OF BENEFITS

Please refer to the Bimbi Village Floodplain Risk Management Study and Plan Report Volume 2.

APPENDIX E
ESTIMATE OF COSTS

Please refer to the Bimbi Village Floodplain Risk Management Study and Plan Report Volume 2.