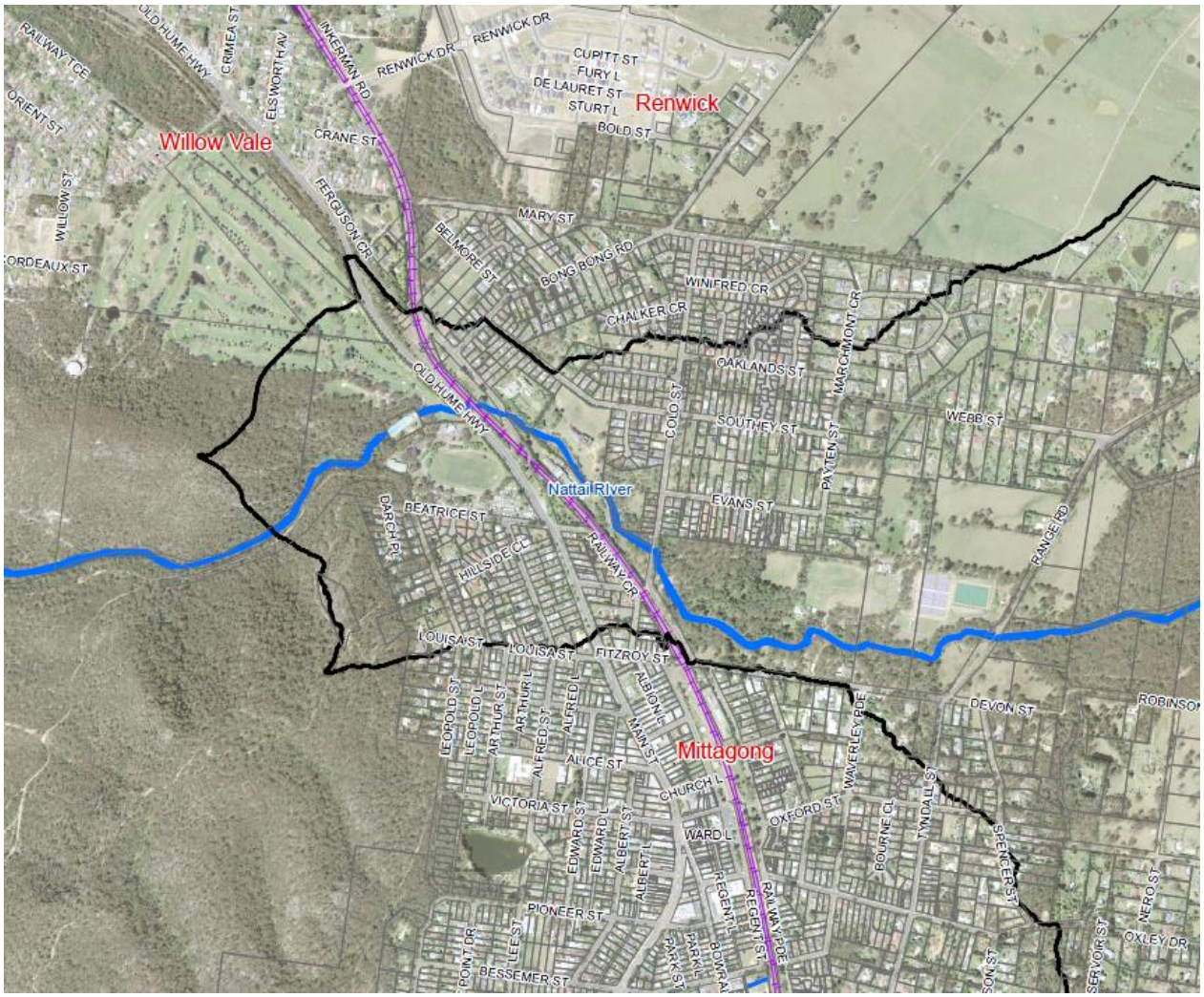
WINGECARRIBEE SHIRE COUNCIL

NATTAI RIVER
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
FINAL REPORT



wma water

September 2016

Level 2, 160 Clarence Street
Sydney, NSW, 2000

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

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SEPTEMBER 2016

Project Nattai River Floodplain Risk Management Study and Plan Final Report	**Project Number** 115033
Client Wingecarribee Shire Council	**Client's Representative** Sha Prodham
Authors Dan Morgan Catherine Goonan Ella Harrison	**Prepared by**
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TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff have produced a set of draft guidelines for appropriate terminology when referring to the probability of floods. In the past, AEP has generally been used for those events with greater than 10% probability of occurring in any one year, and ARI used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, EY.

Annual Exceedance Probability (AEP) is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

Where the % AEP of an event becomes very small, for example in events greater than the 0.02 % AEP, the ARR draft terminology suggest the use of 1 in X AEP so a 0.02 % AEP event would be the same as a 1 in 5,000 AEP.

The PMF is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum Precipitation.

This report has adopted the approach of the ARR draft terminology guidelines and uses % AEP for all events greater than the 10% AEP and EY for all events smaller and more frequent than this.

EY	AEP (%)	AEP (1 in x)	ARI	Use
6	99.75	1.002	0.17	WSUD
4	98.17	1.02	0.25	
3	95.02	1.05	0.33	
2	86.47	1.16	0.50	
1	63.21	1.58	1.00	
0.69	50.00	2	1.44	Stormwater/pit and pipe design
0.5	39.35	2.54	2.00	
0.22	20.00	5	4.48	
0.2	18.13	5.52	5.00	
0.11	10.00	10	9.49	
0.05	5.00	20	20	Flooding
0.02	2.00	50	50	
0.01	1.00	100	100	
0.005	0.50	200	200	
0.002	0.20	500	500	
0.001	0.10	1000	1000	
0.0005	0.05	2000	2000	Limit CRC FORGE
0.0002	0.02	5000	5000	Extreme risk /Dams
PMF	**1 x 10^{-5} AEP - 1 x 10^{-7} AEP**			

A copy of the draft terminology is available at: http://www.arr.org.au/arr-guideline/draft-chapters/

FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government co-funds floodplain risk management studies, plans and measures to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

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

1. Data Collection

- Data requirements for an ensuing flood study are assessed. Existing data sets are assessed for usability and existing reports collected and summarised.

2. Flood Study

- Determine the nature and extent of the flood problem.

3. Floodplain Risk Management

- Evaluates management options for the floodplain in respect of both existing and proposed development.

4. Floodplain Risk Management Plan

- Involves formal adoption by Council of a plan of management for the floodplain.

5. Implementation of the Plan

- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Nattai River Floodplain Risk Management Study and Plan (FRMS&P) presented herein constitutes the third and fourth stages of the NSW Floodplain Risk Management Program for these catchments. Prior to commencement of the FRMS&P, a review of the 2013 Flood Study (Reference 3) was undertaken and the results updated for the catchment.

WMAwater has been engaged by Wingecarribee Shire Council to prepare this Study under the guidance of Council's Floodplain Risk Management Advisory Committee.

EXECUTIVE SUMMARY

This Floodplain Risk Management Study assesses floodplain management issues in the Nattai River catchment, and investigates potential management options for the area. The study, which follows on from the Nattai River Flood Study (Reference 3), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the catchment, over floor flooding of residential, commercial and industrial properties, road flooding and emergency response during a flood event. A range of mitigation options aimed at managing this flood risk were also assessed for their efficacy across a range of criteria, which allowed certain options to be recommended, forming the basis of the Floodplain Risk Management Plan for the area. Mitigation options included upgraded culvert works, emergency management measures, and various property modification measures including Development Control Planning. The mitigation options investigated are outlined in Table 1.

Table 1 Nattai River Management Options for Investigation

Option	Description
FM01	Removal of weir upstream of Swimming Pool
FM02	Removal of weir and Swimming Pool
FM03	Removal of weir at Maltings
FM04	Increase channel at Evans Street Waterway
FM05	Upgrade Colo Street
FM06	Combination of FM04 and FM05
PM01	Changes to FPL and FPA
PM02	Amendments to s149 Certificates
PM03	Changes to Floodplain Risk Precincts (FPRs)
RM01	Amendments to Wingecarribee Shire Local Flood Plan (Volume 2)
RM02	Installation of Flood Signs and Depth Indicators to frequently inundated roads

Background

The Nattai River catchment in the suburb of Mittagong is located in Wingecarribee Shire in the Southern Highlands of NSW about 130 km south west of Sydney. The Nattai River catchment drains to Lake Burragorang as part of the Hawkesbury/Nepean catchment. The Nattai River drains in a northerly direction through the eastern section of Mittagong until it flows beneath the Old Hume Highway and the swimming pool. Further downstream it is joined by Gibbergunyah Creek.

The Nattai River Flood Study (2013) was carried out to define existing flood behaviour for the catchment in terms of flood levels, depth, velocities, flows, hydraulic categories and provisional hazard. An XP-RAFTS hydrological model was adopted to convert rainfall into runoff hydrographs

to be applied as input boundaries into the hydraulic model. The TUFLOW model consisted of a linked 1D/2D hydraulic model of the creek, floodplain, stormwater network and overland flow path. The model was used to define flood depths and levels for the 5 year ARI, 10%, 5%, 2%, 1%, 0.2% AEP design flood and PMF events. Several flooding hot spots were also identified in the study. In addition, a desktop floor level survey and damages assessment were undertaken to identify properties that are liable to over floor inundation.

Existing Flood Environment

Flooding across the Nattai River catchment can occur as a result of major watercourses overtopping their banks, as well as from overland flooding when the capacity of the stormwater system is exceeded. A number of locations within the catchment have been identified as flood liable, including Evans St between Payten and Colo Street (along which houses back on to a natural waterway), the Mittagong Swimming Centre and Oxley Drive between Bracken and Reservoir Street.

Four residential properties within the catchment are liable to inundation on the property in the 1% AEP event, while 2 properties are liable in the 5 year ARI event. Of these, 2 properties are liable to over floor inundation in the 1% AEP event, and 1 in the 5 year ARI event. A flood damages assessment for existing development was undertaken, with the average annual damages (for residential properties) estimated to be approximately $52,000 for the catchment. With a small number of commercial properties in the catchment, the damages were also calculated for non-residential properties. The 1% AEP event would cause inundation of 2 properties (only 1 above floor level). No commercial properties are flood affected in the 5 year ARI event. The annual average damages was calculated to be approximately $11,000 for the catchment.

Flood Risk Management Options

The Floodplain Risk Management Study also included an investigation of possible options for the management of flood risk in the area. These included structural works such as drainage and culvert upgrades, as well as planning measures and SES-related actions. The measures were assessed for their ability to reduce flood risk while also considering their economic, social and environmental impact. A multi-criteria matrix assessment was used to directly compare the options. Of the seven flood mitigation options considered, none offered any reduction in over-floor damages and hence have not been included for implementation. Two property modification measures and one response modification measure were however included, as shown in Table 2.

Table 2 Nattai River Management Options for Implementation

Ref	Options	Priority
PM01	Changes to FPL and FPA	High
PM02	Amendments to s149 Certificates	Medium
PM03	Changes to Floodplain Risk Precincts (FPRs)	Medium
RM01	Amendments to Wingecarribee Shire Local Flood Plan (Volume 2)	High
RM02	Installation of Flood Signs and Depth Indicators to frequently inundated roads	High

1. INTRODUCTION

1.1. Study Area

Nattai River catchment in the suburb of Mittagong is located in Wingecarribee Shire in the Southern Highlands of NSW about 130km south west of Sydney. The study area is shown in Figure 1. The Nattai River catchment drains to Lake Burragorang as part of the Hawkesbury/Nepean catchment. Nattai River drains in a northerly direction through the eastern section of Mittagong until it flows beneath the Old Hume Highway and the swimming pool. Further downstream it is joined by Gibbergunyah Creek.

1.2. Floodplain Management Process

As described in the Floodplain Development Manual (Reference 1), the floodplain risk management process is formed of sequential stages:

- Data Collection;
- Flood Study;
- Floodplain Risk Management Study;
- Draft Floodplain Risk Management Plan; and
- Plan Implementation.

The first key stage of the process has been undertaken with the completion of the Data Collection and Nattai River Flood Study (Reference 3). Following this, the Draft Floodplain Risk Management Study and Plan (FRMS&P) are undertaken for the catchment in two phases:

Phase I – Draft Floodplain Risk Management Study in which the floodplain management issues confronting the study area are assessed, management options investigated and recommendations made. The objectives of this phase for Nattai River catchment include:

- Review of Council's existing environmental planning policies and instruments including Council's long term planning strategies for the Study Area;
- Obtain damage estimates under the range of design floods under existing conditions;
- Identification of works, measures and restrictions aimed to reduce the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;
- To assess the effectiveness of the works and measures for reducing the effect of flooding on the community and development, both existing and future;
- To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.

- Examine ways in which the river and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding; and
- Identification of modifications to current policies required in the light of investigations.

Phase II – Draft Floodplain Risk Management Plan which is developed from the Floodplain Risk Management Study and details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with flood hazard now and in the future. The Plan consists of prioritised and costed measures for implementation.

1.3. Available Data

1.3.1. Digital Elevation Model (DEM)

The DEM was created using the data from an Aerial Laser Survey (ALS) provided by Land and Property Information (LPI). The DEM is shown in Figure 2. The DEM was created to be applied as the base for the TUFLOW 1D/2D hydraulic model.

The ALS has a horizontal accuracy of +/- 0.55m and a vertical accuracy of +/- 0.15m. It should be noted that the accuracy of the ALS can be adversely affected by the nature and density of vegetation, the presence of varying terrain, the vicinity of buildings and/or the presence of water.

1.3.2. GIS Data

WSC has provided the following GIS data for the study:

- Stormwater pits – Location of stormwater inlet pits. Does not provide entrance or invert levels;
- Stormwater pipes – Location, size and length of stormwater pipes. Does not provide pipe inverts;
- Easements – Locations of easements and in some instances the easement width;
- Roads – Location of roads, road name and road type;
- Cadastre – Cadastre for the suburb of Mittagong;
- Zoning – Land zoning for the Wingecarribee Shire LGA; and
- Aerial – Aerial photograph of the study area at 0.5m pixels size

1.4. Floor Level Survey

A floor level survey was not undertaken for the suburb of Mittagong. It was decided through consultation with WSC that the floor levels of properties within the PMF extent would be estimated by WMAwater using the DEM provided from (Reference 3) and Google Street View. This was determined to adequately meet the requirements of the study and was far more cost effective than contracting a surveyor.

1.5. Previous Studies

1.5.1. Nattai River Flood Study – Catchment Solutions January 2014

The Flood Study completed by Catchment Simulations Solution in January 2014 was undertaken to determine design flood behaviour for events ranging from the 20% AEP event to the PMF for Nattai River catchment. The study area encompasses Nattai River from its origin at the intersection of Range Road and Old South Road in Mittagong, through the eastern sections of Mittagong, under the Old Hume Highway finishing downstream of the swimming pool.

A hydrological model XP-RAFTS was adopted to convert rainfall into runoff hydrographs to be applied as input boundaries into the TUFLOW 1D/2D hydraulic model. The TUFLOW model consisted of a linked 1D/2D hydraulic model of the creek, floodplain, stormwater network and overland flow path. The 2D domain of the TUFLOW model consisted of a 2 m grid that was based on a Digital Elevation Model (DEM). The DEM was derived from an Air Laser Survey (ALS) and 10 m contours of the areas not covered by the ALS.

The study provides detailed flood depth and flood level mapping of the study area as well as mapping of provisional hydraulic hazards and hydraulic categorisations.

1.5.2. Mittagong Drainage Master Plan – Catchment Simulation Solutions May 2013

The Mittagong Drainage Master Plan was completed by Catchment Simulation Solutions in September 2013.The report documents the nature and extent of the existing drainage problem across West Mittagong and identifies potential measures for mitigating the drainage problem. Eight drainage upgrades were identified for potential investigation. A preliminary evaluation selected four upgrades to be modelled to determine their hydraulic benefits. The options were:

- Option 2 – Upgrade of pits, pipes and overland flow system between John Street and Thomas Street.
- Option 3 – Upgrade of pits, pipes and culvert system between Hood Street and Spring Street.
- Option 4 – Upgrade of pits, pipes and overland flow system between Old Bowral Road and Cook Street.
- Option 5 - Upgrade of pits, pipes and overland flow system between Old Bowral Road and Old Hume Highway.

It was recommended that each of the four options be implemented if funding was available. Cost estimates for each option are provided in the report.

2. CATCHMENT CHARACTERISTICS

2.1. Land Use

Assessment of the Nattai River Catchment showed that land use was approximately split into:

- Urban (34%) – Imperviousness (30%)
- Rural/Open space (47%)
- Bush land (19%)

The rural/open space mainly consists of large privately owned properties in the upstream section of the catchment adjacent to Old South Road and Range Road. The bushland consists of heavily vegetated areas between Old South Road and Range Road and downstream of the swimming pool. The urban area is made up of residential, business, light industry and special uses and is mainly located within the middle of the catchment area.

The *Wingecarribee Local Planning Strategy 2015 – 2031* (see Section 4.3.2) provides details of predicted development across the Shire, which estimates that between 501 – 1000 additional dwellings will be required in Mittagong township. This represents a 22 – 45% increase on the number of occupied dwellings recorded in the 2011 census (see Section 2.3). It is expected that 75% of these new dwellings will be in the form of detached dwellings. The Local Planning Strategy also concluded that the forecasted demand could readily be accommodated from within existing land zonings, which have an estimated capacity of 4,811 additional dwellings.

2.2. Environmental Characteristics

All of Wingecarribee Shire is part of the catchment area for water supply to Sydney, Wollongong and the Northern Shoalhaven. The Shire contains extensive areas of natural bushland and is recognised as a key locality for koala habitat. The Shire has a rich heritage which is recognised in the list of 327 heritage items, 16 heritage conservation areas and 8 archaeological sites, including items listed on the State Heritage Register.

The Nattai River catchment is situated within Wingecarribee Shire and consists of extensive rural areas, urban developments and natural bushland. The environmental features of interest within this catchment are:

- The catchment has numerous areas classified as general heritage areas, conservation areas and archaeological areas. A significant archaeological area extends south of Hume Highway in the northern area of the catchment. South of this archaeological area is a general heritage area and a conservation area both north and south of the old Hume Highway.
- The majority of waterways within Nattai River Catchment have been classified under the category Bank Stability and Water Quality except for a small area categorised as Aquatic and Terrestrial Habitat and Nattai River, which is defined as an Environmental Corridor.
- There is one small area specified as Land Reservation and Acquisition.

2.3. Demographic Characteristics

The statistical information provided in this section is an analysis of the entire suburb of Mittagong with postcode 2575. The data is based on the Australian Bureau of Statistics' 2011 Census data, and is summarised in Table 3 below.

Table 3 Census data summary

	NSW	Mittagong	2575
Population Age:			
0 – 14 years	19.2%	18.2%	21.5%
15 - 64 years	66.1%	58.5%	62.1%
> 65 years	14.7%	23.3%	16.5%
Average people per dwelling	2.6	2.3	2.6
Own/mortgage property	66.6%	69.8%	75.8%
Rent property	30.1%	26.3%	21.2%
Moved into area:			
- within last year	-	14.8%	13.4%
- within last five years	-	40%	37.1%
No cars at dwelling	10.9%	7.2%	4.7%
Speak only English at home	72.5%	91.2%	91.4%

The population of Mittagong in 2011 was 8,432 with a median age of 44. Statistics show 18% of the population below the age of 14 and 51% of the population below the age of 44. This could be explained by young families moving into newly developed areas.

English is the main language spoken at home with 95% of the population identifying English as their first language. The Wingecarribee Shire Community Engagement Policy states 'All materials and methods developed by Council to support community engagement will be genuine, unbiased, understandable and appropriate to ensure the community can participate in a meaningful way'. The use of English in any community consultation brochures, questionnaires or press releases will be adequate for this study.

In the 2011 Census there were 2,186 occupied dwellings in Mittagong with a breakdown of type shown in Table 4.

Table 4 Dwelling Structures

Dwelling Structure	Number	Percentage
Separate House	1925	88.1%
Semi-detached, Terrace or Townhouse	124	5.7%
Flat, Unit or Apartment	83	3.9%
Other Dwelling	50	2.3%
Total	2186	100%

2.4. Key Infrastructure on the Floodplain

Key infrastructure in the floodplain are those that impact on flood levels, for example upstream backwatering (and retention of floodwater) and lower levels in the downstream (relative to the case if the major structure was not there). Some of these may be deliberate flood management measures to control flooding. Key infrastructure within the Nattai River Catchment is summarised in the Flood Study (Reference) including location map and photographs.

In Mittagong, the key infrastructure affecting the Nattai River and its tributaries include the railway embankment and the Old Hume Highway, which are generally well built up. Both of these embankments are crossed by the river, and when the culvert capacities are exceeded act as weirs, backing up flow on the upstream sides. The swimming pool, the weir upstream of the pool and the weir at The Maltings also have an effect on the river levels, and their removal has been explored. (see Section 7).

3. EXISTING FLOOD BEHAVIOUR

The existing flood behaviour was determined in the Flood Study (Reference 3) and is caused by the Nattai River overtopping its banks as well as overland flow conveyed towards the waterways. The peak flood depths and levels for the 20%, 10%, 5%, 2%, 1%, 0.5% AEP and PMF events are shown in Figure 3 to Figure 9. The main flood affected areas in the catchment are as follows:

3.1.1. Evans Street between Payten Street and Colo Street

A small waterway and overland flow path originates in Argyle Street and flows in a north westerly direction until it reaches Payten Street. From Payten Street it traverses through the properties in Evans Street inundating the backyards and trapped low points of the properties until the waterway crosses Colo Street. The peak flood depths and flows at approximately the half way point between Payten Street and Colo Street for the 20%, 5% and 1% AEP events are shown in Table 5.

Table 5 Peak Depths and Flows Evans Street Waterway

Design Flood Event	Peak Flow (m^3s)	Peak Depth (m)
20% AEP	4.4	0.98
5% AEP	9.6	1.22
1% AEP	16.4	1.44

3.1.2. Mittagong Swimming Centre

The Mittagong Swimming Centre is located on top of the Nattai River downstream of the Old Hume Highway. A culvert, with dimensions 2.1 m x 1.2 m conveys flows beneath the swimming pool. Once the capacity of the culvert is reached the swimming pool is overtopped. The swimming pool is overtopped in all design events. The peak flood depths and the peak flows above the swimming pool for the 20%, 5% and 1% AEP events are shown in Table 6.

Table 6 Peak Depths and Flows Mittagong Swimming Pool

Design Flood Event	Peak Flow (m^3s)	Peak Depth (m)
20% AEP	50.4	1.22
5% AEP	83.5	1.59
1% AEP	132.0	2.01

3.1.3. Oxley Road between Nero Street and Murchison Street

An overland flow path originates west of Oxley Street travelling in an easterly direction until it reaches the Nattai River. Oxley Road is overtopped and nearby properties are inundated. The peak flood depths on Oxley Road are shown in Table 7.

Table 7 Peak Depths Oxley Road

Design Flood Event	Peak Depth (m)
20% AEP	0.15
5% AEP	0.24
1% AEP	0.3

3.2. Flood Emergency Response Planning

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 1) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines (Reference 16), communities are classified as either; Flood Islands; Road Access Areas; Overland Escape Routes; Trapped Perimeter Areas or Indirectly Affected. The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 8).

Table 8 Emergency Response Planning Classifications of Communities

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

Key considerations for flood emergency response planning in these areas include:

- Cutting of external access isolating an area;
- Key internal roads being cut;
- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres, emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
- The extent of the area flooded.

Flood liable areas within the study area have been classified according to the ERP classification above, with the additional criteria of flood depths being greater than 0.1 m as people can move through this depth of water without concern. Therefore, all flood depths of less than 0.1 m were removed from the PMF flood extents prior to classification. The ERP classifications for the study area are shown in Figure 10.

3.3. Hydraulic Categories

3.3.1. Introduction

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to different areas of the floodplain; namely floodway, flood storage or flood fringe. Floodway describes areas of significant discharge during floods,

which, if partially blocked, would cause a significant redistribution of flood flow. Flood storage areas are used for temporary storage of floodwaters during a flood, while flood fringe is all other flood prone land.

There is no single definition of these three categories or a prescribed method to delineate the flood prone land into them. Rather, their categorisation is based on knowledge of the study area, hydraulic modelling and previous experiences. The Flood Study (Reference 3) defined hydraulic categories as:

Floodway:	Velocity x Depth > 0.3 m^2/s AND Velocity >0.5 m/s
Flood Fringe	Velocity <0.4 m/s AND Depth <= 0.05 m
Flood Storage:	If not Floodway or Flood Fringe

The Floodplain Development Manual (Reference 1) provides definitions for all three categories, however these are descriptive definitions and aren't suitable for directly calculating/assessing the categories. The definitions as per Reference 1 are provided below for clarity.

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Two further definitions that are suitable for directly calculating/assessing the floodway extent and that are widely used to describe the characteristics of the floodway are described below:

1. The extent which comprises a significant proportion of flow in a flow path (80 to 90% is often used as the portion of flow within the floodway); and

2. The extent which if partially blocked causes impacts in excess of 0.1 m to occur upstream of the partial blockage.

These two definitions have been used to assist in determining the floodway extent for the Nattai River.

3.3.2. Approach

There is no definitive method for defining a floodway, and it is often an iterative process. In the context of 1D/2D models, a raster presents flood modelling outputs for each grid cell in the given study area. The velocity depth (VD) product for each cell can, and has in previous studies, been used to define the floodway.
The Floodplain Development Manual (Reference 1) recommends encroachment analyses to check the delineations of categories determined by the criteria set out in this section. This was carried out for the Nattai River Catchment by artificially increasing the roughness of areas zoned as 'flood storage', and ensuring this did not cause an increase in levels in the 'floodway' of over 150 mm.

The hydraulic categories for the 1% AEP event and PMF is shown on Figure 11 and Figure 12.

3.4. Flood Hazard Classification

Flood hazard is a measure of the overall adverse effects of flooding and the risks they pose. The 2005 NSW Government's Floodplain Development Manual (Reference 1) describes two *provisional flood hazard* categories; High and Low, based on the product of the depth and velocity of floodwaters. These hazard categories do not consider other factors which may influence the flood hazard (Figure L2 of the Floodplain Development Manual); hence they are a provisional estimates only with "true" hazard to be defined through the process of the current study. The boundary of the provisional High and Low hazard classification will change according to the magnitude of the flood in question.

Provisional hazard was established as part of the Flood Study (Reference 3) based on the Floodplain Development Manual criteria (Appendix L of the Floodplain Development Manual).
To assess the true flood hazard, all adverse effects of flooding have to be considered. This includes the provisional (hydraulic) hazard, threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production including those detailed in Table 9. The classification is a qualitative assessment, which results in two categorisations:

High Hazard - *an area or situation where there is possible danger to personal safety, evacuation by trucks is difficult and able-bodied adults would have difficulty in wading to safety. There could also be potential for significant structural damage to buildings.*

Low Hazard - *people and possessions can still be evacuated by trucks if necessary and able-bodied adults would have little difficulty wading to safety.*

Table 9 Hazard Classification

Criteria	Comment
Size of the Flood	Relatively low flood hazard is associated with more frequent minor floods while the less frequent major floods are more likely to present a high hazard situation.
Depth & Velocity of Floodwaters	The provisional hazard is the product of depths and velocity of flood waters. These can be influenced by the magnitude of the flood event.
Rate of Rise of Floodwaters	Rate of rise of floodwaters is relative to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events.
Duration of Flooding	The greater the duration of flooding the more disruption to the community and potential flood damages. Permanent inundation due to sea level rise is of indefinite duration.
Flood Awareness and Readiness of the Community	General community awareness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood aware community is unlikely to be wise to the impacts of a larger, less frequent, event.
Effective Warning & Evacuation Time	This is dependent on rate at which waters rise, an effective flood warning system and the awareness and readiness of the community to act.
Effective Flood Access	Access is affected by the depths and velocities of flood waters, the distance to higher ground, the number of people using and the capacity of evacuation routes and good communication.
Evacuation Problems	The number of people to be evacuated and limited resources of the SES and other rescue services can make evacuation difficult. Mobility of people, such as the elderly, children or disabled, who are less likely to be able to move through floodwaters and ongoing bad weather conditions is a consideration.
Provision of Services	In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Permanent inundation from sea level rise may lead to permanent loss of services.
Additional Concerns	Floating debris, vehicles or other items can increase hazard. Sewerage overflows can occur when river levels are high preventing effective discharge of the sewerage system.

Due to the nature of flooding in the Nattai River Catchment, the extent of flooding is generally confined to the creek channels and some minor overland flow paths up to the 0.5% AEP event with only 2 houses flooded above floor level. In the PMF the flood extent is increased dramatically as the capacity of the culvert under the Old Hume Highway and railway line is exceeded. Both these embankments act as weirs, backing up flow on the upstream side resulting in 17 properties being flooded above floor level.

Larger flood events in the catchment are associated with increased depths and velocities, however, this is largely accounted for by the provisional hazard criteria being considered for these events.

A fast rate of rise can leave residents unaware of the flood event, and they can become stranded in their homes or on high flood islands. The rate of rise for this catchment is fast (up to 1.5 – 2 m/h in the Evans Street waterway and up to 2.5 – 3.5 m/h in the Nattai River upstream of the Old Hume Highway) and flood prone areas will become inundated soon after the rainfall event begins. If evacuation is required in the catchment, the fast rate of rise will likely mean it is undertaken after the peak flood level.

Flood awareness in the community appears to be moderate, with 57% of questionnaire respondents aware of the Flood Study and that their properties were classified as flood affected. This is likely to exaggerate the awareness, as only 14% of those surveyed responded and flood affected community members are more likely to respond to flood related surveys.

Effective warning and evacuation time in the catchment is relatively low, as the flooding is likely

to be sudden, with a fast rate of rise. For a resident without additional warning or forecast, flood events will initially resemble more benign (but still heavy) storms, with awareness of the flood coming from direct experience of it. However, effective access, which refers to an exit route that remains trafficable for sufficient time to evacuate people and possessions, is likely to be available to the majority of affected residents up to the 0.5% AEP event as the flooding is contained in the Nattai River and tributary waterways. The vehicular and pedestrian access routes are all along sealed roads with no unexpected hazards if the roads have been adequately maintained. In the PMF the properties on Evans Street have the evacuation route via Payten Street cut but they still have pedestrian evacuation access through residential properties or adequate high ground to evacuate to.

At depths of 0.3 m wading should be possible for most mobile adults, but could be problematic for children, elderly or disabled people. The majority of flood prone properties in the catchment do have access with flood depths of 0.3 m or less up to the 0.5% AEP events.

At a depth of 0.3 m, larger vehicles can easily travel through water and aid evacuation. Nevertheless, for areas within the catchment without effective flood access, evacuation is generally not recommended considering the short duration of flooding experienced as residents are more likely to put themselves in harm's way by evacuating.

The impact of debris is unlikely to be a significant factor due to the low flood depths and/or velocities for large parts of the catchment outside the river channel. It would impact the time of inundation as waters would take longer to recede, however as the duration of the flooding is generally short across the catchment this is not considered significant.

The main concerns in the Nattai River Catchment are the properties on Evans Street, the Mittagong Swimming Centre and adjacent Golf Course and the overtopping of roadways on the Old Hume Highway, Colo Street, Payten Street, Range Road and Oxley Drive which may pose a hazard to pedestrians and motorists. Several works are proposed in Section 7 to mitigate these hazards.

3.4.1. Wingecarribee Shire Council Hazard Categories

Wingecarribee Shire Council has defined their own hazard classifications based on the following:

- High Hazard Flood Extent – Discussed above (Appendix L of the Floodplain Development Manual) and Table 9;
- 1% AEP Flood Extent – Current study;
- Flood Planning Area – Current study (Section 7.10); and
- PMF Flood Extent - Current study.

The four hazard categories are:

High Flood Risk Precinct
Land below the 1% AEP flood level that is either subject to high hydraulic hazard or where there are significant evacuation difficulties.

Medium Flood Risk Precinct
Land below the 1% AEP flood level that is not subject to high hydraulic hazard and where there are no significant evacuation difficulties.

Fringe Low Flood Risk Precinct
Land between the 1% AEP flood extent and a level 0.5m above the 1% AEP flood level.

Low Flood Risk Precinct
Land with a low probability of flooding lying above a level 0.5m above the 1% AEP flood and below the probable maximum flood (PMF).

The hazard categories for the Nattai River catchment are shown in Figure 13.

4. PLANNING AND POLICY REVIEW

4.1. Floodplain Management Policy

It is important to understand the state legislation that overarches all local planning so as to enable appropriate floodplain risk management measures to be proposed that are in keeping with both state and local statutory requirements. This section discusses the state legislation that influences planning in relation to flood risk at the local government level.

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling development.

Pursuant to Section 117(2) of the EP&A Act, the Minister has directed that Councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. Specifically, Direction 4.3 states:

Objectives

- *The objectives of this direction are:*
- *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*
- *to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.*

Clause (3) of Direction 4.3 states:

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

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

- *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).*
- *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.*
- *A planning proposal must not contain provisions that apply to the flood planning areas which:*
- *permit development in floodway areas,*
- *permit development that will result in significant flood impacts to other properties,*
- *permit a significant increase in the development of that land,*

- *are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or*

- *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.*

- *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).*

- *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).*

- *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:*

- *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*

- *the provisions of the planning proposal that are inconsistent are of minor significance.*

4.1.1. NSW Flood Prone Land Policy

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

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

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

The NSW Floodplain Development Manual 2005 (the Manual), relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

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

The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it

recognises that a different emphasis is required to address issues particular to a rural floodplain. These issues include:

- The large area of land under investigation;
- The complexity of flood behaviour;
- The impacts of protection works for valuable crops on flood behaviour;
- The period of inundation;
- The uncertainties associated with flood related data, and
- The environmental values associated with flood dependent ecosystems on a rural floodplain.

4.1.2. Section 149 Planning Certificates

Section 149 of the EP&A Act states:

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

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

- *(Repealed)*

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

The Environmental Planning and Assessment Regulation 2000 prescribes the matters which must be included in a s.149 Planning Certificate, including whether a parcel of land is subject to controls relating to flooding.

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

The aims of State Environmental Planning Policy (Exempt and Complying Development) 2008 are:

This Policy 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, and*

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

- *identifying, in the complying development codes, types of complying development that may be*

carried out in accordance with a complying development certificate as defined in the Act, and

- *enabling the progressive extension of the types of development in this Policy, and*

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

4.1.4. General Housing Code

Part 3 of the SEPP relates to the *"General Housing Code"*.

Division 1 of Part 3 of the SEPP, which comprises clauses 3.1-3.6 of the SEPP, relates to:

Development that is complying development under this code

Clause 3.1 states:

3.1 Land to which code applies

This code applies to development that is specified in clauses 3.2-3.5 on any lot in Zone R1, R2, R3, R4 or RU5 that:

(a) has an area of at least 200 m^2, and

(b) has a width, measured at the building line fronting a primary road, of at least 6 m.

Clause 3.2 of the SEPP states:

3.2 New single storey and two storey dwelling houses

The erection of a new single storey or two storey dwelling house is development specified for this code.

Clauses 3.3-3.5 generally relate to single and two storey dwelling houses and ancillary development.

Division 2 of Part 3 of the SEPP contains:

Development standards for this code

Subdivision 9 contains:

Development standards for particular land

Subdivision 9 contains Clause 3.36C of the SEPP which relates to development standards for the General Housing Code on *"flood control lots"*. A *"flood control lot"* is defined in the SEPP as:

flood control lot *means a lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).*

Note. *This information is a prescribed matter for the purpose of a certificate under section 149 (2) of the Act.*

As such, a *"flood control lot"* is a lot where the Council has provided for flood related development controls, which are all lots with notation on a s.149 Planning Certificate that flood related development controls apply. This is generally land which falls within the *"Flood Planning Area"*.

Clause 3.36C states:

3.36C Development standards for flood control lots

(1) This clause applies:

(a) to all development specified for this code that is to be carried out on a flood control lot, and

(b) in addition to all other development standards specified for this code.

(2) The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering as not being any of the following:

(a) a flood storage area,

(b) a floodway area,

(c) a flow path,

(d) a high hazard area,

(e) a high risk area.

(3) The development must, to the extent it is within a flood planning area:

(a) have all habitable rooms no lower than the floor levels set by the council for that lot, and

(b) have the part of the development at or below the flood planning level constructed of flood compatible material, and

(c) be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and

(d) not increase flood affectation elsewhere in the floodplain, and

(e) have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and

(f) have open car parking spaces or carports that are no lower than the 20-year flood level, and

(g) have driveways between car parking spaces and the connecting public roadway that

will not be inundated by a depth of water greater than 0.3 m during a 1:100 ARI (average recurrent interval) flood event.

(4) A standard specified in subclause (3) (c) or (d) is satisfied if a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering confirms that the development:

(a) can withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), or

(b) will not increase flood affectation elsewhere in the floodplain.

(5) If a word or expression used in this clause is defined in the Floodplain Development Manual, the word or expression has the same meaning as it has in that Manual unless it is otherwise defined in this clause.

(6) In this clause:

***flood compatible material** means building materials and surface finishes capable of withstanding prolonged immersion in water.*

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

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

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

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

4.1.5. Rural Housing Code

Part 3A of the SEPP contains the *"Rural Housing Code"*.

Division 1 of Part 3A of the SEPP defines:

Development that is complying development under this code

Clauses 3A.1 and 3A.2 state:

3A.1 Land to which code applies

This code applies to development that is specified in clauses 3A.2-3A.5 on lots in Zones RU1, RU2, RU3, RU4, RU6 and R5.

3A.2 New single storey and two storey dwelling houses

(1) The erection of a new single storey or two storey dwelling house is development specified for this code if the development is erected on a lot:

(a) in Zone RU1, RU2, RU4 or RU6 that has an area of at least 4,000 m^2, or

(b) in Zone R5.

(2) This clause does not apply if the size of the lot is less than the minimum lot size for the erection of a dwelling house under the environmental planning instrument applying to the lot.

Clause 3A.38 contains:

Development standards for flood control lots

The development standards contained in clause 3A.38 are the same as those contained in clause 3.36 as detailed above.

4.1.6. Summary of State Legislative and Planning Polices

From the above discussion of both the General Housing Code and the Rural Housing Code, it is clear that, unless a lot affected by flooding is included as a *"flood control lot"*, a s.149 notification is not required and, as a result, planning controls relating to flooding do not apply and a Complying Certificate can be granted without having regard to any Council flood controls. This scenario has considerable implications with regard to Council deciding whether a lot which is flood affected is included in the Flood Planning Area.

4.2. Local Council Policy

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding. Plans and Polices have been discussed below and later have been reviewed in regards to flood risk management to identify where improvements might be made (see Section 7.10).

A LEP guides land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and Development Planning Controls (DCPs). LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. Wingecarribee Shire Council's LEP was adopted in 2010 and was prepared under the Standard Instrument LEP program.

4.2.1. Wingecarribee Local Environment Plan (LEP) (2010)

Chapter 7.9 of the LEP is title *Flood Planning* and states:

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

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

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

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

(2) This clause applies to :
(a) land that is shown as "Flood Planning Area" on the Flood Planning Area 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) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

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

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

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

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

(5) In this clause:
***flood planning level** means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5m freeboard*
***Flood Planning Area Map** means the Wingecarribee Local Environmental Plan 2010 Flood Planning Area Map*

4.2.2. Mittagong Development Control Plan (DCP) (2010)

The Development Control Plan (DCP) provides a comprehensive review on the development controls, standards and provisions that apply within the Wingecarribee Shire LGA. Section 4 of the DCP 'Flood Liable Land' serves to guide development to ensure risk to life and property associated with flooding is minimised in a manner consistent with the Policies of Council

formulated under the NSW Government's Flood Prone Land Policy and Floodplain Development Manual.

In the Mittagong DCP land within the Probable Maximum Flood (PMF) extent is categorised into four Flood Risk Precincts (FRPs) in order to grade the relative severity of flood risks across the floodplain and thereby provide a basis for assigning development controls. The FRPs are:

- High Flood Risk Precinct
- Medium Flood Risk Precinct
- Fringe-Low Risk Flood Precinct
- Low Flood Risk Precinct

The list of land use definitions contained within the LEP has been grouped into eight major land use categories based on their sensitivity to flood risk. A matrix is used to determine what flood related development controls apply to each land use in a particular FPR. The matrix is shown in Image 1. A list of controls for each planning consideration is outlined in the DCP. Flood levels for the 0.2 EY and 1% AEP as well as the PMF are used for development controls. The freeboard requirement is 0.5m.

Image 1: Flood Control Matrix

Prescriptive Controls

Template: V6.0

Planning Consideration	Flood Risk Precincts (FRP's)																					
	Low Flood Risk						Fringe-Low Flood Risk						Medium Flood Risk						High Flood Risk					
	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Floor Level		3						3	2,6,7	5,6,7	1,6	4,7			2,6,7	5,6,7	1	4,7					1	4,7
Building Components		2						2	1	1	1	1			1	1	1	1					1	1
Structural Soundness		3						3	2	2	2	2			2	2	2	2					1	1
Flood Effects		2						2	2	2	2	2			2	2	2	2					1	1
Car Parking & Driveway Access		1,3,5, 6,7						1,3,5, 6,7	1,3,5, 6,7	1,3,5, 6,7	2,3,4, 6,7	6,7,8			1,3,5, 6,7	1,3,5, 6,7	2,3,4, 6,7	6,7,8					2,3,4, 6,7	6,7,8
Evacuation		2						2	2	1 or 2	3	2			2	1 or 2	3	2					3	2
Management & Design		1,4,5						1,4,5	1	1,2,3,5	1,2,3,5	1,2,3,5			1	1,2,3,5	1,2,3,5	1,2,3,5					1,2,3,5	1,2,3,5

4.3. Future Development Planning and Strategies

4.3.1. Wingecarribee Shire Community Strategic Plan – Wingecarribee 2031+

Wingecarribee 2031+ (W2031+) is Council's blueprint for the future of the Southern Highlands. It represents the vision, aspirations, goal, priorities and challenges for the community. The timeframe for W2031+ was aligned to the Sydney to Canberra Corridor Regional Strategy 2006-2031 (Reference 8) as this planning document is seen as a major influence over the future of the Shire.

W2031+ is comprised of five themes – People, Places, Environment, Economy and Leadership. The five themes provided the focus and direction for the development of goals and strategies by the community. The goals strategies provide a framework for delivery of sustainable and equitable outcomes for the community.

One of the five themes is 'Places' which includes Goal 3.4 'Wingecarribee housing options are diverse'. Goal 3.4 includes strategy 3.4.3 'Provide higher density development within the towns of Mittagong, Bowral, Mossvale and Bundanoon'. The current Floodplain Risk Management Study is aimed at reducing the flooding impact in Mittagong which in turn informs the LEP and DCP and facilitates development.

4.3.2. Wingecarribee Local Planning Strategy 2015-2030

The Local Planning Strategy provides long term direction for the future development of Wingecarribee Shire upon which any proposed amendments to the Local Environmental Plan (LEP) can be based.

Chapter Four 'Managing Our Housing Needs' predicts the population of Wingecarribee Shire to increase to 51,000 in 2031 with associated dwelling requirements of 7,560. The projected requirements for the suburb of Mittagong will be between 501 and 1000 dwellings. The relevant population and housing challenges outlined are:

- 'Cater for the estimated additional population, matching housing with changing demographic trends, particularly an ageing population and declining household occupancy rates'.
- 'Maintain the rural landscape character whilst accommodating an increasing population pressure and migration from Sydney'.
- Reinforce the distinctive character of Bowral, Mittagong and Moss Vale through the separation of their respective urban areas by extensive bushland, floodplain and rural land'.

The current Floodplain Risk Management Study is aimed at reducing the flooding impact in Mittagong which in turn informs the LEP and DCP and facilitates development.

4.3.3. Sydney – Canberra Corridor Regional Strategy

The Sydney-Canberra Corridor Regional Strategy applies to the local government areas of Wingecarribee, Goulburn Mulwaree, Upper Lachlan, Yass Valley, Palerang and Queanbean. The Regional Strategy represents an agreed NSW Government position on the future of the Sydney-Canberra Corridor. It is the pre-eminent planning document for the region. The primary purpose of the Regional Strategy is to accommodate and manage growth while ensuring that the rural landscapes and environmental settings that define the regions character are not compromised.

Section 4 'Housing and Settlement' states that the population of the region is projected to increase by 16 400 with the need for an extra 8700 dwellings. The suburb of Mittagong is identified as allocation for greenfield development with 1000 additional lots to be located in the suburb.

4.4. SES Plans and Local Disaster Plans

4.4.1. Wingecarribee Shire Local Flood Plan

The high level plan entails a detailed description of how to respond to all levels of flooding within the Wingecarribee Shire LGA. Volume 1 of the plan covers preparedness measures, the conduct of response operators and the coordination of immediate recovery measures from flooding within the LGA. Volume 2 provides more detail on the flooding mechanism, and should be updated based on the findings of this study. Suggested changes are provided in Section 7.11

4.4.2. Flood Intelligence Cards

There are no Flood Intelligence Cards for the suburb of Mittagong due to the absence of height gauges in the catchment.

5. STAKEHOLDER CONSULTATION

Community consultation is an important element of the floodplain risk management process ultimately facilitating community engagement and acceptance of the overall project. During the Flood Study (Reference 3), community consultation was undertaken to assess the flood experience of the community and gather additional data. Further community consultation has also been undertaken as part of the FRMS&P. To date this has included a questionnaire, a community open day and a number of FMC meetings. Goals of ongoing community consultation are to keep residents informed of progress and in the later stages gain their feedback on potential mitigation and management measures proposed. Final community consultation proposed is in the form of public exhibition of the Floodplain Risk Management Study and Draft Floodplain Risk Management Plan.

5.1. Questionnaire Distribution

In collaboration with WSC an information brochure with survey was distributed to residents that were identified as potentially flood affected. The survey was also available to be completed online through the website. The function of this was to describe the role of the Floodplain Risk Management Study in the floodplain risk management process and to ask residents for suggestions with regard to reducing flood risk.

There were approximately 50 surveys distributed within the study area with 7 surveys being returned or completed through the online survey platform. From the 7 responses 4 residents were aware of the Nattai River Flood Study and all of those residents had their property identified as flood affected as part of the Flood Study with the results shown in Figure 14. The community was asked to suggest any mitigation options that could possibly reduce flood risk. The locations of the suggested mitigation options are shown in Figure 15. The community was asked to identify what mitigation options they would prefer with the results shown in Figure 16. The specific suggestions are as follows:

- Evans Street – Clear vegetation, deepen and widen channel between Payten Street and Colo Street.
- Evans Street – Install pipe from Payten Street to Frenchmans School
- Improve blockage at Swimming Pool and upstream of Old Hume Highway

5.2. SES

WMAwater has consulted with the local and regional SES representatives in regard to local flood and evacuation plans and flood intelligence cards. As a result of the consultation WMAwater is to provide information in the report to allow SES to update Volume 2 of the Local Flood Plan to include the suburb of Mittagong. Flood Intelligence Cards are unable to be developed due to the lack of a water level gauge in the catchment.

5.3. Public Exhibition of the Draft Final Nattai River FRMS&P

Draft reports of the Nattai River Floodplain Risk Management Study and Plan were placed on Public Exhibition from 15th July to 22nd August 2016. The public exhibition period was advertised in the local newspaper. The digital version of the report was made available on Council's website, with hard copies made available at the following locations:

- Bowral Library
- Mittagong Library
- Moss Vale Library
- Moss Vale Civic Centre

Two submissions were received in regard to the Study and Plan exhibited, responses to which have been summarised in Table 10.

Table 10 Public Exhibition Comments

Received	Date	ID	Query	Response	Report Reference
WSC	24/09/2016	SS01	Is Council going to remove vegetation, fallen trees in the Nattai River to create more flow downstream and to prevent creation of new blockages when trees and vegetation pile up?	Clearing vegetation in the riparian corridor was modelled and it does not prevent any above floor flooding of properties in the catchment. Therefore it provides no financial benefit to the community and is not recommended.	No amendments to report. Discussed in Section 7.9
		SS02	Is Council going to remove the weirs in the Nattai Creek to prevent a backup of water in the 1% AEP and PMF event?	The removal of the weir adjacent to the Maltings was modelled and it does not prevent any above floor flooding of residential properties in the catchment. Therefore it provides no financial benefit to the community and is not recommended.	No amendments to report. Discussed in Section 7.5.
		SS03	Is Council going to increase the size of the culvert at the swimming pool to accommodate at least for the 1% AEP event if not the PMF?	The removal of the Swimming Pool and weir was modelled and it does not prevent any above floor flooding of properties in the catchment. Therefore it provides no financial benefit to the community and is not recommended.	No amendments to report. Discussed in Section 7.4
		SS04	Is Council going deepen and widen the Nattai Creek to minimize the effect of the PMF?	Clearing vegetation in the riparian corridor to effectively widen the River and increase conveyance was modelled and it does not prevent any above floor flooding of properties in the catchment. Therefore it provides no financial benefit to the community and is not recommended.	No amendments to report. Discussed in Section 7.9
		SS05	Is Council going to spend rate payers money on the swimming pool repairs every time the swimming pool gets flooded?	The purpose of this report is to investigate the potential benefits of flood risk mitigation options. Further assessment of Council's maintenance program is not within the scope of this study.	No amendments to report.
		SS06	How many times is Council prepared to keep cleaning and repairing the swimming pool and spending good money over a bad idea? Or is Council prepared to invest money in increasing the size of the culvert to avoid the swimming pool getting flooded?	The purpose of this report is to investigate the potential benefits of flood risk mitigation options. Enlarging the culvert was investigated and found to not provide any reduction in over-floor property flooding. Further assessment of Council's maintenance program is not within the scope of this study.	No amendments to report. Discussed in Section 7.4
		SS07	How much money is Council losing every time the swimming pool is closed to the public?	The purpose of this report is to investigate the potential benefits of flood risk mitigation options. Further economic assessment of the Council's operation of the swimming pool is not within the scope of this study.	No amendments to report.
		SS08	What is Council going to do to prevent an environmental impact every time when the swimming pool gets flooded?	The purpose of this report is to investigate the potential benefits of flood risk mitigation options. Assessment of Council's maintenance in regards to environmental impact of the swimming pool flooding is not within the scope of this study.	No amendments to report.
		SS09	What measures is Council going to take to prevent a major disaster and possibly loss of life in the PMF event?	As part of the Floodplain Risk Management Plan it is has been recommended to update the Wingecarribee Shire Local Flood Plan to include the suburb of Mittagong with the relevant data from the current study. Installation of flood depth markers on roads affected by flooding has also been recommended as part of the Floodplain Risk Management Plan.	No amendments to report. Discussed in Section 7.13 and 7.14
		SS10	Is Council willing to fix, improve and increase drains and pipes where necessary to minimize the flood effect?	An upgrade to the Colo Street culvert was modelled but it does not prevent any above floor flooding of properties in the catchment. No works to upgrade the drainage network have been recommended as part of the Floodplain Risk Management Plan.	No amendments to report. Discussed in Section 7.7
WSC	22/09/2016	BA01	The report shows that the 1% AEP event (figure 7) is lower than the previous report by Catchment Solutions for the 1% AEP event.	The Nattai River Flood Model was updated by Catchment Simulation Solutions to include the latest topographic data from Land Property Information (LPI). This data was not available at the time of the Flood Study. The new topographic data has caused slight changes in peak flood levels throughout the catchment. The updated results will be provided to Council at the conclusion of this study and will supersede the previous Flood Study results.	No amendments to report.
		BA02	The mapping of the flood planning level at 0.5m higher (figure 26) than the 1% AEP event creates areas that are not subject to flooding as requiring flood precautions. The flood planning level should follow the 1% AEP event line with a provision that development in or near the flood planning level should have a floor level of 0.5m above the 1% AEP level.	A flood planning level that consists of the 1% AEP flood event + 0.5m freeboard (factor of safety) for main channel flooding is standard practice as outlined in Appendix K – Floodplain Development Manual: The Management of Flood Liable Land (NSW Government April 2005). The 1% AEP event is not the largest flood that can occur, and it is commonly the event chosen as a basis for planning controls. The 1% AEP event is used as there is a 50% chance of it occurring once in a person's life time (estimated at 70 years). The 0.5 m freeboard is a factor of safety that takes into account errors in modelling, events more extreme than the 1% AEP event, possible increases in rainfall and flooding due to climate change, local surge and wave action, and the cumulative effect of subsequent infill developments on existing zoned land.	Section 7.10. updated with adjacent explanation.

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Received	Date	ID	Query	Response	Report Reference
		BA03	The report highlights the problem of the weir before the swimming pool and the swimming pool in relation to flooding surrounding areas.	The removal of the Swimming Pool and weir was modelled and while it does reduce flood levels downstream of the Old Hume Highway on the Golf Course it does not reduce flood levels upstream of the Old Hume Highway. It does not prevent any above floor flooding of properties in the catchment, therefore it provides no financial benefit to the community and is not recommended.	No amendments to report. Discussed in Section 7.4.
		BA04	Clearly with the swimming pool now being severely damaged from the June 2016 storm the conclusion should be that the pool is best removed and replaced outside the flood zone.	The purpose of this report is to investigate the potential benefits of flood risk mitigation options, specific advice to Council regarding the management of the swimming pool is beyond the scope of this study. The removal of the swimming pool and weir was modelled and it does not prevent any above floor flooding of properties in the catchment, and was therefore not included in the FRMP.	No amendments to report.
		BA05	The report does not appear to take into account the new bridge to be constructed in Colo Street.	The Colo Street bridge was not constructed at the time of the study therefore it was not considered in this Study and Plan. Floodplain Risk Management is an ongoing process and the Plan will be revised and updated with new information as it becomes available.	No amendments to report.
		BA06	The area of the Nattai passing through the Maltings could be lowered to reduce flooding impacts and will be outlined in the DA for the Maltings site.	The removal of the weir adjacent to the Maltings was modelled. The weir removal does reduce flood levels but does not prevent any above floor flooding of residential properties in the catchment, although there is a small reduction in Average Annual Damages (AAD) for Commercial and Industrial Properties. Even considering this small reduction in (AAD) and reduction in flood levels the removal of the weir provides no financial benefit to the community and is not recommended. There are also heritage and environmental issues to consider if the weir's removal is to be proposed.	No amendments to report. Discussed in Section 7.5

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6. ECONOMIC IMPACT OF FLOODING

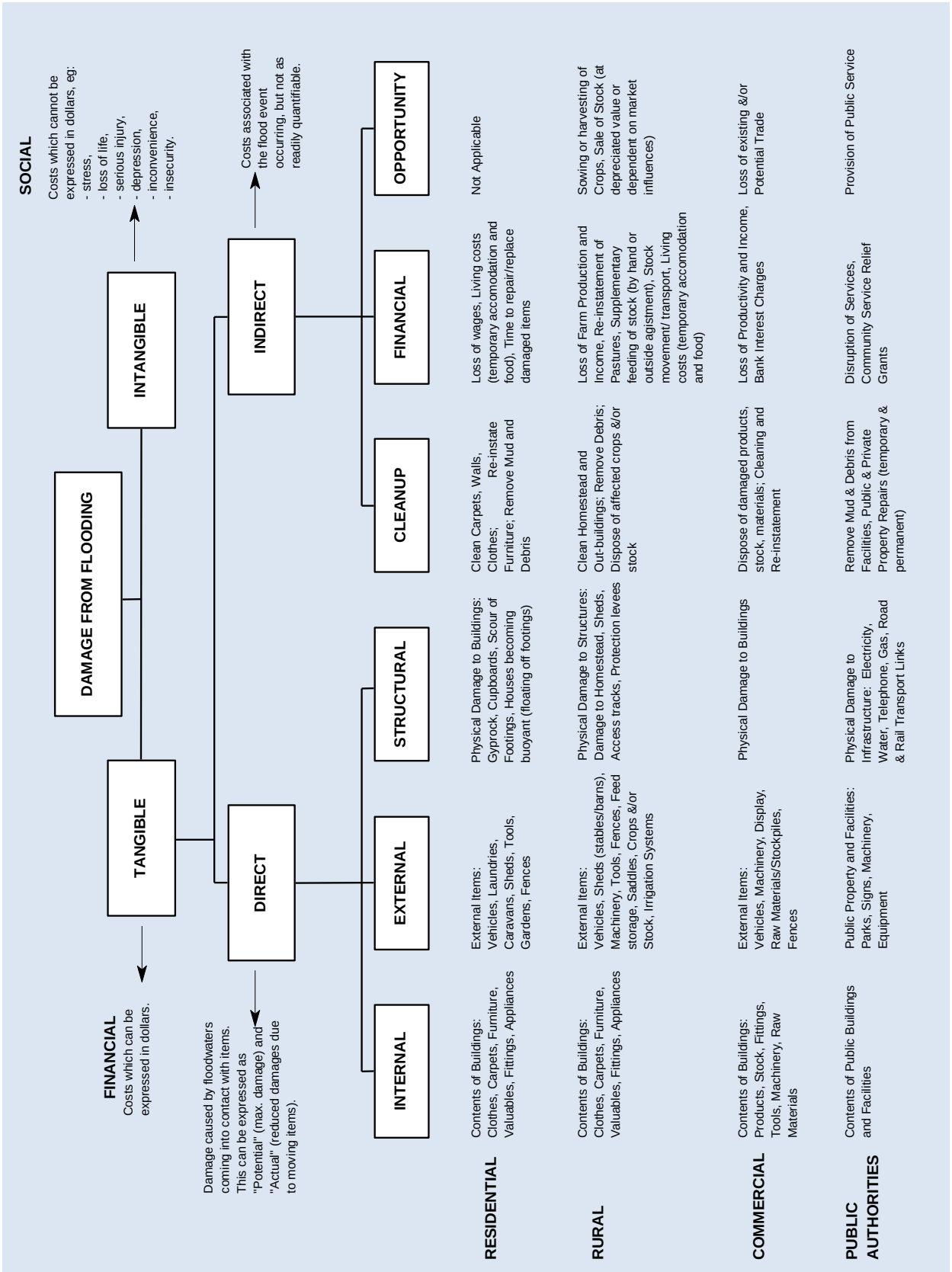
The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Diagram 1.

The assessment of flood damages not only looks at potential costs due to flooding but also identifies the event at which properties are likely to become flood affected by either flooding on the property or by over floor flooding as shown on Figure 17.

Diagram 1 Flood Damages Categories (including damage and losses from permanent inundation)



6.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Diagram 1). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development a desktop estimation of floor levels was undertaken using the provided DEM, aerial imagery and Google Street-view. As part of this floor level data collection, an indicative ground level was recorded for use in the damages assessment. This was used in conjunction with modelled flood level information to calculate damages. Damage calculations were carried out for all properties within the PMF extent, and floor levels were estimated for these properties. It should be noted that by including properties in the PMF event, properties that are inundated in the rarest events have been accounted for. Therefore damage calculations for the PMF event are likely to be conservative. The impact of this on AAD estimates is however insignificant.

The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

Damages were calculated for residential and commercial/industrial properties separately and the process and results are described in the following sections. The combined results are provided in Table 11. This flood damages estimate does not include the cost of restoring or maintaining

public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements damages can be under estimated.

Table 11 Estimated Combined Flood Damages for the Nattai Catchment

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	2	1	$ 74,000	47%	$ 37,000
10% AEP	3	1	$ 81,000	12%	$ 27,000
5% AEP	4	3	$ 253,000	13%	$ 63,000
2% AEP	5	3	$ 268,000	12%	$ 54,000
1% AEP	5	3	$ 287,000	4%	$ 57,000
0.5% AEP	7	3	$ 304,000	2%	$ 43,000
PMF	26	18	$ 1,788,000	8%	$ 69,000
Annual Average Damages			$ 63,000		$ 2,400

Section 7.15 presents results of the damages assessment undertaken for a selection of the proposed mitigation options, and compared these to the existing base case to determine the reduction in AAD.

6.1.1. Residential Properties

The flood damages assessment for residential development was undertaken in accordance with OEH guidelines (Reference 14). For residential properties, external damages (damages caused by flooding below the floor level) were set at $6,700 and additional costs for clean-up as $4,000. For additional accommodation costs or loss of rent a value of $220 per week was allowed assuming that the property would have to be unoccupied for up to three weeks. Structural damages vary on whether the property is slab/low set or high set. In some instances external damage may occur even where the property is not inundated above floor level and therefore tangible damages include external damages which may occur with or without house floor inundation.

A summary of the residential flood damages for the Nattai River catchment is provided in Table 12. Overall, for residential properties in the catchment the average tangible damages per property increases with the rarity of each design event. This is reflective of the differences in flood levels between the design flood events. Average damage per property increases for events larger than the 1% AEP when significantly more properties become flooded above floor level. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 12 Estimated Residential Flood Damages (Nattai River Catchment)

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	2	1	$ 74,000	57	$ 37,200
10% AEP	2	1	$ 75,000	14	$ 37,400
5% AEP	3	2	$ 139,000	10	$ 46,400
2% AEP	4	2	$ 146,000	8	$ 36,400
1% AEP	4	2	$ 151,000	3	$ 37,600
0.5% AEP	5	2	$ 155,000	1	$ 30,900
PMF	22	14	$ 1,013,000	6	$ 46,100
Average Annual Damages (AAD)			$ 52,000		$ 2,400

6.1.2. Commercial and Industrial Properties

The tangible flood damage to commercial and industrial properties is more difficult to assess. Commercial and industrial damage estimates are more uncertain and larger than residential damages, and can vary significantly depending on:

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not be able to moved and in other instances there may not be sufficient warning time to move stock to dry locations; and
- Ability to transfer business to a temporary location.

Costs to business can occur for a range of reasons, some of which will affect some businesses more than others dependent on the magnitude of flooding and the type of business. Common flood costs to businesses are:

- Removal and storage of stock before a flood if warning is given;
- Loss of production – caused by damaged stock, assets and availability of staff;
- Loss of stock and/or assets;
- Reduced stock through reduced or no supplies;
- Trade loss – by customers not being able to access the business or through business closure;
- Cost of replacing damages or lost stock or assets; and
- Clean-up costs.

No specific guidance is available for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the

methodology for residential properties but with the costs/damages increased to a value which is consistent with commercial/industrial development. For example, the maximum value of internal (contents) damages was increased to $191,250 since the building contents are of higher value whilst loss of rent was set at $1,000 per week to account for the loss of business through having to close for a period. Flooding below floor level uses the same damages curve as the residential properties.

Though the original OEH guidelines for flood damages calculations are not applicable to non-residential properties, they can still be used to create comparable damage figures. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and for benefit-cost analysis.

A summary of the commercial/industrial flood damages for the Nattai River catchment is provided in Table 13.

Table 13 Estimated Commercial and Industrial Flood Damages (Nattai Catchment)

Event	No. Properties Affected	No. Flooded Above Floor Level	Total Damages for Event	% Contribution to AAD	Ave. Damage Per Flood Affected Property
20% AEP	0	0	$ -	0	$ -
10% AEP	1	0	$ 6,000	3	$ 6,100
5% AEP	1	1	$ 114,000	27	$ 114,400
2% AEP	1	1	$ 122,000	32	$ 121,800
1% AEP	1	1	$ 136,000	12	$ 136,500
0.5% AEP	2	1	$ 149,000	6	$ 74,700
PMF	4	4	$ 775,000	21	$ 193,800
Average Annual Damages (AAD)			$ 11,000		$ 2,800

6.2. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may

affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

7. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. This section sets out a number of measures which could be of benefit to Mittagong. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options have been considered to effectively manage existing and future flood risks along Nattai River.

7.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 1) separates risk management measures into three broad categories.

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

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

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

Table 14 provides a summary of typical floodplain risk management measures that have been assessed for the current study. It should be noted that many of these management measures are not appropriate for the Nattai River Catchment and have not been recommended.

Table 14 Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees (Lv)	Land zoning	Community awareness
Temporary Defences (TD)	Voluntary purchase	Flood warning
Channel Construction (CC)	Building & development controls	Evacuation planning
Channel Modification (CM)	Flood proofing	Evacuation access
Major Structure Modification (MSM)	House raising	Flood plan / recovery plan
Drainage Network Modification (DNM)	Flood access	
Drainage Maintenance (DM)		
Retarding Basins (RB)		

7.2. Proposed Mitigation Options Considered

The proposed mitigation options have been selected after identifying the flood affected areas from the Nattai River Flood Study and reviewing the mitigation suggestions of the local residents that were collected from the community consultation mailout and during the community consultation meeting. Options that have previously been investigated as part of the Mittagong Drainage Master Plan (Reference 4) were not included as part of this study. The location of the proposed mitigation options is shown in Figure 18. The proposed options are outlined below.

Option FM01: Removal of weir upstream of Swimming Pool
Option FM02: Removal of Swimming Pool
Option FM03: Removal of weir at The Maltings
Option FM04: Increase channel at Evans Street Waterway
Option FM05: Upgrade Colo Street Culvert
Option FM06: Combination of FM04 and FM05
Option FM07: Riparian Management of River (All creeks)
Option PM01: Changes to Flood Planning Level and Flood Planning Area
Option PM02: Changes to Wingecarribee Shire Council s149 Certificate
Option RM01: Changes to Wingecarribee Shire Local Flood Plan
Option RM02: Installation of Flood Signs and Depth Indicators at frequently inundated roads

7.3. Removal of Weir Upstream of Swimming Pool (FM01)

7.3.1. Aim

To reduce flood levels upstream of Hume Highway and increase conveyance of the Nattai River during a flood.

7.3.2. Discussion

This option was outlined in the consultant brief and flagged for investigation by property developers during the community consultation meeting. There is a reinforced concrete weir situated in the Highlands Golf Course just downstream of the Hume Highway. This structure raises the water level behind it by approximately 2 m and causes ponding upstream.

The works involved in the removal of a weir would include pre-removal surveys to establish baseline information on water quality, fish habitat, fish species, terrestrial habitat and riparian vegetation. The river morphology must also be considered, with fluvial modelling recommended to assess the likely impact of a change in flow and predict how the river will react to the weir removal. Engineering considerations include the weir condition, stability and functioning as well as the bank and bed stability, especially for safe access of equipment. The impact of potential sediment release should also be considered, and sediment held by the weir may need to be excavated prior to the removal of the weir.

Removal of the weir may improve flood risk by improving conveyance along the Nattai River and

lowering river levels. Weir removal however, can have complex, unexpected and long term effects upon a river system. If done properly, the removal of a weir can yield several environmental benefits as sediment and nutrients are allowed to be transported along a river, rather than being deposited upstream of the weir. Restoring river continuity may also improve fish passage and habitat connectivity, though consideration must be given to the ecosystem based on the pond in its current state.

The tasks required for the completion of proposed Option FM01 include but are not limited to the items listed in Table 15.

Table 15 Option 1 Works

The Removal Process

• Environmental Assessment Process
• Stakeholder Consultation
• Pre-removal Surveys
• Weir Removal
  ○ Sediment/ Oil boom installed downstream of structure prior to removal
  ○ Siphon hoses run over the weir overnight to move water downstream and draw down weir pool
  ○ Site access may need to be established by tree removal/ lopping
  ○ Destruction and removal of concrete weir by excavator and truck
• Post Removal
  ○ Visual monitoring of native plant regeneration and local wildlife
  ○ Post-removal bed level surveys may be required to determine changes to the creek bed over time

7.3.3. Impact on Flood Behaviour

To investigate the impact of the weir on flood levels and the flood extent, the removal of the weir was modelled by regrading 50 m of the channel upstream of the weir to be continuous at a slope of 1.3%.

The impact of Option FM01 is shown on Figure 19 for the 1% AEP event. Modelling indicated a significant reduction in flood levels of up to 0.3 m in a localised area of approximately 0.35 ha upstream of the removed weir. There would be a minor reduction in flood level in the culvert under the Old Hume Highway. With removal of the weir there is a localised increase in flood levels immediately downstream of the structure, however the river level downstream of the swimming pool was largely not affected.

7.3.4. Recommendation

This option is not recommended to Council as the removal of the weir would not improve flood levels for any properties upstream of the Old Hume Highway.

7.4. Removal of Weir and Swimming Pool (FM02)

7.4.1. Aim

To reduce flood levels upstream of Hume Highway and increase conveyance of the Nattai River during a flood.

7.4.2. Discussion

The Mittagong Swimming pool is situated on the Nattai River just downstream of the Old Hume Highway at the southern end of the Highlands Golf Course. During construction and early use of the railway from 1867, a 2.4 m high dam wall was constructed on the Nattai River to form a water supply for steam trains travelling between Picton and Braemar. This became a popular swimming spot, but was unsafe with significant depths and obscured underwater rock ledges. In 1931 the dam was converted into the Mittagong Baths with the original dam wall becoming the western wall of the pool. In 1959 the baths were converted to an Olympic Pool. The pool has experienced periodic flooding since its construction, and local residents and developers requested investigation into its removal at the community consultation meeting.

Decommissioning of the Mittagong Swimming Centre would require extensive investigation into the environmental impacts involved and would include the weir removal investigated in Option FM01. Access constraints may also affect ease of decommissioning.

7.4.3. Impact on Flood Behaviour

Option FM02 was modelled by simulating the removal of the pool, the weir upstream of the pool and the box culvert beneath the pool, and the channel regraded over a length of approximately 100 m.

In the 1% AEP event modelling indicated a significant reduction in flood levels of greater than 0.3 m from downstream of the Old Hume Highway to downstream of the pool, and some areas of the flood fringe would no longer be affected, as shown in Figure 20. Localised increases downstream of the pool are as expected due to the increased conveyance. Most notably however is that there are no impacts upstream of the railway, and only minor reductions in flood levels in the culvert under the Old Hume Highway.

7.4.4. Recommendation

The lack of impacts upstream of the Old Hume Highway mean there are limited properties that would benefit from this option. It is therefore not recommended for further consideration, especially given the extensive costs involved in the demolition and removal of the weir, pool and culvert and regrading the river channel.

7.5. Removal of weir at The Maltings (FM03)

7.5.1. Aim

To reduce flood levels in 'The Maltings' upstream of Ferguson Crescent

Photo 1 Weir Pool at Maltings

Photo 2 Weir at Maltings

7.5.2. Discussion

The Mittagong Maltings was a large 3 malthouse complex first established in 1899 by the Malting Company of NSW to supply malt to the breweries throughout New South Wales. The dam was built to provide a water supply to the malthouses before the town supply became available. The weir is 4 m tall, and an investigation into the impacts of its removal was requested by residents and property developers at the community consultation meeting on the 24th August 2015.

The works involved in the weir removal would be much the same as for Option FM01, as discussed in Section 7.3.

7.5.3. Impact on Flood Behaviour

Option FM03 was modelled by removing the weir and regrading the channel for a length of 50 m upstream and downstream to a slope of 2%. In a 1% AEP event, modelling showed the impact of removing the weir would be significant for the adjacent property, with the flood level lowered by 1 m next to the weir with reductions lessening further upstream. As shown on Figure 21, there

would be no impacts on flood levels downstream of Ferguson Crescent.

7.5.4. Recommendation

There is no benefit to any existing properties from the removal of the Maltings Weir or any current flood liability issues that could be used to motivate it. There may also be heritage and environmental issues to contend with removal if proposed.

7.6. Channel Upgrade: Evans Street Waterway (FM04)

7.6.1. Aim

To increase conveyance of the Evans Street waterway and thereby reduce flood levels in surrounding properties.

Photo 3 Evans St waterway

7.6.2. Discussion

There is a waterway running behind the residential properties that front Evans Street in Mittagong which conveys water from the south and meets the Nattai River just west of Fernbrook Crescent, as shown on Figure 7. In a 1% AEP event this small creek is overtopped, inundating several of the backyards through which it runs.

The works required to implement Option FM04 would involve the excavation of the creek bed, which may require removal of overgrown vegetation for access. Appropriate environmental impact

assessment may also be necessary.

7.6.3. Impact on Flood Behaviour

Option FM04 was modelled by lowering the creek bed by 0.5 m. As shown on Figure 22, modelling indicates variable impacts along the creek. Some areas would be no longer flooded, and in other areas flood levels would be reduced by up to 0.2 m. Modelling indicates localised areas of increased flood levels on the upstream sides of culverts as the increased flow is retained behind the structures.

The maximum reduction in flood level is located in the channel on the property at 26 Evans St, and is consistent for all design events. The peak impact in each event is shown in Table 16 and indicates more significant benefits in more frequent events.

Table 16 Evans St Waterway: Peak Impacts

Event (ARI)	Peak Impact (m)
5	-0.39
10	-0.36
20	-0.32
50	-0.26
100	-0.22
200	-0.2
PMF	-0.1

7.6.4. Recommendation

While there are some reductions in flood levels there is no economic benefit or reduction in hazard resulting from increasing the size of the Evans Street waterway, and hence this option is not recommended to Council.

7.7. Culvert Upgrade: Colo Street (FM05)

7.7.1. Aim

To reduce flood levels around Evans Street and Colo Street by increasing the capacity of the culvert on Colo Street

Photo 4 Colo Street box culvert, just east of Evans Street

7.7.2. Discussion

The waterway discussed in Section 7.6 crosses Colo Street just east of Evans Street and passes through two box culverts each measuring 3 m wide by 0.75 m tall. Figure 7 indicates how this culvert capacity is exceeded during a 1% AEP event, causing water to back up behind Colo Street and overtop the road. Works would involve excavation of Colo Street, installation of two new precast reinforced concrete box culverts and resurfacing of the road.

7.7.3. Impact on Flood Behaviour

Option FM05 involves the addition of two new box culverts of the same dimensions to allow more flow beneath the road. The flood levels immediately upstream were reduced by up to 0.1 m, and a greater area experienced a minor reduction in flood levels of up to 0.05 m. There is an increase in flood levels experienced downstream, with the increased conveyance raising flood levels by up to 0.1 m. These impacts are shown in Figure 23. Refer to Table 17 for a summary of the depths of overtopping on Colo Street in each design event.

Table 17 Option FM05 Maximum Depths over Colo St

	Depth over Colo St (m)	
Event (AEP)	Existing Case	FM05
20%	0.21	0.10
10%	0.26	0.19
5%	0.32	0.26
2%	0.37	0.33
1%	0.41	0.37
0.50%	0.44	0.41
PMF	0.80	0.79

7.7.4. Recommendation

This option is not recommended to Council. Despite lowering flood levels in the waterway and in the park, it does not improve over-floor flooding for any properties in the area.

7.8. Combination of Option FM04 and FM05 (FM06)

7.8.1. Aim

To reduce flood levels around Evans Street and Colo Street by increasing the capacity of the creek and the culvert on Colo Street.

7.8.2. Discussion

Option FM04 investigated deepening the Evan Street waterway by 0.5 m to improve conveyance, and Option FM05 modelled the doubling of the culvert that allowed this creek to flow beneath Colo Street. Option FM06 applies both these modifications in conjunction with each other to ascertain the net benefit to properties around Evans Street and Colo Street.

7.8.1. Impact on Flood Behaviour

Figure 24 shows the impact of applying both options simultaneously in the 1% AEP event. Modelling indicates there would be significant reductions in flood levels at the upstream end of the waterway (up to 0.2 m) and in patches along the waterway. There would be minor reductions in depths over Colo Street and in the open area just upstream of the Colo Street culvert.

7.8.2. Recommendation

The execution of Options FM04 and FM05 together does yield benefits for the area, however these reductions in flood level are generally limited to backyards and the park rather than reducing over-floor inundation. Without improving residential damages the economic benefit is limited, and it would be difficult to justify the works.

7.9. Riparian Management of all creeks (FM07)

7.9.1. Aim

To reduce flood levels along and adjacent to existing creeks by improving the conveyance by removing overgrown vegetation.

7.9.2. Discussion

During the site visit on the 21/1/16 the Nattai River and its tributaries were found to be uniformly overgrown with weeds and in some cases choked with debris or litter. Option FM07 involves clearing this debris and vegetation in order to increase the conveyance of these channels and reduce flood levels. Works would be ongoing and may include spraying weeds and removing excess vegetation and debris.

It should be noted though that Riparian Management may cause an increase in flood levels if the creek conveyance is increased but culverts along the creek do not have capacity to convey these increased flows. Consultation with environmental specialists may be required to target Council's approach and to prevent adverse impacts to any natural habitats along the many creeks in the catchment.

7.9.3. Impact on Flood Behaviour

Option FM07 has been modelled by reducing the Mannings coefficient by 50% to simulate clearing vegetation. As shown in Figure 25, modelling indicates there would be very little reduction in flood levels out of the channel bank area, and an increase in flood levels downstream of the cleared creek reaches.

7.9.4. Recommendation

This option is not recommended as it does not provide significant benefits to properties adjacent to the creeks, and causes adverse impacts in the reaches downstream of Colo Street. There would also be extensive ecological issues with the implementation of this option.

7.10. Option PM01: Changes to Flood Planning Level and Flood Planning Area

The LEP Standard Instrument for NSW does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area (FPA) map to be included as a layer imposed across all land zones.

A flood planning level that consists of the 1% AEP flood event + 0.5m freeboard (factor of safety) for main channel flooding is standard practice as outlined in Appendix K (Reference 1). The 1% AEP event is not the largest flood that can occur, it is the event that has been chosen for planning purposes. The 0.5 m freeboard is a factor of safety that takes into account events more extreme than the 1% AEP event, possible increases in rainfall and flooding due to climate change, errors

in modelling, the cumulative effect of subsequent infill developments on existing zoned land and local surge and wave action which cannot be replicated in hydraulic modelling.

The FPA is used to define an area to which flood related development and planning controls are applied and Councils are required to include a FPA map in their LEP. Like the FPL, it is usually taken as the extent of the 1% AEP flood level plus 0.5 m. Therefore planning controls may be applied to development which is not necessarily within the 1% AEP flood extent but is within the FPA. It is important to base the FPA on suitable criteria appropriate to the nature of flooding so as not to over or understate the need to control development impacted by floods in some areas.

The FPA has only been applied to mainstream flooding for this study. The 1% AEP event plus 0.5 m freeboard is presented in Figure 26

Recommendation
This study has updated the hydraulic modelling for the study area since the Flood Study (Reference 3) and it is therefore recommended that the updated FPA map be included in the LEP.

FRMP RECOMMENDATIONS
The following measure is recommended:

► Update the Flood Planning Area map in Council's LEP to which flood planning controls apply.

7.11. Option PM02: Changes to Wingecarribee Shire Council Section 149 Certificates

7.11.1. Description

When a property is sold in NSW, the vendor must attach to the contract of sale a planning certificate. Schedule 4 of the Regulations gives requirement for inclusions on s149 certificates under section 149(2) of the Act. In particular Schedule 4, 7A refers to flood related development control information and requires that Council include whether or not development on the land or part of the land is subject to flood related development controls.

Section 149 (5) is a more detailed certificate and could for instance include "notes" on flood risk for instance below and above the FPL, details of other events including the PMF, giving percentage of lot affected, potential flood heights and hazard categories. Where only parts of lots are flood affected the 149 certificate may notify either the percentage area of a lot that is affected and / or only include lots that are 15% affected or greater.

7.11.2. Discussion

It is important that the information presented in the planning certificate is clear because although flood controls only apply to land in the FPA, the full flood extent extends out to the PMF. Land

outside of the FPA therefore can still flood during rare events and the community can be made aware of this via notes of the 149 (2)/ (5) certificate.

Land owners have expressed concern when their property is tainted as flood affected when only a portion of the site is actually impacted. With the new FPA mapping the identification of flood affectation can include percentage of site area that is impacted and can also apply a category of flood hazard. Categories of flood hazard include:

- Low Hazard – trucks able to evacuate people and possessions easily. Able-bodied adults readily able to wade out of danger.
- High Hazard – Possible danger to personal safety. Difficult to evacuate by trucks. Able-bodied adults would have difficulty wading out of danger.

Section 17.2 and 17.3 of Appendix I to the FDM (Reference 1) detail typical examples of information for inclusion in 149 certificates.
99

7.11.3. Evaluation

Currently Council uses information from the 2013 Flood Study (Reference 3) to provide classification of flood risk and estimated flood levels. Following review of an example Council Flood Certificate and informed by findings from this Floodplain Risk Management Study, several amendments are proposed to improve and update the current s149 certificates. At minimum, the following measures are recommended to be incorporated into 149(5) certificates:

- Whether the land is within the FPA;
- Hazard Classification, and definition of low and high hazard as described above;
- Hydraulic Category (Floodway, Storage or Fringe);
- Design flood heights specific to the property in the 1% AEP, and
- Percentages of lots affected by the FPA if not 100%.

7.12. Option PM03: Changes to Floodplain Risk Precincts (FRPs) in Wingecarribee Development Control Plan

Section 4 of (Reference 9) Flood Liable Land identifies the various Flood Risk Precincts (FRPs) identified in Mittagong. The identification of these Precincts is to grade the relative severity of flood risks across the floodplain and there by provide a basis for assigning development controls. The various FRPs in Mittagong are described below:

High Flood Risk Precinct

This Precinct contains that land below the 100 year flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated or development would significantly and adversely affect flood behaviour. Most development should

be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.

Medium Flood Risk Precinct

This Precinct contains that land below the 100 year flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

Fringe-Low Flood Risk Precinct

This Precinct contains that land between the extents of the 100 year flood and the 100 year flood plus 0.5m in elevation (being a freeboard). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

Low Flood Risk Precinct

This Precinct contains that land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

Recommendation

Update the flood mapping and dataset that determines the FRPs with the updated hydraulic modelling results from the current Nattai FRMS&P.

7.13. Option RM01: Changes to Volume 2 - Wingecarribee Shire Local Flood Plan

Following investigation of flood behaviour and the production of revised design flood levels in the Floodplain Risk Management Study, a number of amendments are proposed to update the Wingecarribee Shire Council Local Flood Plan. This includes:

- Revised summary of flood behaviour in the Nattai River Catchment;
- Number and location of houses flooded above floor level in each design event; and
- Road closures and the flood event by which the closure is triggered.

7.13.1. Summary of Flood Behaviour

The Nattai River originates near the intersection of Range Road and Old South Road at Mittagong and drains in a northerly direction through the eastern sections of Mittagong. The catchment is drained primarily by natural watercourses. The urbanised sections of the catchment are drained by a stormwater system which carries local catchment runoff into the watercourses via a network of stormwater pipes, pits, open channels and culverts.

During periods of heavy rainfall, there is potential for the capacity of the stormwater system to be exceeded and for water to overtop the banks of the natural watercourses and inundate the adjoining floodplain. Accordingly, there is potential for inundation of properties located in close proximity to the creeks and drainage lines. Flooding has been experienced on several occasions in the past, particularly across properties fronting Evans Street. Other flooding hotspots include the Mittagong Swimming Centre and Oxley Drive between Bracken and Reservoir Street.

7.13.2. Houses Flooded Above Floor Level

As part of the damages assessment undertaken in Section 6.1 estimated floor level data was used to predict over-floor flooding in various design events. In Table 18 the number of properties affected and the number of buildings (residential and non-residential) flooded above floor level are listed for each design event. The locations of buildings that experience inundation above floor level are shown in Figure 17.

Table 18 Properties inundated in design flood events

Event	No. Properties Affected[1]	No. Flooded Above Floor Level
20% AEP	2	1
10% AEP	3	1
5% AEP	4	3
2% AEP	5	3
1% AEP	5	3
0.5% AEP	7	3
PMF	26	18

[1] Flood affectation occurring within an owner's lot boundary

7.13.3. Road Closures

Section 2.5 in the Wingecarribee Shire Local Flood Plan (Volume 2) lists roads subject to flooding in the Wingecarribee Shire LGA. Following analysis as part of the Floodplain Risk Management Study, several roads are recommended to be added to this list. Roads affected by the Nattai River and various overland flow paths that receive over 150 mm of inundation have been included in the below list. Please note this list is not exhaustive and other streets may be subject to minor and temporary inundation.

Table 19 Roads subject to Inundation

ID	Location	Cause of Inundation	Event First Flooded (> 150 mm)
N01	Colo St, btw. Evan St & Southey St	Overland Flow Path	5yr
N02	Old Hume Hwy, btw. Hawkins Dr & Bong Bong Rd	Nattai River	5yr
N03	Ferguson Cr, btw. Bong Bong Rd & Railway line	Overland Flow Path	5yr
N04	Colo St, btw. Railway Pde & Evans St	Nattai River	5yr
N05	Southey St, btw. Colo St & Payten St	Overland Flow Path	5yr
N06	Payten St, btw. Evans St & Southey St	Overland Flow Path	5yr
N07	Webb St, near Payten St	Overland Flow Path	10yr
N08	Mary St, near Farnham Cl	Overland Flow Path	5yr
N09	Payten St, end of road at Frencham School	Overland Flow Path	5yr
N10	Range Rd, near intersection Tyndall St	Nattai River	5yr
N11	Cnr Robinson St & Devon St	Overland Flow Path	5yr
N12	Oxley Dr, near intersection Reservoir St	Overland Flow Path	5yr
N13	Near intersection Old South Rd & Range Rd	Overland Flow Path	5yr
N14	Range Rd, btw. Webb St & Range Rd	Overland Flow Path	10yr
N15	Evans St, btw. Payten St & Colo St	Overland Flow Path	50yr

7.14. Option RM02: Flood Access

Evacuation can be improved by ensuring that there are adequate evacuation routes available and appropriate warning as to when the routes will become impassable. Providing safer flood access can also reduce risk to life and assist emergency response.

It is recommended that Council maintain a record of flood prone roads including details of likely inundation and alternative routes. Then, when flooding is likely Council can ensure that appropriate road closures and diversions are put in place to prevent people unnecessarily traversing through flood waters. For roads which may be more frequently inundated, such as those listed in Table 19, flood depths indicators and flood signs can be used to provide information to drivers and pedestrians. Flood signs and indicators may also assist in resident awareness as the will be installed at roads liable to overtopping.

Flood signs must be installed in accordance with AS 1742.2-2009 *Manual of Uniform Traffic Control Devices Part 2: Traffic Control Devices for General Use*, which stipulates that *"The 'ROAD SUBJECT TO FLOODING, INDICATORS SHOW DEPTH' sign shall be erected on the left side of the road on which Depth Indicators are used, to advise drivers that the road ahead may be covered by floodwaters…the NEXT x km sign may be used in conjunction with this sign when there are two or more floodways ahead, not more than 2km apart." (Clause 4.10.6.9)*

It also specifies that a depth indicator sign *"…shall be used at all fords, floodways and low level bridges. It shall be displayed so as to be clearly visible to drivers before reaching the flooded part*

of the road. Where necessary, separate indicators should be provided on each approach. The zero mark shall be set at the lowest pavement level on the section of road liable to flooding." (Clause 4.10.6.10)

Photograph 1: Examples of flood depth indicators

SUMMARY

Placement of depths markers and flood signs at flood liable roads could assist in preventing drivers from traversing through flood waters. In addition Council should put measures in place to temporarily close flooded roads where possible.

7.15. Economic Assessment of Site Specific Options

7.15.1. Damage Assessment of Options

Total damages were evaluated for 4 of the 7 investigated mitigation options and compared against the base case, as shown Table 20 for residential and non-residential damages respectively. Options not assessed in this section were those shown to not yield significant benefits for either roads or properties, and included Option FM01 (Removal of weir upstream of swimming pool), Option FM02 (removal of swimming pool) and Option FM07 (riparian management of all rivers and creeks).

Table 20 Average Annual Damage Reduction of Mitigation Options (Residential)

Option	Description	AAD	Reduction in AAD due to Option
Existing Base Case	No Option Implemented	**$ 52,000**	
FM03	Removal of weir at The Maltings	**$ 52,000**	**$ 0**
FM04	Channel Upgrade: Evans Street Waterway	**$ 52,000**	**$ 0**
FM05	Culvert Upgrade: Colo Street	**$ 52,000**	**$ 0**
FM06	Combination of Option FM04 and FM05	**$ 52,000**	**$ 0**

As shown in Table 20, none of the proposed options reduce the incidence of over-floor inundation

to residential properties in the Nattai River Catchment, and accordingly provide no reduction in Average Annual Damages.

Table 21 Average Annual Damage Reduction of Mitigation Options (Commercial/Industrial)

Option	Description	AAD	Reduction in AAD due to Option
Existing Base Case	No Option Implemented	**$ 11,000**	
FM03	Removal of weir at The Maltings	**$ 6,000**	**$ 5,000**
FM04	Channel Upgrade: Evans Street Waterway	**$ 11,000**	**$ 0**
FM05	Culvert Upgrade: Colo Street	**$ 11,000**	**$ 0**
FM06	Combination of Option FM04 and FM05	**$ 11,000**	**$ 0**

As shown in Table 21, only the removal of the weir at The Maltings reduces the average annual damages for commercial/ industrial properties in the Nattai River Catchment. The land currently part of the former Maltings site is currently zoned as commercial, and removal of the weir would reduce flood levels on the as-yet undeveloped property.

8. FLOODPLAIN RISK MANAGEMENT PLAN

This section comprises the Floodplain Management Plan and forms a framework identifying aims, objectives and a guide to the list of strategies by which the plan will be implemented. Any recommendations in terms of policy should be reviewed and approved by Council's planners.

8.1. Aims and Objectives

The primary objective of the Floodplain Management Plan is to recommend a range of property, response and flood modifications that address the existing and future flood problems, in accordance with the Floodplain Development Manual (Reference 1). The recommended works and measures presented in the Plan will:

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

8.2. Identifications of Actions Suitable for Implementation

8.2.1. Background

Multi-variate decision matrices are recommended in the Floodplain Development Manual (Reference 1) and therefore it is also a recommendation of this report that multi-variate decision matrices be developed for specific management areas, allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- Risk to life;
- Impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- Number of properties benefited by measure;
- Compliance with EP&A Act 1979 (whether the work adversely impacts existing development, involves development in the floodway, or encourages development which increases spending on flood mitigation, infrastructure or services)
- Technical feasibility (design considerations, construction constraints, long-term performance);
- Community acceptance and social impacts;
- Economic merits (capital and recurring costs versus reduction in flood damages);
- Financial feasibility to fund the measure;
- Long term performance;
- Environmental and ecological benefits;
- Impacts on the State Emergency Services;
- Political and/or administrative issues; and
- Long-term performance given the potential impacts of climate change.

The scoring system for the above criteria is provided in Table 22 and largely relates to the impacts in a 1% AEP event. The matrix below is designed to set out a general scheme to illustrate how a local matrix might be developed. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions. Tangible costs and damages are also used as the basis of B/C analysis for some measures.

Table 22 Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm	>100mm decrease
Number of Properties Benefitted	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straightforward	straight forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

8.2.2. Results

The preliminary assessment matrix is given in Table 23, with each of the assessed management options scored against the range of criteria. The scores for ‘Community Acceptance’ have been estimated at this time, as the community information session is yet to be held (the matrix will be updated when the information is available). Also, it is important to note that the approach undertaken does not provide an absolute “right” answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

The Nattai River Catchment Draft Floodplain Risk Management Plan is shown in Table 24.

Table 23 Nattai River Catchment Mitigation Options Matrix

Report Ref	Option		COMMENT	Impact on Flood Behaviour	Number of Properties Benefitted	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmentall Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	TOTAL	RANK
7.3	FM01	**Removal of weir upstream of Swimming Pool**	Aims to reduce flood levels upstream of the Hume Highway and increase conveyance of the Nattai River.	3	0	-3	-2	0	-3	-3	0	-2	0	0	-10	10
7.4	FM02	**Removal of Swimming Pool**	Aims to reduce flood levels upstream of the Hume Highway and increase conveyance of the Nattai River.	3	0	-3	-3	-3	-3	-3	0	-3	0	0	-15	12
7.5	FM03	**Removal of weir at The Maltings**	Aims to reduce flood levels in 'The Maltings' property upstream of Ferguson Crescent.	3	0	-3	-3	0	-3	-3	0	-3	0	0	-12	11
7.6	FM04	**Increase Channel at Evans Street Waterway**	Deepening and widening the channel so as to improve conveyance and thereby reduce flood levels on surrounding properties.	2	3	2	2	2	3	-2	0	-1	0	0	11	7
7.7	FM05	**Culvert Upgrade: Colo Street**	Increase hydraulic conveyance of existing box culverts and reduce upstream flood levels.	2	2	3	3	1	2	0	0	0	3	0	16	3
7.8	FM06	**Combination of FM04 and FM05**	Increase hydraulic conveyance of the waterway and culverts to reduce upstream flood levels.	3	3	2	2	2	2	-2	0	-1	2	0	13	4
7.9	FM07	**Riparian Management of all creeks**	Reduce flood levels along and adjacent to existing creeks by improving the conveyance by removing overgrown vegetation.	0	-1	2	-2	0	-1	-3	0	-3	0	0	-8	9
7.10	PM01	**Changes to Flood Planning Level and Flood Planning Area**	Redefining FPL and FPA based on updated hydraulic modelling and results undertaken in the FRMS	0	0	3	1	1	3	0	1	-3	3	1	10	8
7.11	PM02	**Changes to Section 149 (2) and (5) Certificates**	Redefining FPL and FPA based on updated hydraulic modelling and results undertaken in the FRMS	0	0	3	3	2	3	0	0	-1	2	0	12	5
7.12	PM03	**Changes to Floodplain Risk Precincts**	Update the flood mapping and dataset that determines the FRPs with the updated hydraulic modelling results from the current Gibbergunyah Creek FRMS&P.	0	0	3	2	1	3	0	0	0	3	0	12	5
7.13	RM01	**Changes to Volume 2 - Wingecarribee Shire Local Flood Plan**	Updating the Local Flood Plan based on updated hydraulic modelling results in the FRMS	0	0	2	3	3	3	0	3	1	1	2	18	2
7.14	RM02	**Flood Signs & Depth Indicators**	Installation of flood signs and depth indicators to improve motorist safety	0	0	3	3	2	3	0	3	1	1	3	19	1

Table 24 Nattai River Catchment Draft Floodplain Risk Management Plan

Reference	Option	Description	Priority	Benefits	Concerns	Responsibility	Cost	B/C Ratio
PROPERTY MODIFICATION MEASURES								
PM01	Changes to FPL and FPA	The FPL defines land subject to flood related development controls.	High	Update FPL and FPA in line with findings from FRMS which involved revising the Gibbergunyah Flood Model	None	Council in consultation with property owners.	Minimal	N/A
PM02	Amendments to s149 Certificates	Section 149 Certificates provide property owners with a brief (149(2)) or detailed (149(5)) description of flood affectation (if any) at their property	Medium	Clear presentation of information regarding flood affectation	Addition of information regarding hazard classification, hydraulic categories and revised flood levels from the FRMS are recommended	Council - and to be clearly communicated to residents	Minimal	N/A
PM03	Changes to Floodplain Risk Precincts (FPRs) in DCP	Section 4 of the DCP identifies the various (FRPs) identified in Mittagong. The identification of these Precincts is to grade the relative severity of flood risks across the floodplain and there by provide a basis for assigning development controls.	Medium	Update the flood mapping and dataset that determines the FRPs with the updated hydraulic modelling results from the current Gibbergunyah Creek FRMS&P.	None	Council - and to be clearly communicated to residents	Minimal	N/A
RESPONSE MODIFICATION MEASURES								
RM01	Amendments to Wingecarribee Shire Local Flood Plan (Volume 2)	The Local Flood Plan is a reference document shared by Council and the SES and provides guidance for actions required in preparation for and response to a flood event in Mittagong.	High	Improved and updated information available regarding flooding in the Gibbergunyah Creek catchment including flood behaviour and the properties and roads affected in various events.	Updates to Local Flood Plan to be adopted by Council and SES in cooperation	SES and Council in cooperation	Minimal	N/A
RM02	Installation of Flood Depth Indicators and Flood Signs	Several roads are affected by flooding, and safety could be improved throught the use of flood signs and depth indicators.	High	Improved flood awareness and information for residents and motorists, reduced risk to life.	Signs need to be installed in visible locations.	Council	Minimal	N/A

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Figures

FIGURE 1
NATTAI RIVER CATCHMENT STUDY AREA

Willow Vale
Renwick
Mittagong
Nattai River
Iron Mines Creek
Chinamans Creek

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
CRANE ST
FERGUSON CR
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
EVANS ST
RANGE RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
LOUISA ST
FITZROY ST
LEOPOLD ST
ARTHUR ST
ALFRED ST
ALBION L
MAIN ST
ALICE ST
CHURCH L
VICTORIA ST
EDWARD ST
ALBERT ST
WARD L
REGENT ST
RAILWAY PDE
WAVERLEY PDE
OXFORD ST
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
PIONEER ST
SUNSET POINT DR
LEE ST
BESSEMER ST
PARK ST
BOWRAL RD
FARADAY ST
MURCHISON ST
RESERVOIR ST
NERO ST
OXLEY DR
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
GIBRALTAR RD
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
ETHERIDGE ST
HUXLEY ST
ROSCOE ST
EARL ST

N

Railway Line
Study Area
Rivers and Creeks
Cadastre

0 100 200 400 600 800 m

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FIGURE 2
NATTAI RIVER CATCHMENT
DIGITAL ELEVATION MODEL

RAILWAY TCE
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
RENWICK DR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
Renwick
BOLD ST
ORIENT ST
Willow Vale
CRANE ST
WILLOW ST
FERGUSON CR
MARY ST
BELMORE ST
BONG BONG RD
ARGYLE ST
CORDEAUX ST
WINIFRED CR
CHALKER CR
MARCHMONT CR
OAKLANDS ST
OLD HUME HWY
COLO ST
SOUTHEY ST
WEBB ST
PAYTEN ST
EVANS ST
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
RANGE RD
OLD SOUTH RD
LOUISA ST
LOUISA ST
FITZROY ST
ALBION L
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
ALFRED ST
ALFRED L
MAIN ST
Mittagong
ALICE ST
CHURCH L
WAVERLEY PDE
DEVON ST
ROBINSON ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
OXFORD ST
BOURNE CL
TYNDALL ST
SPENCER ST
NERO ST
PIONEER ST
REGENT L
REGENT ST
RAILWAY PDE
SUNSET POINT DR
LEE ST
BESSEMER ST
OLD HUME HWY
PARK ST
PARK L
BOWRAL RD
RESERVOIR ST
OXLEY DR
MURCHISON ST
FARADAY ST
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
GIBRALTAR RD
HENDERSON AV
RAINBOW RD
BREWSTER ST
HUXLEY ST
SEDGMAN AV
ROSCOE ST
ETHERIDGE ST
EARL ST

N

Study Area
Railway line
Cadastre
Elevation (mAHD)
High : 750
Low : 610

0 100 200 400 600 800 m

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FIGURE 3
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
20% AEP EVENT

Renwick Renwick

Mittagong Mittagong

RENWICK DR
BOLD ST
HIGHLANDER ST
OLD HUME HWY
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
FERGUSON CR
MARCHMONT CR
ARGYLE ST
WANDEVAN PL
OAKLANDS ST
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
OLD HUME HWY
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
CHURCH L
WARD L
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
GOVERNMENT RD
OXLEY DR
RESERVOIR ST
MURCHISON ST
FARADAY ST
PRINCE ST
ACACIA ST
MORTS L
HARNETT L (Priv.)
OLD SOUTH RD
PIONEER ST
LEE ST
BESSEMER ST
SUNSET POINT DR
PARK ST
PARK L
BOWRAL RD
HENDERSON AV

620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740

N

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

0 0.25 0.5 0.75 1 Km

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FIGURE 4
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
10% AEP EVENT

Renwick Renwick
Mittagong Mittagong

RENWICK DR
FERGUSON CR
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
COLO ST
MARCHMONT CR
ARGYLE ST
WANDEVAN PL
OAKLANDS ST
SOUTHEY ST
PAYTEN ST
WEBB ST
EVANS ST
RANGE RD
OLD SOUTH RD
DARCH PL
BEATRICE ST
ALFRED ST
OLD HUME HWY
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
CHURCH L
WARD L
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
GOVERNMENT RD
OXLEY DR
RESERVOIR ST
MURCHISON ST
FARADAY ST
PRINCE ST
ACACIA ST
MORTS L
HARNETT L (Priv.)
HENDERSON AV
SUNSET POINT DR
BESSEMER ST
PIONEER ST
LEE ST
PARK ST
PARK L
BOWRAL RD

N

Peak Flood Contours
Study Area
Railway line
Cadastre

Dpeth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

0 0.25 0.5 0.75 1 Km

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FIGURE 5
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
5% AEP EVENT

Renwick
Mittagong
RENWICK DR
BOLD ST
HIGHLANDER ST
OLD HUME HWY
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
COLO ST
FERGUSON CR
MARCHMONT CR
ARGYLE ST
WANDEVAN PL
OAKLANDS ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
CHURCH L
WARD L
PIONEER ST
LEE ST
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
GOVERNMENT RD
OXLEY DR
RESERVOIR ST
HARNETT L (Priv.)
ACACIA ST
PRINCE ST
MORTS L
OLD SOUTH RD
MURCHISON ST
FARADAY ST
HENDERSON AV
BESSEMER ST
SUNSET POINT DR
PARK ST
PARK L
BOWRAL RD
OLD HUME HWY

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

N

0 0.25 0.5 0.75 1 Km

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FIGURE 6
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
2% AEP EVENT

Renwick Renwick

Mittagong Mittagong

RENWICK DR
BOLD ST
HIGHLANDER ST
OLD HUME HWY
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
COLO ST
FERGUSON CR
WANDEVAN PL
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
OLD HUME HWY
RAILWAY CR
LOUISA ST
LEOPOLD L
LEOPOLD ST
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
CHURCH L
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
NERO ST
GOVERNMENT RD
OLD SOUTH RD
PIONEER ST
LEE ST
BESSEMER ST
SUNSET POINT DR
PARK L
PARK ST
BOWRAL RD
FARADAY ST
HENDERSON AV
MURCHISON ST
DEVON ST
ROBINSON ST
RESERVOIR ST
OXLEY DR
PRINCE ST
ACACIA ST
MORTS L
HARNETT L (Priv.)

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

0 0.25 0.5 0.75 1 Km

N

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FIGURE 7
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
1% AEP EVENT

Renwick Renwick

Mittagong Mittagong

RENWICK DR
BOLD ST
HIGHLANDER ST
OLD HUME HWY
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
COLO ST
FERGUSON CR
WANDEVAN PL
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
OLD HUME HWY
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
CHURCH L
WARD L
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
GOVERNMENT RD
OXLEY DR
RESERVOIR ST
MURCHISON ST
FARADAY ST
PRINCE ST
ACACIA ST
MORTS L
HARNETT L (Priv.)
OLD SOUTH RD
PIONEER ST
LEE ST
BESSEMER ST
SUNSET POINT DR
PARK ST
PARK L
BOWRAL RD
HENDERSON AV

N

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

0 0.25 0.5 0.75 1 Km

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FIGURE 8
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
0.5% AEP EVENT

Renwick Renwick
Mittagong Mittagong

RENWICK DR
HIGHLANDER ST
OLD HUME HWY
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
COLO ST
MARCHMONT CR
ARGYLE ST
FERGUSON CR
WANDEVAN PL
OAKLANDS ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
OLD HUME HWY
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
MAIN ST
ALBION L
ALICE ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
CHURCH L
REGENT L
REGENT ST
RAILWAY PDE
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
GOVERNMENT RD
OXLEY DR
RESERVOIR ST
PRINCE ST
ACACIA ST
MORTS L
HARNETT L (Priv.)
OLD SOUTH RD
PIONEER ST
LEE ST
BESSEMER ST
PARK ST
PARK L
BOWRAL RD
OLD HUME HWY
SUNSET POINT DR
SUNSET POINT DR
FARADAY ST
MURCHISON ST
HENDERSON AV

N

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

0 0.25 0.5 0.75 1 Km

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FIGURE 9
NATTAI RIVER CATCHMENT
PEAK FLOOD DEPTHS AND LEVELS
PMF EVENT

Renwick
Mittagong
RENWICK DR
BOLD ST
HIGHLANDER ST
OLD HUME HWY
MARY ST
BELMORE ST
BONG BONG RD
JANE CT
WINIFRED CR
CHALKER CR
GOLD ST
ARGYLE ST
MARCHMONT CR
WANDEVAN PL
OAKLANDS ST
FERGUSON GR
PAYTEN ST
WEBB ST
SOUTHEY ST
EVANS ST
BEATRICE ST
DARCH PL
ALFRED ST
RANGE RD
OLD SOUTH RD
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
HELENA ST
ALICE ST
MAIN ST
ALBION L
DEVON ST
ROBINSON ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
CHURCH L
VERNON ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
OXFORD ST
SPENCER ST
NERO ST
GOVERNMENT RD
PIONEER ST
LEE ST
REGENT L
REGENT ST
RAILWAY PDE
PARK L
PARK ST
BOWRAL RD
OLD HUME HWY
BESSEMER ST
SUNSET POINT DR
OXLEY DR
RESERVOIR ST
HARNETT L (Priv.)
ACACIA ST
PRINCE ST
MORTS L
MURCHISON ST
FARADAY ST
HENDERSON AV

Peak Flood Contours
Study Area
Railway line
Cadastre

Depth (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5

N

0 0.25 0.5 0.75 1 Km

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FIGURE 10
NATTAI RIVER CATCHMENT
FLOOD EMERGENCY RESPONSE CLASSIFICATION

RAILWAY TCE
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
RENWICK DR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
Renwick
BOLD ST
ORIENT ST
Willow Vale
CRANE ST
WILLOW ST
FERGUSON CR
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
ARGYLE ST
CORDEAUX ST
CHALKER CR
MARCHMONT CR
OAKLANDS ST
OLD HUME HWY
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
DARCH PL
BEATRICE ST
HILLSIDE CL
EVANS ST
RANGE RD
RAILWAY CR
OLD SOUTH RD
LOUISA ST
LOUISA ST
FITZROY ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
ALFRED ST
ALFRED L
ALBION L
MAIN ST
Mittagong
ALICE ST
CHURCH L
WAVERLEY PDE
DEVON ST
ROBINSON ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
OXFORD ST
BOURNE CL
TYNDALL ST
SPENCER ST
REGENT L
REGENT ST
RAILWAY PDE
PIONEER ST
LEE ST
SUNSET POINT DR
BESSEMER ST
OLD HUME HWY
PARK ST
PARK L
BOWRAL RD
NERO ST
OXLEY DR
RESERVOIR ST
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
FARADAY ST
MURCHISON ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
HUXLEY ST
SEDGMAN AV
ROSCOE ST
ETHERIDGE ST
EARL ST

N

Study Area
Railway line
Cadastre

Flood Emergency Classification
Indirectly Affected
High Flood Island
Low Flood Island
Overland Escape Route
Rising Road Access

PMF Depths (m)
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.8

0 100 200 400 600 800 m

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FIGURE 11
NATTAI RIVER CATCHMENT
HYDRAULIC CATEGORIES
1% AEP EVENT

Willow Vale
Renwick
Mittagong

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
CRANE ST
FERGUSON CR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
EVANS ST
RANGER RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
LOUISA ST
FITZROY ST
LEOPOLD ST
ARTHUR ST
ALFRED ST
ALBION L
MAIN ST
ALICE ST
CHURCH L
VICTORIA ST
EDWARD ST
WARD L
ALBERT ST
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
OXLEY DR
RESERVOIR ST
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
EARL ST
PIONEER ST
LEE ST
BESSEMER ST
SUNSET POINT DR
OLD HUME HWY
PARK L
PARK ST
BOWRAL RD
REGENT L
REGENT ST
RAILWAY PDE
FARADAY ST
MURCHISON ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
HUXLEY ST
ROSCOE ST
ETHERIDGE ST

N

Study Area
Railway line
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe

0 100 200 400 600 800 m

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FIGURE 12
NATTAI RIVER CATCHMENT
HYDRAULIC CATEGORIES
PMF EVENT

Willow Vale
Renwick
Mittagong

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
CRANE ST
FERGUSON CR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
EVANS ST
RANGE RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
LOUISA ST
FITZROY ST
LEOPOLD ST
ARTHUR ST
ALFRED ST
ALBION L
MAIN ST
ALICE ST
CHURCH L
VICTORIA ST
EDWARD ST
ALBERT ST
WARD L
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
OXLEY DR
RESERVOIR ST
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
EARL ST
PIONEER ST
REGENT L
REGENT ST
RAILWAY PDE
PARK L
PARK ST
BOWRAL RD
OLD HUME HWY
SUNSET POINT DR
LEE ST
BESSEMER ST
FARADAY ST
MURCHISON ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
HUXLEY ST
ROSCOE ST
ETHERIDGE ST

N

Study Area
Railway line
Cadastre
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe

0 100 200 400 600 800 m

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FIGURE 13
NATTAI RIVER CATCHMENT HAZARD CATEGORIES

Willow Vale
Renwick
Mittagong

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
CRANE ST
FERGUSON CR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
EVANS ST
RANGER RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
LOUISA ST
FITZROY ST
LEOPOLD ST
ARTHUR ST
ALFRED ST
ALBION L
MAIN ST
ALICE ST
CHURCH L
VICTORIA ST
EDWARD ST
ALBERT ST
WARD L
REGENT ST
RAILWAY PDE
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
NERO ST
OXLEY DR
RESERVOIR ST
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
EARL ST
PIONEER ST
LEE ST
SUNSET POINT DR
BESSEMER ST
OLD HUME HWY
PARK L
PARK ST
BOWRAL RD
FARADAY ST
MURCHISON ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
HUXLEY ST
ROSCOE ST
ETHERIDGE ST

N

Study Area
Railway line
Cadastre

Hazard Categories
High Flood Risk Precinct
Medium Flood Risk Precinct
Fringe Low Flood Risk Precinct
Low Flood Risk Precinct

0 100 200 400 600 800 m

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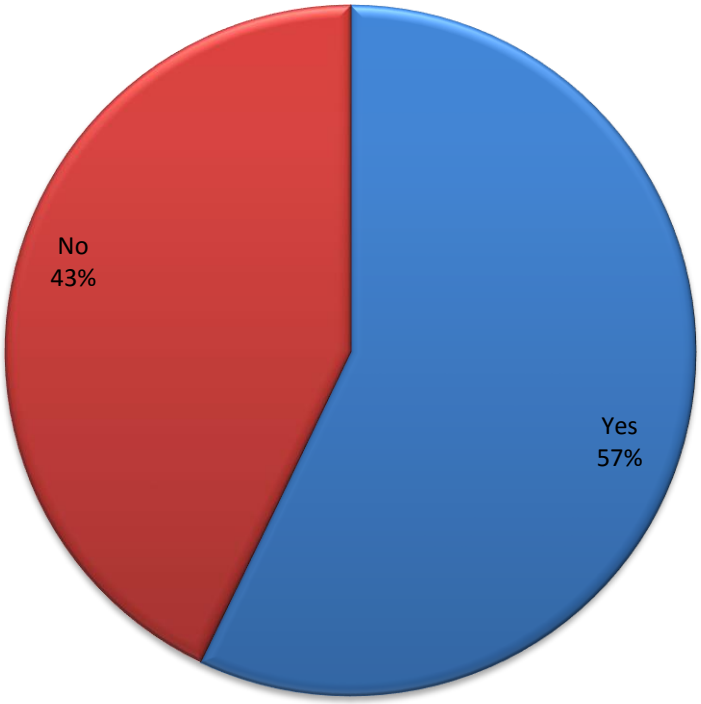
Are you aware of the Nattai Creek Flood Study?



If yes, was your property identified as being at risk of flooding or near a flood affected area?

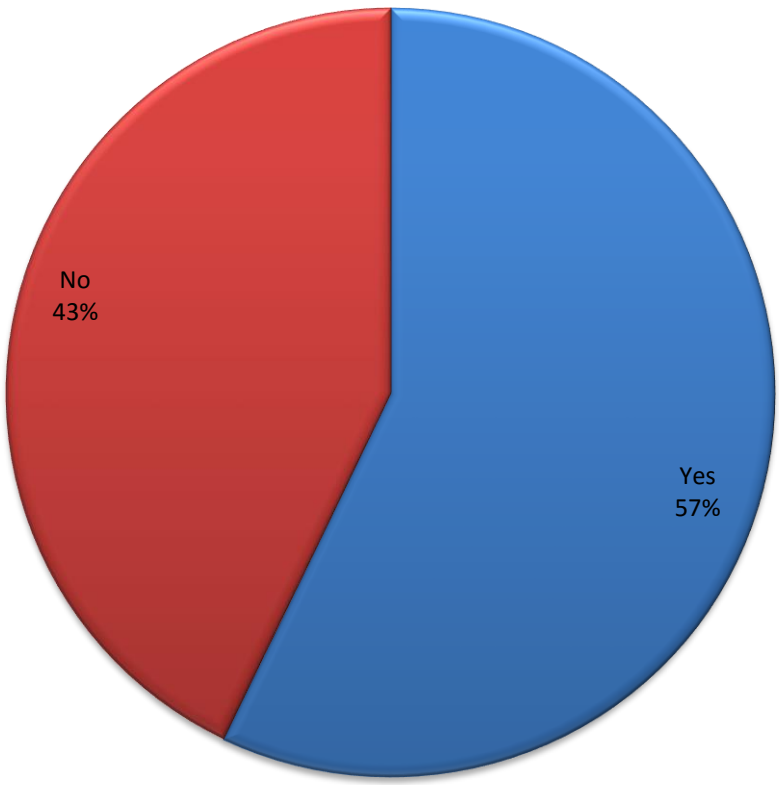


FIGURE 15
NATTAI RIVER CATCHMENT
COMMUNITY IDENTIFIED AREAS REQURING MITIGATION

Willow Vale
Renwick
Mittagong
Nattai River
Iron Mines Creek
Chinamans Creek

RAILWAY TCE
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
ORIENT ST
CRANE ST
WILLOW ST
CORDEAUX ST
FERGUSON CR
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
COLO ST
OAKLANDS ST
MARCHMONT CR
ARGYLE ST
WEBB ST
SOUTHEY ST
EVANS ST
RANGE RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
OLD HUME HWY
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
ALFRED ST
ALFRED L
ALICE ST
ALBION L
MAIN ST
CHURCH L
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
GOVERNMENT RD
NERO ST
RESERVOIR ST
MURCHISON ST
REGENT L
REGENT ST
RAILWAY PDE
PARK L
PARK ST
BOWRAL RD
PIONEER ST
LEE ST
SUNSET POINT DR
BESSEMER ST
FARADAY ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
HUXLEY ST
ROSCOE ST
ETHERIDGE ST
PRINCE ST
ACACIA ST
MORTS L
OXLEY DR
DUKE ST
EARL ST

Mitigation Works Required
Study Area
Rivers and Creeks
Railway Line
Cadastre

N

0 100 200 400 600 800 m

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FIGURE 16
COMMUNITY RESPONSES
FLOOD MITIGATION SUGGESTIONS

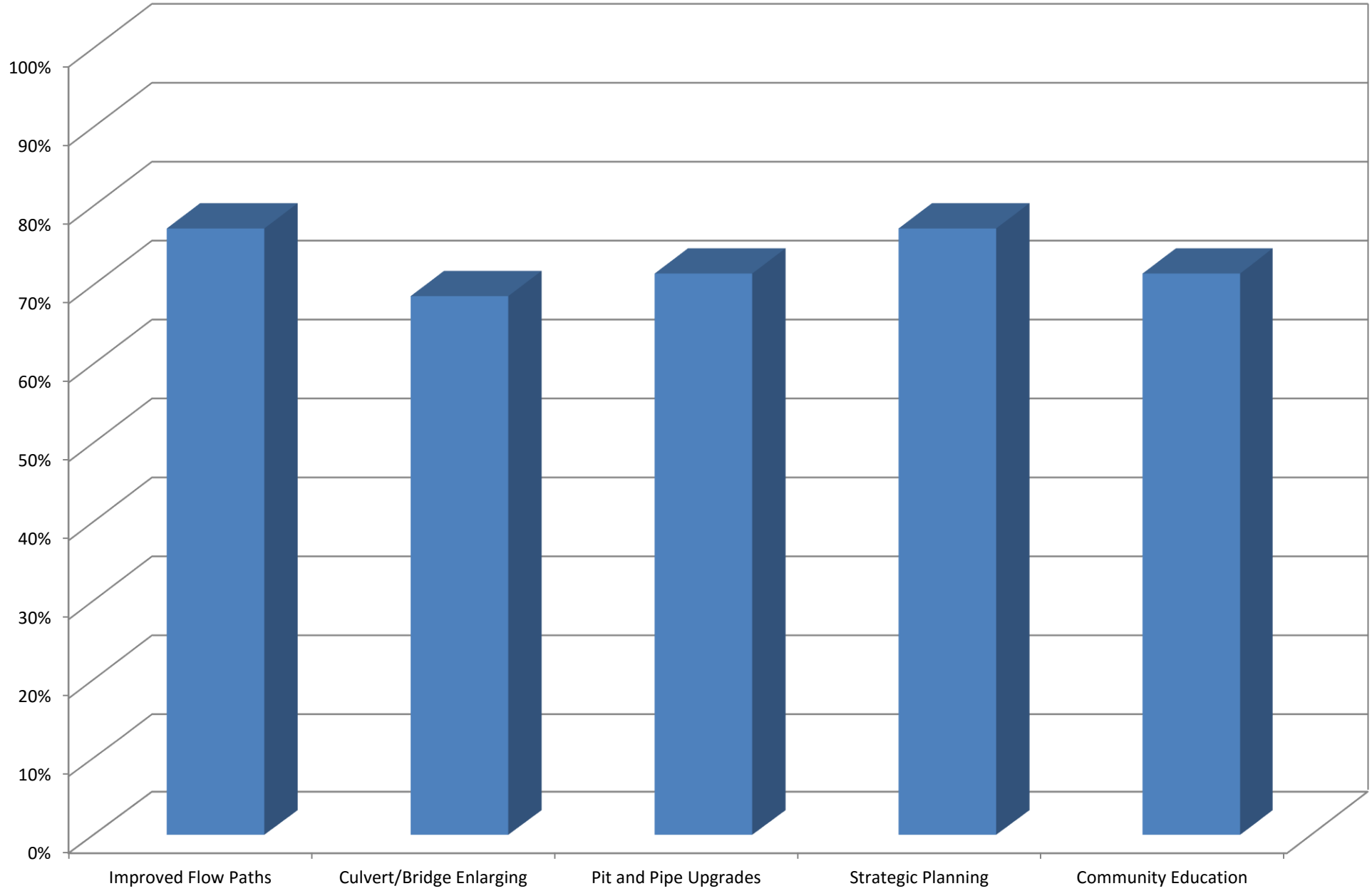

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FIGURE 17
NATTAI RIVER CATCHMENT
ABOVE FLOOR INUNDATION LIABILITY

RAILWAY TCE
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
RENWICK DR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
Renwick
BOLD ST
ORIENT ST
Willow Vale
CRANE ST
WILLOW ST
FERGUSON CR
CORDEAUX ST
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
ARGYLE ST
MARCHMONT CR
OAKLANDS ST
OLD HUME HWY
COLO ST
SOUTHEY ST
PAYTEN ST
WEBB ST
DARCH PL
BEATRICE ST
HILLSIDE CL
RAILWAY CR
EVANS ST
RANGE RD
OLD SOUTH RD
LOUISA ST
LOUISA ST
FITZROY ST
ALBION L
MAIN ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
ALFRED ST
ALFRED L
ALICE ST
Mittagong
CHURCH L
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
DEVON ST
ROBINSON ST
SPENCER ST
REGENT L
REGENT ST
RAILWAY PDE
PIONEER ST
SUNSET POINT DR
LEE ST
BESSEMER ST
OLD HUME HWY
PARK ST
PARK L
BOWRAL RD
FARADAY ST
MURCHISON ST
NERO ST
OXLEY DR
RESERVOIR ST
ACACIA ST
PRINCE ST
MORTS L
DUKE ST
GIBRALTAR
HENDERSON AV
RAINBOW RD
BREWSTER ST
HUXLEY ST
SEDGMAN AV
ROSCOE ST
ETHERIDGE ST
EARL ST

N

Study Area
Railway line
Cadastre

First Event Flooded Above Floor Level

- PMF Event
- 0.5% AEP Event
- 1% AEP Event
- 2% AEP Event
- 5% AEP Event
- 10% AEP Event
- 20% AEP Event
- Not Flooded

0 100 200 400 600 800 m

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FIGURE 18
NATTAI RIVER CATCHMENT
MITIGATION OPTION LOCATIONS

Willow Vale
Renwick
Mittagong

FM01
FM02
FM03
FM04
FM05
FM07

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
CRANE ST
FERGUSON CR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
COLO ST
WINIFRED CR
MARCHMONT CR
ARGYLE ST
WANDEVAN PL
OAKLANDS ST
SOUTHEY ST
PAYTEN ST
WEBB ST
RANGE RD
OLD SOUTH RD
DARCH PL
BEATRICE ST
HILLSIDE CL
RAILWAY CR
LOUISA ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
HELENA ST
ALBION L
MAIN ST
ALICE ST
ALFRED ST
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
REGENT L
REGENT ST
RAILWAY PDE
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
ROBINSON ST
NERO ST
OXLEY DR
MURCHISON ST
ACACIA ST
MORTS L
PRINCE ST
DUKE ST
GIBRALTAR RD
EARL ST
PARK L
PARK ST
OLD HUME HWY
BOWRAL RD
PIONEER ST
LEE ST
SUNSET POINT DR
BESSEMER ST
FARADAY ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
SEDGMAN AV
ETHERIDGE ST
HUXLEY ST
ROSCOE ST

N

Railway Line
FRMS Options
Study Area
Cadastre

0 100 200 400 600 800 m

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FIGURE 19
OPTION FM01
REMOVAL OF WEIR UPSTREAM OF SWIMMING POOL
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

FERGUSON CR
OLD HUME HWY
HAWKINS DRIVE

N

Existing Pits
Existing Pipes
Weir
Channel Regraded
Railway Line
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 25 50 100 150 200
m

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FIGURE 20
OPTION FM02
REMOVAL OF MITTAGONG SWIMMING POOL AND WEIR
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

BONG BONG RD
FERGUSON CR
OTHEY ST
OLD HUME HWY
HAWKINS DRIVE
BEATRICE ST

N

Existing Pits
Existing Pipes
Weir
Channel Regraded
Railway line
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 25 50 100 150 200 m

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FIGURE 21
OPTION FM03
REMOVAL OF WEIR AT THE MALTINGS
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

FERGUSON CR
SOUTHEY ST
WANDEVAN PL
FERNBROOK CR
OLD HUME HWY
HAWKINS DRIVE

N

- Existing Pits
- Existing Pipes
- Weir
- Channel Regraded
- Railway Line
- Cadastre

Impact (m)

- No Longer Flooded
- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1- -0.05
- -0.05 - -0.01
- No Impact
- 0.01- 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- > 0.5
- Newly Flooded

0 25 50 100 150 200 m

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FIGURE 22
OPTION FM04
INCREASE CHANNEL AT EVANS STREET WATERWAY
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

SOUTHEY ST
PAYTEN ST
COLO ST
EVANS ST

N

Location of the Maximum of impact
Existing Pits
Existing Pipes
Creek
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 25 50 100 150 200 m

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FIGURE 23
OPTION FM05
UPGRADE COLO STREET CULVERT
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

2x3m x0.75m RCBC

COLO ST

EVANS ST

Existing Pits
Existing Pipes
Upgraded Pipes
Creek
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 12.5 25 50 75 100 m

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FIGURE 24
OPTION FM06
COMBINATION OPTIONS FM04 AND FM05
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

SOUTHEY ST

COLO ST

PAYTEN ST

EVANS ST

2x3m x0.75m RCBC

N

Existing Pits
Existing Pipes
Upgraded Pipes
Creek
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 25 50 100 150 200 m

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FIGURE 25
OPTION FM07
RIPARIAN MANAGEMENT OF RIVER
PEAK FLOOD LEVEL IMPACT - 1% AEP EVENT

BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
COLO ST
WILLIS PL
LIVINGSTONE CT
FARNHAM CL
MARCHMONT CR
FERGUSON CR
OAKLANDS ST
WANDEVAN PL
OLD HUME HWY
FERNBROOK CR
SOUTHEY ST
WEBB ST
HAWKINS DRIVE
PAYTEN ST
EVANS ST
BEATRICE ST
DARCH PL
CONIFER PL
LEOPOLD ST
HILLSIDE CL
ALFRED ST
BELGRAVE ST
ERNEST ST
RAILWAY CR
RAILWAY PDE
BELMORE ST
LOUISA ST
FITZROY ST
REGENT ST
ARTHUR L
LEOPOLD L
HELENA ST
ALFRED L
ALBION L
MAIN ST
ALBION ST
ARTHUR ST
EDWARD ST
EDWARD L
ALICE ST
STANLEY ST
RANGE RD
WAVERLEY PDE
DEVON ST
TYNDALL ST
SPENCE

Existing Pits
Existing Pipes
Cleared Area
Railway Line
Cadastre

Impact (m)
No Longer Flooded
< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1- -0.05
-0.05 - -0.01
No Impact
0.01- 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5
Newly Flooded

0 50 100 200 300 400 m

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FIGURE 26
NATTAI RIVER CATCHMENT FLOOD PLANNING AREA

Willow Vale
Renwick
Mittagong

RAILWAY TCE
ORIENT ST
WILLOW ST
CORDEAUX ST
OLD HUME HWY
CRIMEA ST
ELSWORTH AV
INKERMAN RD
CRANE ST
FERGUSON CR
RENWICK DR
CUPITT ST
FURY L
DE LAURET ST
STURT L
BOLD ST
MARY ST
BELMORE ST
BONG BONG RD
WINIFRED CR
CHALKER CR
OAKLANDS ST
COLO ST
SOUTHEY ST
MARCHMONT CR
PAYTEN ST
WEBB ST
ARGYLE ST
EVANS ST
RANGE RD
OLD SOUTH RD
BEATRICE ST
DARCH PL
HILLSIDE CL
RAILWAY CR
LOUISA ST
FITZROY ST
LEOPOLD ST
LEOPOLD L
ARTHUR ST
ARTHUR L
ALFRED ST
ALFRED L
ALICE ST
ALBION L
MAIN ST
CHURCH L
VICTORIA ST
EDWARD ST
EDWARD L
ALBERT ST
ALBERT L
WARD L
OXFORD ST
WAVERLEY PDE
BOURNE CL
TYNDALL ST
SPENCER ST
DEVON ST
ROBINSON ST
PIONEER ST
REGENT L
REGENT ST
RAILWAY PDE
PARK L
PARK ST
BOWRAL RD
OLD HUME HWY
SUNSET POINT DR
LEE ST
BESSEMER ST
FARADAY ST
MURCHISON ST
RESERVOIR ST
NERO ST
OXLEY DR
PRINCE ST
ACACIA ST
MORTS L
DUKE ST
GIBRALTAR RD
EARL ST
HENDERSON AV
RAINBOW RD
BREWSTER ST
HUXLEY ST
SEDGMAN AV
ETHERIDGE ST
ROSCOE ST

N

Study Area
Railway line
Cadastre
FPA Extent

0 100 200 400 600 800 m

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Appendix A

APPENDIX A: GLOSSARY of TERMS

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of

	connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing

	how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

	in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

	minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to “water level”. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Newsletter - August 2015

Nattai River
Floodplain Risk Management Study and Plan

A Floodplain Risk Management Study and Plan (FRMS&P) is currently being prepared for the Nattai River Catchment. Wingecarribee Shire Council has appointed flood consultants WMAwater to undertake this Study.

The Floodplain Management Process

The State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. Under the Policy, local government is responsible for managing flood liable land.

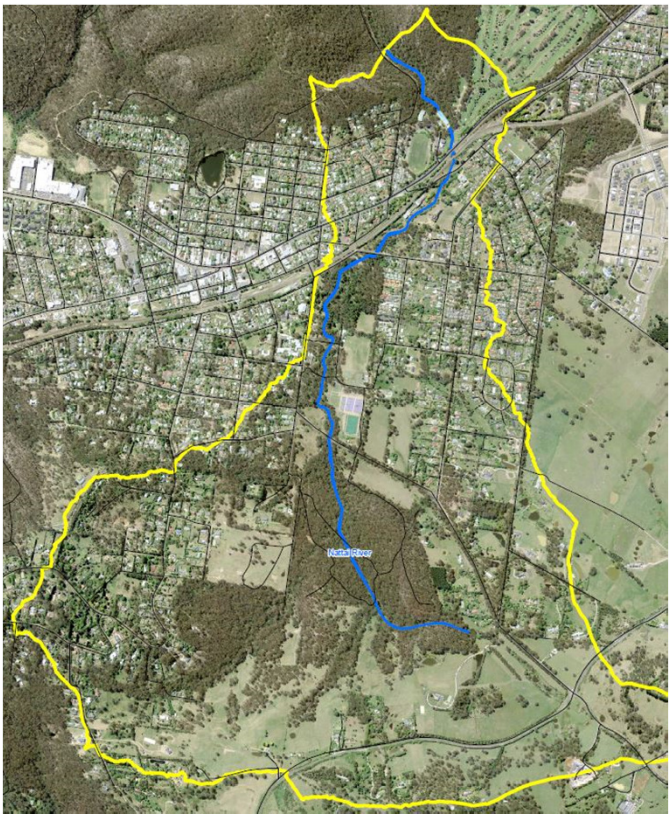
The Policy encourages the development of:

- solutions to existing flood problems in developed areas, and
- strategies for ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in existing developed areas.

The State Government's Flood Policy provides technical and financial support for a number of floodplain management activities. Funding for this Study was provided from the State Government's Flood Risk Management Program and Wingecarribee Shire Council.

Study Area and Background

The Nattai River Catchment is located in the Southern Highlands of NSW and encompasses a total area of 6.75 km². The Nattai River originates near the intersection of Range Road and Old South Road at Mittagong and flows in a northerly direction through the eastern part of Mittagong.



During periods of intense rainfall the Nattai River and its tributaries will overtop their banks and inundate the floodplain with the potential to flood adjacent properties. The stormwater system will reach capacity with excess water being conveyed as overland flow in the road reserve and through properties.

The Nattai River Flood Study has been completed and was adopted by Council in March 2014. The Flood Study determined flood behaviour across the catchment and identified flood affected areas where flood mitigation options could be investigated.

The following areas were identified in the Flood Study as flooding hotspots. Further investigation will be undertaken to identify further flooding hotspots.

Nattai River
Floodplain Risk Management Study and Plan

Weir – Old Hume Highway

The weir and other obstructions downstream of the Old Hume Highway will be investigated to determine their effect on flood behaviour and if any design improvements can be made that may reduce flood affectation on adjacent properties

Watercourse - Evans Street

The watercourse that runs parallel to Evans Street will be investigated to determine if any improvements can be made to alleviate the surrounding properties from flooding.

How can I have my say?

A questionnaire is enclosed with this newsletter. Please complete this and return to the FREEPOST address in the envelope provided. If you prefer, questionnaires can also be completed online at: https://www.surveymonkey.com/r/wingecarribee Please make sure that all surveys are returned before 30th August 2015.

A public open day will be held on Monday August 24th between 5.30pm and 6.30pm in the Joadja-Nattai Room of Mittagong RSL Club (Cnr Hume Highway & Bessemer Street Mittagong).

This newsletter and questionnaire forms part of our community consultation, which aims to provide information to the community and gauge feedback on possible mitigation options that could reduce flooding in flood affected areas and ultimately benefit the community.

After the surveys are collected a number of mitigation options will be identified and investigated to determine their benefit in regards to a reduction in flood levels and cost effectiveness, practicality and environmental impacts.

Contacts

If you would like to know more, or if you have any information on flooding which would assist in this Study, please complete the relevant sections on the questionnaire and return. Additional information and comment can be attached to the questionnaire when you return it or provided to the contacts below.

Sha Prodhan
Floodplain and Stormwater Engineer
sha.prodhan@wsc.nsw.gov.au

Wingecarribee Shire Council
PO Box 141, Moss Vale, NSW 2577

Tel: 02 4869 1203

Dan Morgan
Civil Engineer
morgan@wmawater.com.au

WMAwater
Level 2, 160 Clarence Street
Sydney, NSW 2000

Tel: 02 9299 2855

Nattai River- QUESTIONNAIRE
Floodplain Risk Management Study and Plan

Please complete this questionnaire and return to the FREEPOST address in the envelope provided. If you prefer, questionnaires can also be completed online at: www.surveymonkey.com/r/wingecarribee
Please make sure that all surveys are returned before 30th August 2015 or they may not be counted.

1. Your Details

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

Name:
Address: (please enter Southern Highlands address only)
Telephone:
Email:
Can we contact you directly for more information? ☐ Yes ☐ No

2. Are you aware of the Nattai River Flood Study?

☐ Yes ☐ No

3. If yes, was your property identified as being at risk of flooding or near a flood affected area?

☐ Yes ☐ No

4. As a local resident who has witnessed flooding you may have your own ideas about how to reduce flood risk. Which of the following would you prefer? (1 = least preferred, 5 = most preferred)

Proposed Option	Preference
Improved flow paths - Suggested location/other comments:	1 2 3 4 5
Culvert/bridge enlarging - Suggested location/other comments:	1 2 3 4 5
Pit and pipe upgrades - Suggested location/other comments:	1 2 3 4 5
Strategic planning and other related development controls - Suggested location/other comments:	1 2 3 4 5
Education of the community, providing greater awareness of potential hazards - Suggested location/other comments:	1 2 3 4 5

5. Please use this section to provide any additional information on flood affected areas in the catchment or additional comments if you have them.

Appendix C

APPENDIX C FLOOD DAMAGES ASSESSMENT

C.1. Quantification of Damages

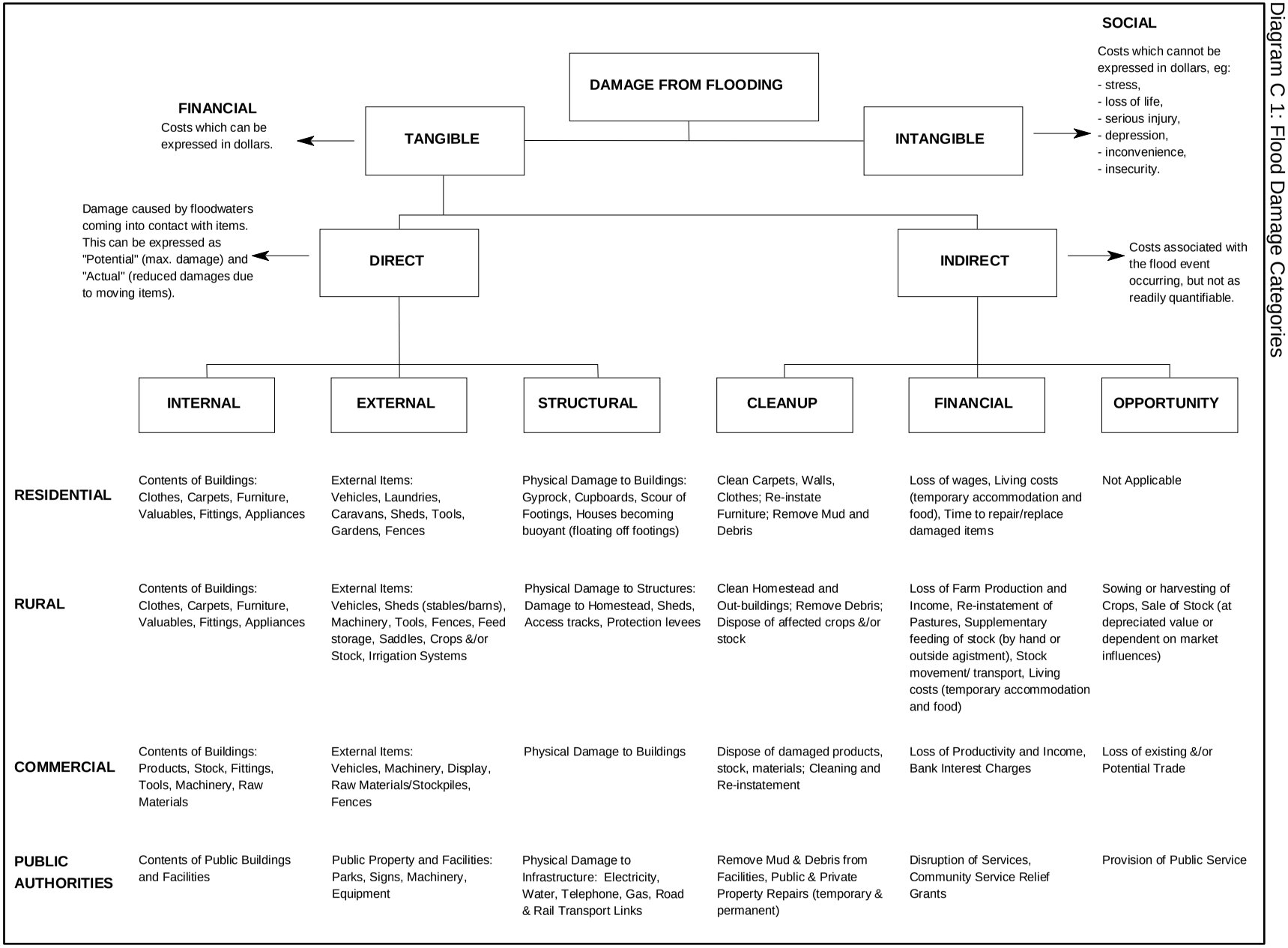
The quantification of flood damages is an important part of the floodplain risk management process. Flood damages can be defined as actual or potential where actual damage refers to the damage incurred during known flood events while potential damage is an estimation of the damage that could occur. Calculating potential flood damages gives a potential value of damage per property per design flood event and an overall average annual damages value which is the average cost to property owners per year owing to flood damages. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including;

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment and can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown on Diagram C 1 overleaf.

To undertake the damages assessment floor level data is required. A desktop floor level survey was performed by WMAwater for residential and commercial properties within the PMF extent using available ALS and Google Street View to estimate levels. Damages for commercial properties have been assessed using separate damage curves to residential damages.

Diagram C 1: Flood Damage Categories



RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accommodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accommodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

C.2. Identifying Flood Affected Properties

The damages assessment does not only look at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding. Figure 17 of the main report show in which design event buildings are first flooded above floor level.

C.3. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (Diagram C 1). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, considering damages estimates is useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

C.4. Expressing Flood Damages

Average Annual Damages (AAD) is equal to the damage caused by all floods over a period of time divided by the number of years in that period and represents the equivalent average damages that would be experienced by the community on an annual basis. This means that the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods total potential damage refers to the total damage estimated for a given flood event. Average damage per property is the Total damage estimated for a particular flood event divided by the number of properties flood affected in this event; either by flooding on the yard and/or above floor level of a building.

C.5. Calculating Tangible Flood Damages

The flood damages assessment was undertaken for existing development in accordance with current OEH guidelines (Reference 16) and the Floodplain Development Manual (Reference 1). Potential flood damages were calculated with the use of a height-damage curves which relate the depth of water above the floor with tangible damages. The height-damage curves were established in accordance with OEH guidelines (Reference 16).

For residential damages the values used are based on the recommendations in the guidance with a post late 2001 adjustment factor applied to increase damage values according to changes in Average Weekly Earnings (AWE) since 2001. Separate curves were established for non-residential damages. The resultant curves are shown in Diagram F 6 and F 7.

Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set.

In calculating AAD, it was assumed that there would be no flood damages in events smaller than the 2-year ARI event. The ARI of the PMF has been estimated to be 100,000 years.

As it is usual that commercial and industrial damages are higher than residential damages a multiplier was applied to the total damage per property for each event by adjusting the typical building size value within the curve development calculations. Other factors including the clean-up costs and external damages were adjusted to reflect the differences between commercial and residential properties.

To adjust the residential damage curve to be applicable to non-residential development, the average contents damages for a business was estimated to be $150,000 ($60,000 for residential) and the clean-up cost have been estimated at $6,000 ($4,000 for residential). This was done to take account the higher costs that businesses would incur compared to residential dwellings when flooded above floor level. The commercial damages curves were also amended to reduce the bench height based on the assumption that many commercial premises would have stock from floor level. External damage was set at $6,700 as per residential properties.

Diagram F 6: Flood Damages Curve – Residential Property

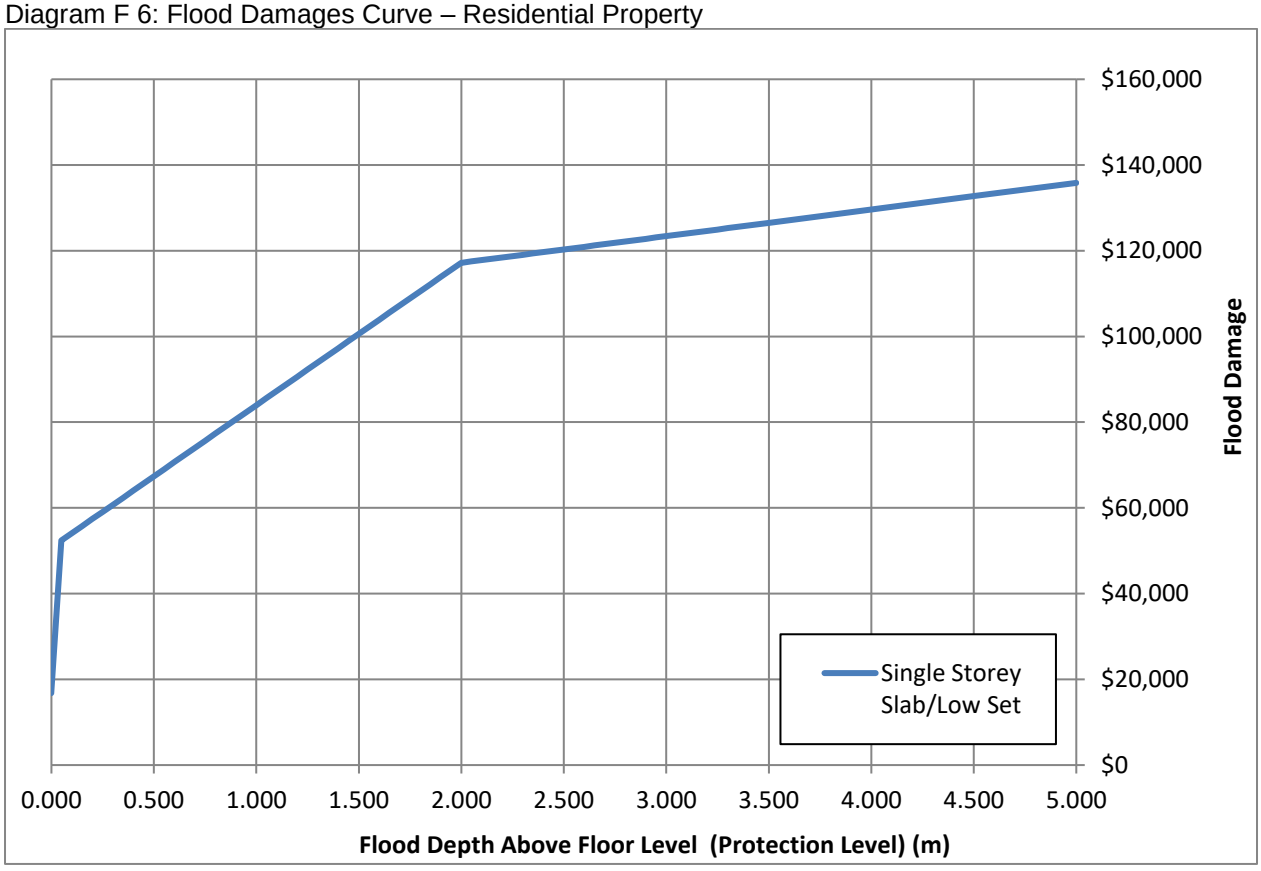
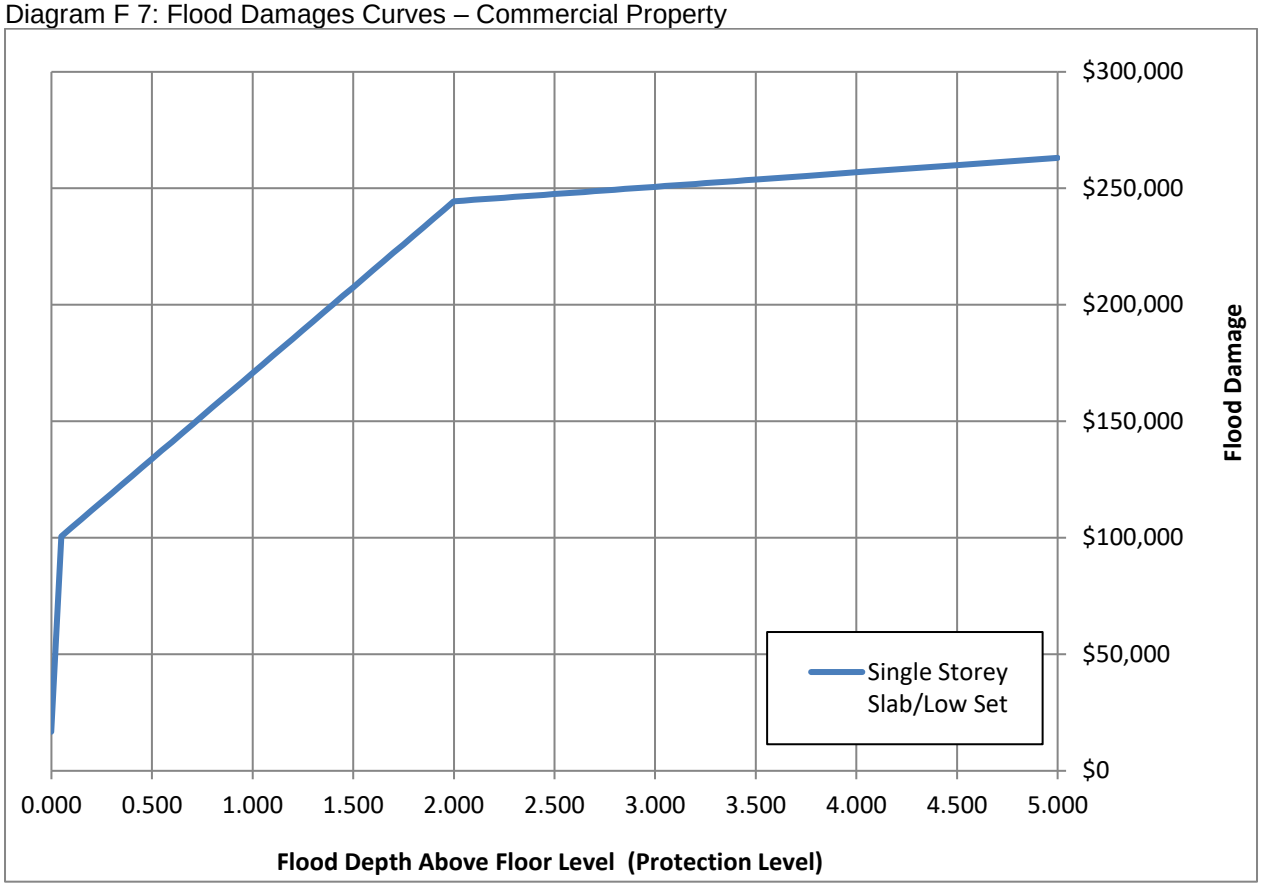


Diagram F 7: Flood Damages Curves – Commercial Property



The OEH guidelines suggest a protection level be applied when calculating damages. This effectively reduces the floor level by the given amount (usually 0.5 m). The level of protection is considered overly conservative and has not been applied in this instance. Applying a level of protection of 0.5 m at Mittagong would increase AAD by 350% and the number of properties flooded above floor level in the 5-year ARI event from 2 to 13. Incorporating this would lead to Council financing flood management measures that provide little benefit.

C.6. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed above, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the

stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. The Nattai River study area generally is classified as low hazard within the built up areas. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

C.7. Benefit/Cost Analyses for Management Options

To assess the full monetary benefits, including taking into account costs of construction and maintenance, Net Present Value (NPV) calculations were used and the B/C ratio established. The B/C approach is used to quantify the economic worth of each option enabling the ranking against other options. A B/C ratio is the benefits expressed in monetary terms, i.e. the reduction in AAD, compared to the actual likely cost of achieving those benefits, i.e. construction and maintenance costs.

The AAD per annum in today's monetary terms was assumed to apply for each year of the NPV damage calculation and was established for each year based on a discount rate of 7% as per the recommendation in the Residential Flood Damages FRM Guidelines (Reference 16). A construction cost was estimated and, using the NPV of the AAD assuming lifetime of 50-years, the B/C ratio was established for each of the options.