OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

July 2019

Item No: 2.7

Title: Adoption of Wyong River Catchment and Ourimbah Creek Catchment Floodplain Risk Management Studies and Plans - Supplementary Report

Department: Environment and Planning

25 May 2020 Ordinary Council Meeting

Reference: CPA/263177 - D13908037
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Manager: Luke Sulkowski, Unit Manager, Environmental Management
Executive: Scott Cox, Director Environment and Planning

Councillor Mehrtens left the meeting at 8.50pm and returned at 8.53pm.
Councillor Best left the meeting at 8.51pm and returned to the meeting at 8.54pm
Councillor Vincent left the meeting at 9.04pm and returned to the meeting at 9.06pm

Moved: ***Councillor Greenaway***
Seconded: ***Councillor MacGregor***

Resolved

404/20 That Council adopt the draft Wyong River Catchment Floodplain Risk Management Study and Plan as amended from the original report to Council dated 28 October 2019 as follows;

- ***Removal of the South Tacoma Floodway from the implementation list in the final Wyong River Catchment Floodplain Risk Management Study and Plan Report dated January 2020***

404/20 That Council adopt the draft Ourimbah Creek Catchment Floodplain Risk Management Study and Plan from the original report to Council dated 28 October 2019, subject to the following amendment;

- ***That an additional action be included in the plan to investigate the potential flooding impacts of the completed Kangy Angy rail facility with particular reference to the February 2020 floods and noted as a high priority with timing of 1 year to be completed.***

For:	***Against:***
Mayor Matthews, Councillors Burke, Gale, Greenaway, Hogan, Holstein, MacGregor, McLachlan, Mehrtens, Pilon, Smith, Sundstrom and Vincent	***Councillors Best and Marquart***

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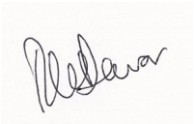
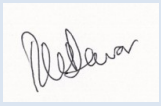
OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

JULY 2019

Project **Ourimbah Creek Floodplain Risk Management Study and Plan**	**Project Number** **115046**
Client Central Coast Council	**Client's Representative** Peter Sheath / Robert Baker / Vic Tysoe / Phil Foster
Authors Zac Richards Richard Dewar	**Prepared by:** 
Date 25 July 2019	**Verified by** 

Revision	Description	Distribution	Date
8	FRMS&P – Final	V Tysoe	25 July 2019
7	FRMS&P – Public Exhibition	V Tysoe	March 2019
6	FRMS – Public Exhibition	P. Sheath	October 2018
5	FRMS – Draft Final	P. Sheath, V Tysoe, L Davis	December 2017
4	FRMS – Draft Final	P. Sheath, R Baker	March 2017
3	FRMS – Draft Revision	Phil Foster	December 2016
2	FRMS – First Draft	Phil Foster	July 2016
1	FRMS – Progress Report 1	Phil Foster	January 2016

OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

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LIST OF ACRONYMS

AAD	Annual Average Damages
ABCB	Australian Building Codes Board
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Aerial Reduction Factor
ARI	Average Recurrence Interval
ARR87	Australian Rainfall and Runoff 1987 edition
BCA	Building Code of Australia
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECC	Department of Environment and Climate Change
DEM	Digital Elevation Model
DoP	Department of Planning
DSC	Dam Safety Committee
ERP	Emergency Response Planning
EP&A Act	Environmental Planning and Assessment Act
EY	Exceedances per Year
FDM	Floodplain Development Manual
FIC	Flood Intelligence Card
FPA	Flood Planning Area
FPL	Flood Planning Level
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
LEP	Local Environmental Plan (GLEP - Gosford, WLEP - Wyong)
LFP	Local Flood Plan
LGA	Local Government Area
LiDAR	Light Detection and Ranging or known as ALS (Airborne Laser Scanning)
LLS	Local Land Services
mAHD	meters above Australian Height Datum
MHL	Manly Hydraulics Laboratory
NOW	NSW Office of Water
PMF	Probable Maximum Flood
RAFTS	Hydrologic model
RFS	Rural Fire Service
RMS	Roads and Maritime Services
RMSVMS	RMS Variable Messaging Service
SES	State Emergency Services
SMS	Short Messaging Service
SRA	State Rail Authority
TBPL	Tuggerah Business Park Levee
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood hydraulic computer model
VHS	Voluntary House Raising
VP	Voluntary Purchase
WSUD	Water Sensitive Urban Design
XP-RAFTS	Hydrologic model

FOREWORD

The NSW State Government's Flood 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 subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Federal Government may also provide subsidies in some circumstances.

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

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management Study***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***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 Ourimbah Creek Floodplain Risk Management Study & Plan (FRMS&P) presented herein constitutes the second and third stages in the NSW Floodplain Risk Management Process for the Ourimbah Creek catchment and follows on from the Flood Study prepared by Catchment Simulation Solutions in October 2013. It updates the previously adopted 2011 Lower Ourimbah Creek FRMP (Paterson Consultants, July 2011) and Bangalow Creek and Cutrock Creek Floodplain Management Plan (Webb McKeown & Associates, March 1997). WMAwater has been engaged by Wyong Shire Council and Gosford City Council (the new Central Coast Council) to prepare this FRMS&P.

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

TERMINOLOGY USED IN REPORT

Australian Rainfall and Runoff (ARR) have produced a set of 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 terminology guidelines and uses % AEP for all events the 50% AEP and greater and EY for all events smaller and more frequent than this. The image below provides the relationship between the various terminologies.

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

The blue shaded areas represent the terminology adopted in this report.

BRIEF OUTLINE OF HOW DESIGN FLOOD LEVELS ARE CALCULATED

There are two broad approaches for calculating design events (floods of a known probability of occurrence such as the old 100 year event now termed the 1% AEP). The first is to undertake statistical analysis (termed flood frequency analysis) of a long record of peak flood levels (such as recorded for over 100 years at Windsor and at Maitland). This approach is rarely used (and not possible for the Ourimbah Creek catchment) as there are few places where these accurate long term records exist. The alternative method (termed rainfall runoff modelling) is to use computer models of the catchment which calculate peak flood levels (based on equations of flow) from design rainfall data provided by the BoM. The BoM is able to calculate design rainfall depths across Australia based on an extensive and long term record of historical rainfalls. The accuracy of the computer models are increased by "calibrating" them to historical flood height data using the actual rainfall records from that historical event. The models include detailed definition of the topography derived from laser aerial scanning of the ground (this data has a vertical accuracy of around +/- 150mm and is available at approximately 1m spacings).

EXECUTIVE SUMMARY

STUDY OBJECTIVE

The main objective of this report is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximate costed recommendations in regards to flood risk mitigation in the catchment.

CATCHMENT DESCRIPTION

The Ourimbah Creek catchment is located on the Central Coast of NSW, approximately 90km north of Sydney. Covering a total area of 160 km^2, the majority of the catchment is contained in the Wyong Shire Local Government Area (LGA), with 8 km^2 of the catchment contained in the Gosford City LGA to the south. In 2016 the two councils were combined into the Central Coast Council.

Ourimbah Creek generally flows in an easterly direction through state forest and rural properties before passing beneath the Pacific Motorway and Pacific Highway near Palmdale. It continues to flow in a northern and then easterly direction before passing beneath the Main Northern Railway Line and Wyong Road and eventually discharging into Tuggerah Lake at Chittaway Point. The catchment also incorporates a number of significant tributaries that are typically situated east of the Pacific Motorway and Pacific Highway. These include Bangalow Creek, Cut Rock Creek, Chittaway Creek, Dog Trap Gully, Canada Drop Down Creek and Kangy Angy Creek.

The Ourimbah Creek catchment west of the Pacific Motorway is typically characterised by state forest and rural land uses. The catchment area on the eastern side of the Pacific Motorway is significantly more developed and incorporates a range of residential, commercial, industrial and rural land uses. A number of major transportation links also extend across the eastern section of the catchment including the Main Northern Railway, Pacific Highway and Motorway, Wyong Road, Enterprise Drive and Chittaway Road.

FLOODING DOWNSTREAM OF WYONG ROAD

Downstream of Wyong Road the predominant cause of flooding is due to elevated levels in Tuggerah Lakes (as occurred in February 1990 and June 2007). Management measures for this area have previously been investigated in the 2014 Tuggerah Lakes Floodplain Risk Management Study and Plan and have not been considered further in this report.

PAST STUDIES

A number of past studies have looked at flooding in Ourimbah Creek. The latest being the 2013 Ourimbah Creek Flood Study. Possible management measures have also been examined in some of these past studies.

STAKEHOLDER AND COMMUNITY CONSULTATION

Throughout this study there has been consultation with the key stakeholders as well as with the community through the floodplain management committee, newsletters, questionnaires and

workshops. Three community meetings were held (one in March 2017 and two in April 2019). The latter was at the time of public exhibition of the Draft Study and Plan. 11 written responses were received following exhibition and the issues raised addressed. No additional management measures were suggested that were not already included. Several of the submissions were seeking clarification and these were addressed by Council.

EXISTING FLOOD PROBLEM

Flooding has been experienced in the catchment since prior to the 1970's and the more recent February 1990 and June 2007 events typify the nature of the problem. Whilst few urban areas are affected and general less than 10 residential floors inundated (note for the area upstream of Wyong Road and thus not affected by elevated levels in Tuggerah Lakes) the key issues are inconvenience and road access issues. The latter is significant as cars being washed away in floods are one of the main rescue activities undertaken by the SES and in Australia results in the main cause of death in floods. In a 10% AEP event 13 house floors are inundated and in the 1% AEP 34. However in the PMF over 500 houses will be inundated above floor.

Recent developments on the fringe of the floodplain have placed further pressure on the flood problem and in particular at the University of Newcastle, Ourimbah campus where inundation of student vehicles has occurred as well as raising risk to life issues with student access.

PREVIOUS FLOOD MITIGATION MEASURES UNDERTAKEN

The most significant works undertaken by the then Gosford City Council was creek re-alignment and stabilisation in the reach from the Pacific Highway to Teralba Street at Lisarow. Retarding basins were also constructed in the upper catchment to minimise the effects of urbanisation.

Both the former Wyong and Gosford Councils also adopted many property and response modification measures to address the issue.

POSSIBLE FLOODPLAIN MANAGEMENT MEASURES

Management measures can be subdivided into flood modification (changes the nature of flooding), property modification (change to the property) or response modification (changes the response of people) measures as summarised below.

Flood Modification	Property Modification	Response Modification
Levees	Land zoning	Community awareness
Temporary defences	Voluntary purchase	Flood warning
Channel construction	Building & development controls	Evacuation planning
Channel modification	Flood proofing	Evacuation access
Major structure modification	House raising	Flood plan / recovery plan
Drainage network modification	Flood access	
Drainage maintenance		
Retarding basins		

Each possible measure has to be investigated considering the positive and negative social, economic, hydraulic and environmental effects (refer Figure 1 (a to l)). As a result several measures were eliminated.

All flood modification measures investigated in detail are listed below:

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);
- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3);
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5);
- Option FM6 – Canntree Road Levee (Section 9.2.1.6);
- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7);
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1);
- Option FM9 – Lees Bridge Widening (Section 9.2.5.1);
- Option FM10 – Footts Road Weir Removal (Section 9.2.5.2);
- Option FM11 – Upstream Pacific Motorway Vegetation Management Area (Section 9.2.6.1);
- Option FM12 – Sohier Park Vegetation Management Area (Section 9.2.6.2);
- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1);
- Option FM14 – Combined Channel and Basin (Section 9.2.8).

The following roads have been investigated for flood access improvements:

- Option RM1 – Tuggerah Street at the Pacific Highway (Section 9.3.1.1);
- Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park (Section 9.3.1.2);
- Option RM3 – Coachwood Drive North of Mahogany Close (Section 9.3.1.3);
- Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus (Section 9.3.1.4);
- Option RM5 – Chittaway Road near Burns Road (Section 9.3.1.5);
- Option RM6 – Howes Road, Link Road (Section 9.3.1.6);
- Option RM7 – Orchard Road, Link Road (Section 9.3.1.7);
- Option RM8 – Tall Timbers, Link Road (Section 9.3.1.8);
- Option RM9 – Burns Road Bridge (Section 9.3.1.9);
- Option RM10 – Burns Road Raising and Culvert Upgrades (Section 9.3.1.10);
- Option RM11 – Elmo Street near Footts Road (Section 9.3.1.11);
- Option RM12 – Tapley Road (Section 9.3.1.12);
- Option RM13 – Macdonalds Road near Indigo Place (Section 9.3.1.13);
- Option RM14 – Pacific Highway at Dog Trap Gully (Section 9.3.1.14).

In addition the following other response modification measures have been evaluated:

- Automatic Road Closures and Boom Gates (Option RM15) (Section 9.3.2.1);
- Warning Signs (Option RM16 and RM17) (Section 9.3.2.2);
- Camera Fines (Option RM18) (Section 9.3.2.3);
- Potential Gauges for Flood Warning (Options RM19 and RM20) (Section 9.3.3.2);
- Opportunities for Increasing Available Warning Time (Options RM21 and RM22) (Section 9.3.3.6);

- Opportunities for Reducing Required Warning Time (Options RM23 and RM24) (Section 9.3.3.7);
- Shelter-in-place Feasibility Assessment (Option RM25) (Section 9.3.3.8);
- Flood Emergency Management Planning (Options RM26, RM27, RM28) (Section 9.3.4);
- Create a SES Flood Intelligence Card for Lees Bridge (Option RM29) (Section 9.3.4.3);
- Emergency Response Plans (Options RM30 and RM31) (Section 9.3.4.4);
- Community Flood Education (Option RM32) (Section 9.3.5).

The following specific property modification measures have been assessed:

- House Raising (Option PM1) (Section 9.4.1);
- Voluntary Purchase (Option PM2) (Section 9.4.2);
- Land Use Zoning (Option PM3) (Section 9.4.4);
- Changes to Planning Policy (Option PM4) (Section 9.4.7).

In addition Council requested the following specific objectives for flood prone areas, identified as part of the Flood Study to be investigated in this report (these are labelled as Brief Specific Objectives on Figure 1a to Figure 1l):

1. Cut Rock Creek between Pacific Highway and Teralba Street (Option FM14, see Section 9.2.8);
2. Pluim Park (improved flood access, see Section 9.3.1.1);
3. Tall Timbers Estate (improved flood access, see Section 9.3.1.8);
4. Sohier Park (improved flood access, see Section 9.3.1);
5. Turpentine, Ourimbah and Orchard Roads Kangy Angy (improved flood access, see Section 9.3.1.7);
6. Howes Road (improved flood access, see Section 9.3.1.6);
7. Chittaway Point (house raising, see Section 9.4.1);
8. University of Newcastle Ourimbah Campus. Issues include; access and evacuation (improved flood access, see Section 9.3.1), possible early flood warning system (see Section 9.3.3.3), flooding of lower car parking areas (see Option FM4 and FM5, Section 9.2.1.4 and 9.2.1.5);
9. Burns Road (improved flood access and road closures, see Section 9.3.1 and 9.3.2);
10. Assessment of existing levees (see Section 6.5).

RECOMMENDED FLOODPLAIN MANAGEMENT MEASURES IN THE PLAN

Fifty individual management measures were investigated of which 38 were included in the Plan (refer Table 4). These measures are summarised as follows:

- no measure was proposed that will reduce flood levels;
- only the house raising measure will reduce tangible damages to residential houses;
- 2 flood modification measures were proposed (levee audit and filling of University car park);
- 32 response modification measures were recommended of which 14 were for improved road access during a flood;
- 4 property modification measures were recommended;
- the measures were ranked using a multi objective matrix approach and given a Priority, Organisation Responsible, Costing and Timeframe label.

1. OURIMBAH CREEK FLOODPLAIN RISK MANAGEMENT PLAN

1.1. Introduction

The Ourimbah Creek Floodplain Risk Management Plan has been prepared for the Central Coast Council in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 1) and:

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

The Ourimbah Creek catchment is located on the Central Coast of NSW, approximately 90km north of Sydney. Covering a total area of 160 km^2, the majority of the catchment is contained in the Wyong Shire Local Government Area (LGA), with 8 km^2 of the catchment contained in the Gosford City LGA to the south. In 2016 the two councils were combined into the Central Coast Council.

Flooding has been recorded periodically since the 1930's but there are many more recorded instances of flooding in Tuggerah Lakes. It is possible that the incidence of flooding has historically been under reported along Ourimbah Creek and its tributaries. In recent times there have been two significant events, in February 1990 and June 2007. In both these events there was extensive flooding in the Newcastle, Lake Macquarie and Wyong/Gosford regions. Flooding causes significant hardship, including both tangible and intangible damages, to the community and for this reason the Central Coast Council has undertaken a program of studies to address the management of the flood problem in accordance with the NSW Government's *Floodplain Development Manual* 2005 (Reference 1).

1.2. Risk Management Measures Considered

A matrix of possible management measures was prepared and evaluated in this Floodplain Risk Management Study taking into account a range of parameters. This process eliminated a number of flood risk management measures (refer Section 9) including flood mitigation dams, additional retarding basins and voluntary purchase of all flood liable buildings. The use of on-site stormwater detention as a flood mitigation measure, as opposed to its use for mitigating the effects of urbanisation was also eliminated.

The full range of measures was evaluated and the outcomes are summarised in Table 1. Table 2 details the matrix scoring system and Table 3 provides the matrix results which ranks the management measures considered.

Community opinion on the full range of options has been canvassed during the public exhibition period. However, it should be noted that these outcomes may change in the future if climate change induced rainfall increases become significant.

Table 1: Summary of Management Measures Investigated in Study

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
ON-SITE DETENTION (Section 9.1)	Decrease effects of increased urbanisation.	• On-site detention or retarding basins are suitable measures to mitigate the potential increase in peak flow on downstream reaches as rural areas become urbanised. • Smaller on-site detention can help water quality and local drainage, but has little impact along the main tributaries.
LEVEES AND FILLING (Section 9.2.1)	Prevent or reduce the frequency of flooding of protected areas.	• Levees are suitable on large river systems where they can protect a number of buildings. • May cause local drainage problems and be unacceptable to the community due to restriction of waterfront access and views. • Levees will still be overtopped in major flood events and for this reason flood planning controls will still apply to areas protected by levees. • Specific sites have been investigated.
CHANNEL CONSTRUCTION / FLOODWAYS (Section 9.2.3)	To channel floodwaters away from affected areas and so reduce flood levels.	• The creation of floodways can provide an effective means of diverting floodwaters away from affected areas and thus reducing flood levels. • There are no practical areas where a floodway could be created due to existing development.
CHANNEL MODIFICATIONS (Section 9.2.4)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by straightening of the channel, widening or removal of vegetation along the banks. • However, such measures can often increase flood risk downstream. • These measures are costly to undertake and generally require on going maintenance, have significant environmental impacts, are not an ecologically sustainable measure and are thus rarely used.
REMOVAL OF HYDRAULIC RESTRICTIONS (Section 9.2.5)	To increase the capacity of the channel and so reduce flood levels upstream.	• The hydraulic capacity of the channel and floodplain can be increased by removal of significant hydraulic restrictions such as narrow culverts or low level bridges or even minimising the potential for blockage. • However, such measures can often increase flood risk downstream. • The larger measures (widen culverts or replace a bridge) are generally costly to undertake. Reducing the potential for blockage through regular maintenance is supported. • No location was identified which would provide a significant reduction in above floor inundation

MEASURE	PURPOSE	COMMENT
		upstream.
DRAINAGE MAINTENANCE (9.2.6)	Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure and may involve removing unwanted vegetation and other debris.	• Is an on going issue for Council. • Is not an environmentally sustainable management measures. • May have significant environmental implications.
FLOOD MITIGATION DAMS, RETARDING BASINS (Section 9.2.7)	Reduce the peak flow from the catchment into Ourimbah Creek and its tributaries by increasing the volume of flood storage in the catchment.	• The size of storages required to make a difference to large creeks such as Ourimbah Creek are very large, making them impractical on environmental, social and economic grounds.
RESPONSE MODIFICATION:		
IMPROVED FLOOD ACCESS (Section 9.3.1)	To ensure safe and reliable access during times of flood.	• There is a significant existing problem and 14 locations were investigated. • Elimination of the flood hazard cannot be eliminated. • Measures have been proposed to reduce the hazard at a number of locations.
ROAD CLOSURES AND NOTIFICATIONS (Section 9.3.2)	To reduce the risk to life of vehicles entering flood waters.	• A number of measures are possible. • Further investigation and liaison with RMS is required to determine the most appropriate and viable measures.
FLOOD WARNING (Section 9.3.3)	Enable people to prepare and evacuate, to reduce damages to property and injury to persons.	• Relatively short warning time makes it impossible to provide a fail safe warning system. • Any system will provide some additional warning. • Installation of water level gauges is supported.
FLOOD EMERGENCY PLANNING (Section 9.3.4)	Effective planning for emergency response is a vital way of reducing risk to life and property.	• The cost to undertake this measure is small and will provide a high benefit/cost ratio. • A range of measures are provided and supported.
COMMUNITY FLOOD EDUCATION (Section 9.3.5)	Educate people to prepare themselves and their properties for floods, to minimise flood damages and reduce the risk.	• A cheap and effective method but requires continued effort. • Possible approaches are provided.
PROPERTY MODIFICATION:		
VOLUNTARY HOUSE RAISING (Section 9.4.1)	Prevent flooding of existing buildings by raising the floor level above the floodwaters.	• All flood damages will not be prevented and only suitable for non-brick buildings on piers. • Costs approximately $80,000 per house but can vary considerably. • Only suitable for a small number of houses (generally with floor levels first inundated in the 10% AEP (1 in

MEASURE	PURPOSE	COMMENT
		10 year)) or smaller events and not attractive to all residents. • Should be investigated further for applicable properties.
VOLUNTARY PURCHASE OF INDIVIDUAL BUILDINGS (Section 9.4.2)	Purchase and removal of the most hazardous flood liable buildings to reduce risk to property and people.	• High cost per property. • Applicable for isolated, high hazard properties in flood liable areas. • Progress applications for 6 existing properties on Mannings Road. • Investigate scheme for Tall Timbers Estate.
FLOOD PROOFING (Section 9.4.3)	Prevent flooding of existing buildings by sealing all the entry points.	• Generally only suitable for brick, slab on ground buildings. • Less viable for residential buildings but should be considered for non residential buildings of slab on ground construction.
LAND USE ZONING (Section 9.4.4)	Reduce potential hazard and losses from flooding by appropriate land use planning.	• Well-established processes are in place for dealing with land-use in flood hazard areas. • Ourimbah Masterplan must address flooding.
FLOOD PLANNING LEVELS (Section 9.4.5)	Provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard.	• Recommended as the 1% AEP + 0.5m freeboard.
FLOOD PLANNING AREA (Section 9.4.6)	It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk.	• Review undertaken and consistent with best practice.
CHANGES TO PLANNING POLICY (Section 9.4.7)	Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages.	• Council should apply further controls is some areas. • Flood mapping should take into consideration the findings of the Flood Study and this FRMS&P.
MODIFICATION TO THE S10.7 CERTIFICATE (Section 9.4.8)	S10.7 certificates should clearly inform owners and purchasers of risks, planning controls and policies that apply to the subject land.	• Council should continue to review flood related information on the Section 10.7 Certificate to bring it in line with the findings of the Flood Study and this FRMS&.
OTHER MANAGEMENT MEASURES		
FLOOD INSURANCE (Section 9.5)	To spread the risk of individual financial loss across the whole community	• Does not reduce damage, but spreads the cost. • These issues are outside the scope of this present

MEASURE	PURPOSE	COMMENT
	through insuring against flood damage.	study. • Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages. • Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not available.

1.2.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows) of the project over its life. It is a standard method for using the time value of money to compare the reduction in flood damages (benefit) with the capital and on going cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure. A multi-variate decision matrix was developed for the Ourimbah Creek area, allowing B/C estimates, community involvement in determining social and other intangible values, and assessment of environmental impacts.

1.2.2. Management Matrix

The criteria assigned a value in the management matrix are:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- number of properties benefited by measure;
- 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;
- environmental and ecological benefits;
- impacts on the State Emergency Services;
- political and/or administrative issues;
- long-term performance given the likely impacts of climate change,
- risk to life.

The above criteria have been adopted in several other floodplain management studies in NSW and were developed to cover the range of issues that should be considered in evaluating floodplain management measures. However it is acknowledged that other criteria would be equally as suitable.

The colour coded scoring system for the above criteria is provided in Table 2 and largely relates to the impacts in a 1% AEP event. Table 3 indicates the weighting assigned to each measure, however these may be adjusted in the light of community consultations and local conditions.

Table 2: Colour Coded 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 decrease	>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 straight forward	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

Table 3: Matrix of Management Measures Investigated in Study

Ref	Measure	Section in Study	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental / Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)	Recommended
FM1	East Chittaway Point Levee	9.2.1.1	3	3	-3	1	-3	-3	0	2	1	3	3	7	29	
FM2	Bangalow Creek Levees	9.2.1.2	3	3	-2	-2	-3	-3	0	1	1	2	2	2	38	
FM3	Mill Street Industrial Area Levee	9.2.1.3	3	2	1	0	-2	-2	0	1	1	2	1	7	29	
FM4	University Lower Carpark Levee	9.2.1.4	3	0	-2	0	-3	-2	0	1	0	2	2	1	41	
FM5	University Lower Carpark Filling	9.2.1.5	3	0	1	0	-3	-1	-1	1	0	3	2	5	35	**Yes**
FM6	Canntree Road Levee	9.2.1.6	3	2	2	-1	-3	-3	0	1	-1	2	2	4	36	
FM7	Existing Levee Survey and Maintenance	9.2.1.7	0	0	3	3	3	3	0	2	3	3	3	23	4	**Yes**
FM8	Baileys Road Diversion Channel	9.2.3.1	1	2	-2	2	-3	-2	-1	0	-2	-1	0	-6	48	
FM9	Lees Bridge Widening	9.2.5.1	1	2	-2	0	-3	-2	0	0	-2	3	0	-3	44	
FM10	Footts Road Weir Removal	9.2.5.2	0	0	1	1	-3	-3	0	0	-1	3	0	-2	42	
FM11	Upstream Pacific Highway Vegetation Management	9.2.6.1	1	1	-2	2	-3	-3	-3	0	-2	-3	0	-12	49	
FM12	Sohier Park Vegetation Management	9.2.6.2	1	1	-2	2	-3	-3	-3	0	-2	-3	0	-12	49	
FM13	Cut Rock Creek Basin	9.2.7.1	1	1	-2	-1	-3	-3	1	0	0	2	0	-4	46	
FM14	Combination of Options FM8 and FM13	9.2.8	2	1	-2	-1	-3	-3	0	0	0	2	0	-4	46	
RM1	Improved access -Tuggerah Street at the Pacific Highway	9.3.1.1	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM2	Improved access -Tuggerah Street and Cutrock Road near Pluim Park	9.3.1.2	0	3	-3	3	-3	-3	0	3	0	3	3	6	31	**Yes**
RM3	Improved access -Coachwood Drive North of Mahogany Close	9.3.1.3	0	3	1	3	-2	-3	0	3	0	3	3	11	25	**Yes**
RM4	Improved access -The Boulevard at the University of Newcastle Ourimbah Campus	9.3.1.4	0	1	-1	1	-3	-3	0	2	0	3	3	3	37	**Yes**
RM5	Improved access -Chittaway Road near Burns Road	9.3.1.5	0	3	-2	2	-3	-3	0	3	0	3	3	6	31	**Yes**
RM6	Improved access -Howes Road, Link Road	9.3.1.6	0	2	-2	3	0	1	0	3	0	3	3	13	24	**Yes**
RM7	Improved access -Orchard Road, Link Road	9.3.1.7	0	3	3	3	0	3	0	3	0	3	3	21	6	**Yes**
RM8	Improved access -Tall Timbers, Link Road	9.3.1.8	-1	3	0	3	-3	1	0	3	-2	3	3	10	26	**Yes**
RM9	Improved access -Burns Road Bridge	9.3.1.9	0	3	-3	3	-3	-3	0	3	0	3	3	6	31	**Yes**
RM10	Improved access -Burns Road Raising and Culvert Upgrades	9.3.1.10	0	3	-2	3	0	1	0	3	0	3	3	14	21	**Yes**
RM11	Improved access -Elmo Street near Footts Road	9.3.1.11	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM12	Improved access -Tapley Road	9.3.1.12	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM13	Improved access -Macdonalds Road near Indigo Place	9.3.1.13	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM14	Improved access -Pacific Highway at Dog Trap Gully	9.3.1.14	0	3	3	3	0	1	0	3	0	3	3	19	11	**Yes**
RM15	Automatic Road Closures and Boom Gates	9.3.2.1	0	3	3	2	1	1	0	2	1	1	2	16	19	**Yes**
RM16	Automatic Warning Signs and Depth Indicators	9.3.2.2	0	3	2	3	1	1	0	1	1	1	1	14	21	**Yes**
RM17	Early Notification and Road Closures	9.3.2.2	0	3	2	3	2	2	0	3	1	1	1	18	18	**Yes**
RM18	Camera Fines	9.3.2.3	0	3	-2	-1	-2	-1	0	0	-1	1	1	-2	42	**Yes**
RM19	Assessment of Feasibility of	9.3.3.2	0	3	2	3	2	2	0	0	2	1	1	16	19	**Yes**

Ref	Measure	Section in Study	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental / Ecological Benefits	Impact on SES	Political / Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)	Recommended
	Gauge Use															
RM20	Additional Gauges Recommended for Installation	9.3.3.2	0	3	3	3	2	2	0	3	2	1	0	19	11	**Yes**
RM21	Increasing Mobile Phone Reception	9.3.3.6	0	3	1	3	1	-2	0	2	2	3	1	14	21	**Yes**
RM22	Provide Accessible Real-time Flood Information	9.3.3.6	0	3	2	2	2	3	0	1	2	3	1	19	11	**Yes**
RM23	Flood Warning Messages	9.3.3.7	0	3	3	3	3	3	0	2	2	3	2	24	2	**Yes**
RM24	Telephone Dial-out System	9.3.3.7	0	3	3	3	3	3	0	3	2	3	2	25	1	**Yes**
RM25	Shelter-in-place Feasibility Assessment	9.3.3.8	0	3	1	2	0	3	0	0	-2	3	0	10	26	**Yes**
RM26	Updating of Wyong and Gosford LFPs	9.3.4	0	3	3	3	3	3	0	1	1	3	1	21	6	**Yes**
RM27	Relocation of Wyong Evacuation Centre	9.3.4.1	0	0	1	3	-3	-2	0	3	1	3	0	6	31	**Yes**
RM28	Resourcing of Wyong and Gosford SES units	9.3.4	0	0	3	3	3	3	0	3	2	3	0	20	9	**Yes**
RM29	Create SES Flood Intelligence Card for Lees Bridge	9.3.4.3	0	3	3	3	3	3	0	3	3	3	0	24	2	**Yes**
RM30	Assist Key Floodplain Exposures to Create Emergency Response Plan	9.3.4.4	0	3	3	1	3	3	0	3	3	2	0	21	6	**Yes**
RM31	Assist Flood Affected Residents to Create Emergency Response Plan	9.3.4.4	0	3	3	2	3	3	0	2	2	1	1	20	9	**Yes**
RM32	Prepare Flood Education Program	9.3.5	0	3	3	3	3	3	0	3	3	1	1	23	4	**Yes**
PM1	House Raising	9.4.1	0	1	-1	2	-1	-2	0	0	1	1	1	2	38	**Yes**
PM2	Voluntary Purchase	9.4.2	0	1	-3	-1	-3	-3	0	3	-3	3	3	-3	44	**Yes**
PM3	Land Use Zoning	9.4.4	0	3	-2	-1	1	0	0	0	-2	3	0	2	38	**Yes**
PM4	Changes to Planning Policy	9.4.7	0	3	-1	0	2	1	0	0	-1	3	3	10	26	**Yes**

1.3. Floodplain Risk Management Measures in Plan

The recommended measures are described in Table 4 according to the ranking in Table 3 and shown on Figure 9. However a high rank in Table 3 may not necessarily be a high priority measure for implementation as for example, funds may not be available and it will depend upon the ease of implementation (agreement between agencies, responsibility etc.).

Table 4: Recommended Management Measures in Plan

Ref	Measure	Section in Study	Priority	Responsibility	Costing	Timeframe	Rank (Total)
RM24	Telephone Dial-out System	9.3.3.7	High	Council / SES	Low	Short Term	1
RM23	Flood Warning Messages	9.3.3.7	High	Council / SES	Low	Short Term	2
RM29	Create SES Flood Intelligence Card for Lees Bridge	9.3.4.3	High	SES	Low	Short Term	2
FM7	Existing Levee Survey and Maintenance	9.2.1.7	High	Council	Low	Short Term	4
RM32	Prepare Flood Education Program	9.3.5	High	Council / SES	Low	Short Term	4
RM7	Improved access -Orchard Road, Link Road	9.3.1.7	Low	Council / RMS	High	Long Term	6
RM26	Updating of Wyong and Gosford LFPs	9.3.4	High	Council	Low	Short Term	6
RM30	Assist Key Floodplain Exposures to Create Emergency Response Plan	9.3.4.4	High	Council / SES	Low	Short Term	6
RM28	Resourcing of Wyong and Gosford SES units	9.3.4	High	SES	Low	Short Term	9
RM31	Assist Flood Affected Residents to Create Emergency Response Plan	9.3.4.4	High	Council / SES	Low	Short Term	9
RM1	Improved access -Tuggerah Street at the Pacific Highway	9.3.1.1	Low	Council / RMS	High	Long Term	11
RM11	Improved access -Elmo Street near Footts Road	9.3.1.11	Low	Council / RMS	High	Long Term	11
RM12	Improved access -Tapley Road	9.3.1.12	Low	Council / RMS	High	Long Term	11
RM13	Improved access -Macdonalds Road near Indigo Place	9.3.1.13	Low	Council / RMS	High	Long Term	11
RM14	Improved access -Pacific Highway at Dog Trap Gully	9.3.1.14	Low	Council / RMS	Medium	Long Term	11
RM20	Additional Gauges Recommended for Installation	9.3.3.2	High	Council	Low	Short Term	11
RM22	Provide Accessible Real-time Flood Information	9.3.3.6	High	Council / OEH	Medium	Short Term	11
RM17	Early Notification and Road Closures	9.3.2.2	High	Council / RMS	Low	Short Term	18
RM15	Automatic Road Closures and Boom Gates	9.3.2.1	High	Council / RMS	Medium	Short Term	19
RM19	Assessment of Feasibility of Gauge Use	9.3.3.2	High	Council	Low	Short Term	19
RM10	Improved access -Burns Road Raising and Culvert Upgrades	9.3.1.10	Low	Council / RMS	High	Long Term	21
RM16	Automatic Warning Signs and Depth Indicators	9.3.2.2	High	Council / RMS	Medium	Short Term	21
RM21	Increasing Mobile Phone Reception	9.3.3.6	High	Telstra	High	Short Term	21
RM6	Improved access -Howes Road, Link Road	9.3.1.6	Low	Council / RMS	High	Long Term	24
RM3	Improved access -Coachwood Drive North of Mahogany Close	9.3.1.3	Low	Council / RMS	High	Long Term	25
RM8	Improved access -Tall Timbers, Link Road	9.3.1.8	Low	Council / RMS	High	Long Term	26
RM25	Shelter-in-place Feasibility Assessment	9.3.3.8	Medium	Council / SES	Low	Short Term	26
PM4	Changes to Planning Policy	9.4.7	High	Council	Low	Short Term	26

Ref	Measure	Section in Study	Priority	Responsibility	Costing	Timeframe	Rank (Total)
RM2	Improved access -Tuggerah Street and Cutrock Road near Pluim Park	9.3.1.2	Low	Council / RMS	High	Long Term	31
RM5	Improved access -Chittaway Road near Burns Road	9.3.1.5	Low	Council / RMS	High	Long Term	31
RM9	Improved access -Burns Road Bridge	9.3.1.9	Low	Council / RMS	High	Long Term	31
RM27	Relocation of Wyong Evacuation Centre	9.3.4.1	Medium	Council / SES	Medium	Short Term	31
FM5	University Lower Carpark Filling	9.2.1.5	High	Council /Univ	High	Short Term	35
RM4	Improved access -The Boulevard at the University of Newcastle Ourimbah Campus	9.3.1.4	Medium	Council / RMS	High	Long Term	37
PM1	House Raising	9.4.1	Medium	Council / OEH	Medium	Long Term	38
PM3	Land Use Zoning	9.4.4	High	Council	Low	Short Term	38
RM18	Camera Fines	9.3.2.3	High	Council	Low	Short Term	42
PM2	Voluntary Purchase	9.4.2	Medium	Council / OEH	High	Long Term	44

Notes:

Costing: Low < $40K, Medium $40K to $100K, High > $100K

Timeframe: Short < 2 years, Long > 2 years

Further details on the costing of each measure are provided in the relevant section listed in Table 4. However it should be noted that all costings are indicative and based on various preliminary assumptions about the nature and extent of the proposed work. Thus the costings must be reviewed when any further action on a measure is undertaken.

None of the measures in Table 4 apart from PM1 – House Raising will reduce tangible damages to residential properties. A benefit cost ratio can be determined for this measure but the ratio will vary from house to house as this depends upon the cost to raise the house and the height of the floor level relative to the local flood levels.

All other measures are intended to provide both a tangible and intangible benefit however these benefits cannot be accurately quantified in economic terms, thus it is not possible to determine a benefit cost ratio for these measures. However an indication of the likely economic benefit is provided in the matrix in Table 3 as Economic Benefits. A more rigorous assessment of the economic benefits should be undertaken when any further action on a measure is undertaken.

2. INTRODUCTION

This Study has been prepared by WMAwater on behalf of Wyong Shire Council and Gosford City Council (now Central Coast Council). The Study is composed of two phases:

1. The Ourimbah Creek Floodplain Risk Management Study; and
2. The Ourimbah Creek Floodplain Risk Management Plan.

This document details; The Ourimbah Creek Floodplain Risk Management Study; and the Ourimbah Creek Floodplain Risk Management Plan (abbreviated to FRMS&P). This FRMS&P follows on from the Flood Study (Reference 2) undertaken by Catchment Simulation Solutions and completed in 2013 which defined the design flood behaviour in the Ourimbah Creek catchment under existing conditions.

2.1. Study Objectives

The main objective of this FRMS&P is to identify floodplain risk, analyse floodplain strategies for the management of risk and to put forward priorities and approximately costed recommendations in regards to flood risk mitigation in the catchment.

Council requires consideration of a range of management options to effectively manage existing, future and continuing flood risks in the catchment. The outcomes from the Floodplain Risk Management Study and Floodplain Risk Management Plan will also assist the SES in updating the Local Flood Plan for the catchment.

The objectives as outlined in the Brief are more specifically described in Section 2.2 and 2.3 below.

2.2. Floodplain Risk Management Study and Plan Objectives

The objective of the FRMS&P is to investigate a range of flood mitigation works and measures to address the existing, future and continuing flood problems, in accordance with the NSW Government's Flood Prone Land Policy. This includes:

- Reduce the flood risk to people and property in the existing community;
- Ensure future development is controlled in a manner consistent with the flood risk (taking into account the potential impacts of climate change);
- Reduce private and public losses due to flooding;
- Protect and where possible enhance the creek and floodplain environment;
- Be consistent with the objectives of, the Government’s Flood Prone Land Policy and Gazetted Floodplain Development Manual (2005);
- Ensure that the floodplain risk management plan is fully integrated with Council’s existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council’s obligations under the Local Government Act 1993, and has the support of the local community;
- Ensure actions arising out of the plan are sustainable in social, environmental, ecological and economic terms;

- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans; and to
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

2.3. Brief Specific Objectives

In addition Council requested the following specific objectives for flood prone areas, identified as part of the Flood Study to be investigated in this report (these are labelled as Brief Specific Objectives on Figure 1a to Figure 1l):

1 Cut Rock Creek between Pacific Highway and Teralba Street (Option FM14, see Section 9.2.8);
2 Pluim Park (improved flood access, see Section 9.3.1.1);
3 Tall Timbers Estate (improved flood access, see Section 9.3.1.8);
4 Sohier Park (improved flood access, see Section 9.3.1);
5 Turpentine, Ourimbah and Orchard Roads Kangy Angy (improved flood access, see Section 9.3.1.7);
6 Howes Road (improved flood access, see Section 9.3.1.6);
7 Chittaway Point (house raising, see Section 9.4.1);
8 University of Newcastle Ourimbah Campus. Issues include; access and evacuation (improved flood access, see Section 9.3.1), possible early flood warning system (see Section 9.3.3.3), flooding of lower car parking areas (see Option FM4 and FM5, Section 9.2.1.4 and 9.2.1.5);
9 Burns Road (improved flood access and road closures, see Section 9.3.1 and 9.3.2);
10 Assessment of existing levees (see Section 6.5).

Additionally, recommendations for future planning (see Section 9.4) and emergency response (see Section 9.3) also assist in addressing the above referenced issues.

Whilst Ourimbah Creek exits to Tuggerah Lakes and potentially a mitigation measure for Tuggerah Lakes may affect flooding within Ourimbah Creek, it should be noted that this study does not include the assessment or review of any measures relating to the management of flooding within Tuggerah Lakes. Refer to Section 3.2 which provides a summary of previous floodplain risk management studies that have been undertaken for both Ourimbah Creek and Tuggerah Lakes.

2.4. Status of Flood Modelling in the Catchment

The 2013 Ourimbah Creek Catchment Flood Study (Reference 2) was undertaken based on the available catchment topography that existed at the time of the study and has not been updated as part of this floodplain management study. However works are continually being undertaken on the floodplain by public and private authorities. This is a common issue in catchment wide flood studies and it is not possible to continually update the flood models. However Council uses all available information when assessing new projects on the floodplain.

3. BACKGROUND

The headwaters of the Ourimbah Creek catchment are located within the Great Dividing Range near Kulnura. The creek generally flows in an easterly direction through state forest and rural properties before passing beneath the Pacific Motorway and Pacific Highway near Palmdale. It continues to flow in a northern and then easterly direction before passing beneath the Main Northern Railway Line and Wyong Road and eventually discharging into Tuggerah Lake at Chittaway Point.

The catchment also incorporates a number of significant tributaries that are typically situated east of the Pacific Motorway and Pacific Highway. These have been summarised in the Flood Study (Reference 2), and are reproduced below:

- **Bangalow Creek**, originates in bushland between Tumbi Umbi and Ourimbah. It drains in a westerly and then northerly direction through the township of Ourimbah before joining Ourimbah Creek. Bangalow Creek drains a sub-catchment area of 27 km² to its confluence with Ourimbah Creek.
- **Cut Rock Creek**, which forms part of the larger Bangalow Creek sub-catchment. The creek drains in a northerly direction through Lisarow, beneath the Main Northern Railway Line, Pacific Highway and Teralba Street before joining Bangalow Creek near Ourimbah. The Cut Rock Creek sub-catchment occupies an area of 10 km².
- **Chittaway Creek**, which has its headwaters along Brush Road and drains in a westerly direction through Fountaindale before making its way north beneath Old Chittaway Drive and then west beneath Enterprise Drive and the Main Northern Railway line before entering Bangalow Creek. Chittaway Creek drains a sub-catchment area of 6 km² to Bangalow Creek.
- **Dog Trap Gully**, which originates in bush land west of Ourimbah and drains in a northerly direction before turning east and flowing through the township of Ourimbah, beneath the Pacific Highway and Main Northern Railway and into Bangalow Creek. The Dog Trap Gully sub-catchment occupies an area of 5 km².
- **Canada Drop Down Creek**, which has its headwaters in the State Forest and drains in an easterly direction through Palmdale before joining Ourimbah Creek just upstream of the Pacific Motorway. The Canada Drop Down Creek sub-catchment occupies an area of 22 km².
- **Kangy Angy Creek**, which originates in State Forest / bush land and drains in a south easterly direction though the village of Kangy Angy before flowing east beneath the Pacific Motorway and Pacific Highway and into Ourimbah Creek. The Kangy Angy Creek sub-catchment drains an area of 4 km².

The Ourimbah Creek catchment west of the Pacific Motorway is typically characterised by State Forest and rural land uses. The catchment area on the eastern side of the Pacific Motorway is significantly more developed and incorporates a range of residential, commercial, industrial and rural land uses. A number of major transportation links also extend across the eastern section of the catchment including the Main Northern Railway, Pacific Highway, Wyong Road, Enterprise Drive and Chittaway Road.

3.1. Summary of Flood Risk and Affectation

Various flooding hotspots and areas of localised risk have been identified by the works undertaken as part of this FRMS&P. The study area can be broadly delineated into four areas or Flood Precincts with individual risk characteristics. These four areas are summarised below with the locations displayed on Figure 1 (a to l):

1. **Ourimbah Creek Downstream of Wyong Road –** Property flood affectation in this area is significant. The majority of over floor flood affectation within the catchment is experienced by properties in this region. During the 1% AEP flood event, of the 450 residential properties that are flooded over floor catchment wide, 416 of these are situated in the area downstream of Wyong Road (see Section 7.1.1). Properties in this area are flooded not only by Ourimbah Creek flows but also elevated water levels in Tuggerah Lake. Examination of the flood hazard in this region indicates that during a 1% AEP flood most properties are situated in areas of H3 Hazard (see Section 6.2 for a description of flood hazard classifications) which means that flood waters are unsafe for vehicles, children and the elderly, however the structural stability of buildings is not an issue. Access roads in this area are typically cut in events smaller than the 20% AEP event and are subject to even higher levels of flood hazard with a H4 classification indicating the flooding conditions are unsafe for all people and vehicles.

2. **Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road –** The Ourimbah Creek floodplain bounded by the Pacific Motorway to the west and Wyong Road to the east is characterised by High Hazard flooding (H5 classification, see Section 6.2) in the 1% AEP event. 12 properties in this area are flooded above floor during the 1% AEP event and numerous properties become isolated in smaller flood events (less than the 20% AEP in many instances) leading to dangerous Low Flood Islands and Low Trapped Perimeter Areas (see Section 6.3).

3. **Ourimbah Creek Floodplain upstream of the Pacific Motorway–** Similar to Ourimbah Creek floodplain downstream of the Pacific Motorway, this region is characterised by High Hazard flooding (H5 and H6 classification, see Section 6.2) during the 1% AEP event. Even during smaller events such as the 20% AEP, flood depths and velocities at properties and on access roads pose an extreme hazard to pedestrians and motorists. Again, due to flooding of access roads by smaller flood events (less than 20% AEP, numerous properties become isolated leading to dangerous Low Flood Islands and Low Trapped Perimeter Areas (see Section 6.3). Seven properties in this area are flooded above floor during the 1% AEP event.

4. **Cut Rock and Bangalow Creeks –** In spite of the large number of residential property situated in this region (~770 total), property flood affectation and flood risk at properties in this region is typically not as high as for the previously described flood hotspots. Approximately 15 residential properties are flooded over floor in the 1% AEP event with flood hazard in the vicinity of properties generally not exceeding the H3 Hazard classification (see Section 6.2).

However, flooding in Cut Rock and Bangalow Creeks is likely responsible for the highest levels of risk to life in the catchment due to the frequent and hazardous flooding of key access routes. Risk to life for motorist at a number of crossings (see Section 6.4) was noted by various key stakeholders (see Section 4.2) to be particularly high for the following reasons:

- High traffic volumes using these access roads;
- Motorist unfamiliarity with these crossings and the associated risk during times of flood;
- Frequency of flooding (events < 1EY) at numerous locations of these crossings;
- Lack of alternative access routes during flood;
- Insufficient early warning and notification of road closures; and
- Inadequate means of deterring motorists from crossing closed roads.

Improving flood access, early warning and deterring motorists from entering floodwaters at these crossings provides the best means of mitigating flood risk throughout the study area and is a key outcome of the current study.

3.2. Relevant Studies

This study is based on the findings of the 2013 Ourimbah Creek Flood Study (Reference 2). A review and summary of this study is presented in Section 5.

Various other reports salient to the current study have been reviewed with details provided in the following sections. These reports have been considered for this FRMS&P, with reference to these studies found throughout this report.

3.2.1. Previous Studies

Prior to completion of the 2013 Ourimbah Creek Flood Study (Reference 2), various other studies applicable to flooding in the catchment have been undertaken. These studies are listed below and a summary of each study is presented in the Flood Study:

- Paterson Consultants - Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan, July 2011 (Reference 3);
- WMAwater - Tuggerah Lakes Floodplain Risk Management Study – Final Report, November 2014 (Reference 4);
- Webb McKeown & Associates - Upper Ourimbah Creek Flood Study, June 1997 (Reference 5);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Study, May 1997 (Reference 6);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Flood Study, December 1994 (Reference 7);
- Sinclair Knight & Partners - Lower Ourimbah Creek Flood Study – Draft, October 1986 (Reference 8);
- Cameron McNamara Consultants - Cut Rock Creek Valley Floodplain Management Study, June 1982 (Reference 9)

- WMAwater – Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, December 2014 (Reference 10) (provided as Appendix G);
- Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Plan, March 1997 (Reference 11).

Additionally, a number of smaller Flood Impact Assessments have been undertaken, typically for proposed developments across the catchment. A complete list is presented in the Flood Study (Reference 2).

Of particular interest to the current study is the Paterson Consultants (2011) and Webb McKeown & Associates (1997) Floodplain Management Studies which the current study will supersede. Details of these studies are presented in Sections 3.2.2 and 3.2.3 respectively.

Additionally, the community consultation questionnaire results collected as part of this study (Section 4.1) further highlighted the communities concerns relating to the condition of the entrance to Tuggerah Lakes, and in particular dredging and enlarging the entrance channel for flood mitigation purposes. This was investigated at length as part of the Tuggerah Lakes Floodplain Risk Management Study (WMAwater, 2010) with the findings reiterated in Section 3.2.4.

3.2.2. Paterson Consultants - Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan, July 2011 (Reference 3)

The Lower Ourimbah Creek Floodplain Risk Management Study Review and Plan was prepared for Wyong Shire Council by Paterson Consultants. The report was commissioned to review the draft Ourimbah Creek Floodplain Management Study" (Hyder Consulting Pty Ltd, January, 2001) and then develop a floodplain risk management plan. The study covers the lower 8 kilometres of Ourimbah Creek extending from the Wyong Road crossing of Ourimbah Creek (i.e., Lees Bridge) upstream to the confluence of Ourimbah Creek and Bangalow Creek. Only the section of Ourimbah Creek upstream of Wyong Road was considered as flood levels downstream of Wyong Road are dominated by Tuggerah Lake.

An important outcome of this study was a review of previous flooding investigations across the lower Ourimbah Creek catchment with comment being made that many of the previous studies had various inadequacies including:

- failure to adequately represent the routing of flow through the catchment;
- failure to consider all available historic information in the calibration and verification of models;
- adopting high Mannings 'n' coefficients in the hydraulic model; and/or,
- attempting to represent the complex 2-dimensional movement of floodwaters using simplified 1-dimensional hydraulic models.

The 2013 Ourimbah Creek Flood Study (Reference 2) is noted to have addressed these issues (see Section 5.2.8) through use of a calibrated/verified 2D hydraulic model.

The study then undertook to develop a floodplain risk management plan in accordance with the

NSW Government flood policy as described by the NSW Floodplain Development Manual. The floodplain management component of the study identified eight issues related to:

- current estimated potential flood damages;
- land use zoning and planning;
- flood warning emergency operations;
- provision for housing for "seniors" and persons with disabilities;
- development of better understanding of flood behaviour;
- voluntary acquisition of flood liable properties;
- public information and education;
- operations and maintenance.

Based on the above, a floodplain risk management plan was derived to address these issues. The Paterson Consultants (2011) Ourimbah Creek Floodplain Risk Management Plan presented in Table 10.1 of the study has been reproduced herein as Table 5.

Table 5: Paterson Consultants (2011) – Floodplain Risk Management Plan

Risk Management Issue	Response	Priority	Duration	Projected Cost
1. Land Use Planning	1. Revise Interim Policy	Immediate	1 month	Council cost only
	2. Develop flooding DCP	High	6 months	Council cost only
2. Transfer of Flood Knowledge	1. Council, through its LEMC, assist SES to condense local flood knowledge in the Local Flood Plan	High	3 months	Council cost only
3. NSW Government State Planning Policy (Housing for Seniors)	Request changes to include flood risk	High	2 months	Council cost only
4. Public Information and Education	1. Ensure flood risk notation on Section 149 Certificates is up to date	High	2 months (and on-going)	Council cost only
	2. Develop site specific flood information brochures	High	6 months	$20,000 plus on-going $4,000 every four years
5. Inspection and maintenance of existing infrastructure	Develop inspection and maintenance procedures	High	On-going	Council cost only
6. Development of Flood Knowledge	1. Update the hydrologic and hydraulic studies	Medium to Low	18 months	$60,000
	2. Obtain high flow measurement	High	On-going	Subject to floods occurring

3.2.3. Webb McKeown & Associates - Bangalow Creek and Cut Rock Creek Floodplain Management Study, May 1997 (Reference 6)

The Bangalow Creek and Cut Rock Creek Floodplain Management Study was prepared by Webb McKeown & Associates for Wyong Shire Council and Gosford City Council. The study outlines a range of flood mitigation measure that could potentially be implemented to reduce the existing flood problem across the Bangalow, Cut Rock and Chittaway Creek catchments and ensure future development is completed in a manner that recognises the variation in flood hazard across different sections of the floodplain. The following locations were identified as areas where significant flood damages are likely to be incurred:

- Pluim Park / Tall Timbers Estate / Manning Road *(12 buildings inundated in 1% AEP flood)*;
- Donna Close / Janine Close / Narelle Close *(1 building inundated in 1% AEP flood)*;
- Subdivisions east of Tuggerah Street *(1 building inundated in 1% AEP flood)*;
- Brands Place / Lisarow Street (*23 buildings inundated in 1% AEP flood)*;
- Shirley Street *(1 building inundated in 1% AEP flood)*;
- Mill Street Industrial Area *(2 buildings inundated in 1% AEP flood)*;

- Dog Trap Gully *(1 building inundated in 1% AEP flood)*; and,
- Chittaway Creek *(3 buildings inundated in 1% AEP flood).*

The Bangalow Creek and Cut Rock Creek Floodplain Management Plan was completed in March 1997 (Reference 11) and a copy of the summary is provided as Appendix G.

A review of the Reference 6 study, the Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, was completed in December 2014 (Reference 10). Further details on this addendum are presented in Section 3.2.6 and a copy is provided as Appendix G.

3.2.4. WMAwater - Tuggerah Lakes Floodplain Risk Management Study - Final Report, November 2014 (Reference 4)

The current study community consultation process highlighted the community's perception that the condition of the entrance to Tuggerah Lakes should be modified as a flood mitigation measure to reduce flooding in the lower reaches of Ourimbah Creek.

The WMAwater 2014 Study undertook a detailed investigation into various potential mitigation measures relating to the condition of the entrance including:

- Maintenance of the entrance channel (dredging);
- Enlarging the entrance channel; and
- Emergency opening of the entrance during flood.

None of the investigated options were recommended as part of the WMAwater 2014 Study due to a number of factors ranging from significant economic, environmental and social costs through to a lack of positive benefits associated with reductions in peak lake levels and flood affectation. Additionally, it was noted that permanent opening of the entrance could lead to increased flooding in some instances due to elevated ocean levels.

Based on the findings from the WMAwater 2014 Study, modification of the entrance as a flood mitigation measure is not recommended and the current study will not revisit investigating these options.

3.2.5. WMAwater – Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, December 2014 (Reference 10)

This study was undertaken after completion of the 2013 Flood Study and is provided as Appendix G. The Reference 10 study is a desktop review of the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan (Area G2 – Pluim Park/Tall Timbers estate/Mannings Road). It was undertaken to review the previous outcomes in light of the inability of residents of the Tall Timber estate to access the estate during frequent storm events experienced on several occasions in 2011, 2012 and 2013.

The outcome is reported as an addendum to the 1997 Floodplain Management Plan and is viewed as an interim measure to ascertain whether any short term measures could be implemented to reduce the risk to life. In the long term, it is Council's intention to provide a long term solution.

The main outcomes of the Reference 10 study that are pertinent to the current study are:

1. *The access road from Tuggerah Street to Tall Timbers estate is privately owned. The road level is not considered to be in accordance with current best practice in floodplain management due to its vulnerability to be cut in minor frequent storm events (potentially several times a year). Construction of an upgraded bridge or high level footbridge on privately owned land to improve access and funded by Council does not conform with Council's responsibilities. The responsibility for upgrading the road should rest with the private owners of the access road. Raising of the access road would provide benefit in minor frequent storm events only and may place people at greater risk in another part of the floodplain.*

2. *The proposed access via the railway maintenance track during rare flood events was not formalized at the time of development of the site and the area has since been fenced off to the public. Council has approached Railcorp regarding permission for Council to construct an elevated pedestrian/cycleway alongside the railway line on Railcorp land to provide flood free pedestrian access from the estate.*

   A pedestrian footbridge over the railway line near Ourimbah Street Lisarow has also been considered however Railcorp have safety concerns.

3. *Council does not undertake creek maintenance on privately owned land where there is no easement in place. Council would only consider such works if a life threatening or similar situation arose. Dredging or clearing within the easement will reduce flood levels and the frequency of overtopping of the private access road but the benefit will be very minor unless the capacity of the waterway opening under the access road is significantly increased.*

4. *Council will clear debris or fallen trees which are causing a blockage in main drainage infrastructure or on local roads. Residents wanting debris removed from their property are responsible for the organisation and payment for the works either through Council's household pick up service or a private company. If an area is declared a Natural Disaster area, government funding could be made available for clean up through the appointed Recovery Committee.*

5. *Council has an annual program for road inspection, maintenance and upgrading. Any road works necessary are prioritised within the limits of the funds available. Council does not maintain privately owned access roads e.g. the access road to Tall Timbers estate.*

6. *Gosford City Council, in conjunction with NSW SES, is in the process of preparing additional flood intelligence for the Gosford City Local Flood Plan for Tall Timbers Estate. The NSW SES will undertake a flood safety awareness program for the residents. Gosford City Council has installed a flood warning system. The construction of a safe refuge in the estate for flood events larger than the 1% AEP (sometimes referred to as vertical evacuation or*

shelter in place) would ensure that residents remain dry in events larger than the 1% AEP. However this measure does not eliminate the risk to life for the entire community.

7. *Voluntary purchase of all houses in Tall Timbers estate is unlikely to receive funding from state or federal government authorities because the house floors are only inundated in events larger than the 1% AEP, consequently this option will have a very low benefit cost ratio.*

8. *Development controls will ensure that any future development are constructed in accordance with best practice but will not reduce the risk to life of the road access.*

3.2.6. Jacobs – Upgrade of Pacific Highway HW10, Ourimbah Street to Parsons Road, Lisarow, Roads and Maritime Services, October 2014 (Reference 12)

This study was not reviewed as part of the 2013 Flood Study. Roads and Maritime Services (RMS) propose to upgrade the Pacific Highway, Ourimbah Street to Parsons Road, Lisarow. A flood impact assessment was prepared as part of the Review of Environmental Factors with the aim of identifying strategies to manage impacts to flooding during construction and operation.

The main features of the Highway Upgrade proposal include:

- Widening to include two additional 3.3 metre wide lanes (one northbound and one southbound);
- Widening of shoulders by up to 2.0 metres, for consistent widths along the length of the proposal;
- Maintaining a 60 kilometres per hour design and posted speed limit;
- A new rail overbridge replacing the existing bridge over the Main Northern Railway Line located to the south of the intersection of the Pacific Highway and Railway Crescent; and
- Intersection upgrades at:
    - Chamberlain Road and Pacific Highway intersection;
    - Rail maintenance access road;
    - Macdonalds Road and Pacific Highway intersection to be relocated around 25 metres to the south to align with Tuggerah Street and new traffic lights installed at the intersection;
    - Railway Crescent and Pacific Highway intersection; and
    - Dora Street and Railway Crescent intersection.

The study determined flood impacts associated with the upgrade for flood levels, flow velocities, flood hazard and flow distributions for the 50%, 20%, 5%, 1% and 0.5% AEP and PMF events. The flood impacts are described below:

- Flood levels are typically not increased by more than 0.01 metres for flood events from the 50% AEP event up to the 1% AEP event, including in flood-sensitive areas such as the Tall Timbers residential estate.
- There are no marked flow velocity impacts or redistribution of flow which increase the flood hazard in the study area. There are flow velocity increases near the upgraded hydraulic structures which can be managed by rock scour protection. Other areas of

relatively high velocity increases on the floodplain do not result in excessively high absolute velocities and are not expected to worsen the scouring potential of overland flows.

- Flood hazard mapping shows that the extent of high flood hazard areas are not increased in each AEP flood event as a result of the proposal.
- The proposal does not increase the duration of inundation in the study area. Potentially susceptible habitats and vegetation species would not be impacted by longer durations of flooding.

The present study has examined the above mentioned report and note that due to the minimal flood impacts associated with the Highway Upgrade, the Flood Study (Reference 2) flood model is suitable for use for this FRMS&P without amendment.

The present study has also made the following observations relating to the proposed Macdonalds Road exit mentioned above:

- The exit is flooded in the 0.5EY event and potentially more frequent events not modelled as part of the Highway Upgrade study.
- In the 20% AEP flood the exit experiences depths > 0.5 m and velocities of ~1 m/s. This is a flood hazard classification of H3 (see Section 6.2) which means that it is unsafe for all vehicles.
- In the 1% AEP flood the exit experiences depths > 1.8 m and velocities >1.5 m/s, placing flooding of the proposed exit in the H5 flood hazard classification. This poses an extreme risk to motorists.

As part of the present study the RMS has been contacted in relation to this exit ramp to request that the access road be made flood free in the 1% AEP event. A letter addressed to RMS outlining this request is presented in Appendix F.

3.3. Overview of Existing Catchment

3.3.1. Demographic Overview

The Ourimbah Creek catchment consists of many suburbs, including Chittaway Point, Fountaindale, Kangy Angy, Ourimbah, Lisarow, Mount Elliot, Palmdale, Palm Grove, Central Mangrove and Kulnura to the west. Understanding the social characteristics of the area can help in ensuring that the most appropriate flood risk management practices are adopted. The Census data and community consultation questionnaire responses can provide useful information on categories including dwelling and tenure type, languages spoken, age of population and movement of people into and out of the area.

Table 6 summarises the 2011 Census results for sub-areas within the catchment, which gives an indication of demographics, language and property tenure.

Of interest is the data on population movement in recent years. Generally residents who have lived in an area for a longer time have a better understanding of local flooding issues than those who have recently moved to the area. Within the last five years 13% of the community

consultation respondents had moved to the Ourimbah catchment area, with the remaining living in the catchment longer than five years. This means that the majority of the current population would have experienced the significant June 2007 flood event and likely have good awareness of flood risk in the region.

Table 6: 2011 Census Data

Suburb	Population	Population Age (%)		English spoken at home (%)	Tenure (%)	
		0-14 years	>65 years		Owned	Rented
Kangy Angy	316	18	18	95	80	18
Ourimbah, Palm Grove, Palmdale	4,162	22	9	92	74	26
Lisarow	5,038	24	9	93	81	17
Fountaindale	631	16	14	93	92	9
Berkeley Vale	8,486	23	14	94	76	22
Chittaway Point	1,901	19	14	94	73	25
Total / Average	**20,534**	20	13	93	79	19

It is useful to consider the tenure of housing. Those living in properties which they own are more likely to be aware of the flood risks and have measures in place to reduce them (where possible). Rental properties are likely to have a higher turnover of people living in them compared to privately owned properties and therefore those people in rental properties may be less aware of the flood risk. The 2011 Census data indicates approximately 80% of the catchment own their homes again indicating the general population is likely to have good awareness of flood risk.

The languages spoken by the population are also useful to consider as this can have implications in regard to the provision of flood information to the public and during assisted flood evacuation. Over 90% of people in each of the suburbs within the catchment speak English at home, with a small number of residents speaking another language at home including German, Cantonese, Indonesian, Tongan, Italian, Spanish, Arabic, French, Greek and Malay.

3.3.2. Land Use

The land use zones as identified in Councils' LEPs (Wyong 2013 and Gosford 2014) are available on Council's website.

The land usage varies significantly throughout the catchment within predominately rural (*RU1 – Primary Production and RU3 – Forestry*) and environmental (*E1 – National Parks and Nature Reserves, E2 – Environmental Conservation and E3 – Environmental Management*) uses upstream of the Pacific Motorway.

In the areas surrounding the Pacific Motorway and downstream, land use is a mix of residential (*R1 – General Residential and R2 – Low Density Residential*), business (*B2 – Local Centre and B7 – Business Park*), industrial (*IN1 – General Industrial and IN2 – Light Industrial*) and environmental (*E1, E2 and E3*) uses. The region bounded by Enterprise Drive, Wyong Road and the Main North Line railway is a large business and industrial hub (*B7 and IN1*) that is subject to flooding with a range of flood liability.

Ourimbah Creek downstream of Enterprise Drive is zoned as a waterway (*W1 – Natural Waterway*) discharging into Tuggerah Lake (*W2 – Recreational Waterway*).

3.4. Available Data for FRMS&P

3.4.1. Data Request

At commencement of the study WMAwater requested all relevant available data from Council. This data included, but was not limited to, the following:

- 2013 Ourimbah Creek Flood Study Report and Data;
    - TUFLOW hydraulic models and results;
    - XP-RAFTS hydrology models and results;
    - All survey data (cross sections, structure survey).
- GIS Data:
    - Aerial photography (2014);
    - Topographic survey data in the form of ALS/LiDAR (2014), Digital Elevation Model (DEM) and contours;
    - Cadastre, layers and names for roads and creeks;
    - Zoning, Council owned land, SEPP 14 or 19 land, vegetation / environmental land uses;
    - Stormwater drainage details including pit and pipe data including dimensions, locations, cross-sections and reduced level heights for inverts etc;
    - General GIS information (roads, watercourses, etc.).
- Prior flood mapping, including flood levels if available;
- Wyong Shire Council DCP 2013;
- Gosford City Council LEP 2014 & DCP 2013;
- Flood Impact Assessment undertaken by RMS for the Pacific Highway Upgrade;
- Any previous flood related studies/reports.

3.4.2. Floor Level Survey and Estimation

The Ourimbah Creek FRMS&P requires building floor levels for all properties contained within the PMF flood extent. Floor level estimates are used to determine flood damage estimates (see Section 7.1). Given the large catchment area and number of flood affected properties, theodolite based survey of all properties was not financially feasible. Details of how building floor levels were estimated are presented below:

- The Bangalow and Cut Rock Creek FRMS Report (Reference 6) contains approximately 147 surveyed property floor levels that were obtained and used in the current study.
- Floor level survey was performed by Cahill & Cameron Surveyors Pty Ltd. for 91 properties contained within the Gosford LGA during December 2015.
- The floor levels of the remaining 1,965 properties within the PMF extent were estimated by use of LiDAR data in combination with visual inspection of floor level heights by WMAwater engineers. Visual inspection was undertaken by two methods:
    - Over 300 properties were visited by WMAwater engineers on a site visit. These properties were those that could not be analysed by available digital imagery and

were predominately situated in rural locations.

- The remaining properties had floor levels estimated based on analysis of available digital imagery.

4. STAKEHOLDER CONSULTATION

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, 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. This includes a questionnaire, liaison with the key stakeholders and agencies listed in Section 4.2 and meetings with Council. Goals of on-going community consultation are to consult with residents to keep them informed of the progress of the study and to obtain community ideas and feedback on potential mitigation and management measures proposed. Final community consultation proposed is in the form of public exhibition of the Draft reports.

4.1. Questionnaire Distribution

A community newsletter and questionnaire (Appendix B) was distributed to residents situated within the Ourimbah Creek PMF extent during November 2015. The newsletter aimed to inform the community of the Ourimbah Creek FRMS&P and the survey provided the community with an opportunity to highlight their flood affectation and to provide input into this FRMS&P. In particular, the questionnaire was intended to obtain ideas for mitigation works or management plans to reduce flood risk and to determine if the community is interested in voluntary purchase or Voluntary House Raising (VHR) schemes (see Sections 9.4.1 and 9.4.2).

A total of 159 replies (out of 2178 distributed) resulted in a return rate of 7% which is similar to questionnaire return rates of other floodplain risk management studies in the area. A summary of the questionnaire results is presented in Figure 2 with the questionnaire returnee locations displayed in Figure 3.

A total of 48 questionnaire respondents mentioned that they thought Tuggerah Lake should be opened up to the ocean, with or without the use of break walls. 23 respondents suggested that improved maintenance of drains and creeks would improve conveyance and reduce peak flood levels. Approximately 63% of all respondents thought that flooding at a frequency of less than 100 years is acceptable which is generally in line with the aims of this FRMS&P. However, 33% of respondents mentioned that they thought any degree of flooding is never acceptable which would require the engineering of mitigation structures to the PMF. It was also found that a significant number of people were interested in voluntary purchase (37 respondents interested) and Voluntary House Raising (29 respondents interested) schemes.

Generally three topics were the focal point of all returned questionnaires. These were, dredging/opening of the Tuggerah Lakes entrance, creek clearing/maintenance and potential mitigation works. A summary of the key topics discussed in the returned questionnaires is presented below:

Potential Flood Mitigation Works Identified via Community Consultation

- Opening, dredging or constructing breakwalls to enhance flow conveyance out of Tuggerah Lakes (see Section 3.2.4);
- Levee banks around eastern Chittaway Point, along Bangalow Creek and along the east of Ourimbah Creek to protect Mill Street industrial area (see Section 9.2.1);
- Straightening creek alignments where possible (see Section 9.2.4);
- Removal of weir at Footts Road (see Section 9.2.5.2);
- Raising Geoffrey Road (see Section 9.3.1);
- Maintenance of drains and creeks, clearing litter, fallen trees and debris regularly (see Section 9.2.6); and
- Construction of retention basins (see Section 9.2.7).

The above listed potential flood mitigation works have been investigated along with those outlined in Section 2.3.

Voluntary Purchase and House Raising Schemes

- Details related to a potential VHR Scheme are presented in Section 9.4.1.
- Details related to a potential voluntary purchase scheme are presented in Section 9.4.2;

Other Flood Ideas

- Installation of flood depth indicators and signage along Ourimbah Creek Road (see Section 9.3.2.2);
- Distribution of instruction booklets for residents – *"What to do in a Flood"* (see Section 9.3.5); and
- Reconsideration of proposed location of Kangy Angy Rail Maintenance Facility (see Section 4.2.7).

Additionally, a number of local residents reported major creek bank erosion on private land. These residents were referred to Local Land Services for advice and assistance (see Section 4.2.4).

4.2. Specific Consultation with Key Stakeholders and Agencies

In addition to the local community the Brief requested consultation with the following key stakeholders and agencies:

- Council Planners;
- The University of Newcastle Ourimbah Campus;
- Tuggerah Lakes Estuary, Coastal and Floodplain Management Committee (subsequently disbanded);
- Gosford Council's Catchments and Coast Committee (subsequently disbanded);
- Office of Environment and Heritage (OEH);
- Local Land Services (LLS);
- Department of Planning (DoP);
- NSW Office of Water (NOW);
- State Emergency Services (SES);

- Bureau of Meteorology (BoM);
- Manly Hydraulics Lab (MHL);
- Roads and Maritime Services (RMS);
- State Rail Authority (SRA);
- Transport for NSW;
- Ourimbah Residents Association.

These stakeholders and agencies have been contacted for input into this FRMS&P. A summary of responses is provided below where applicable, and the information has been incorporated into this FRMS&P.

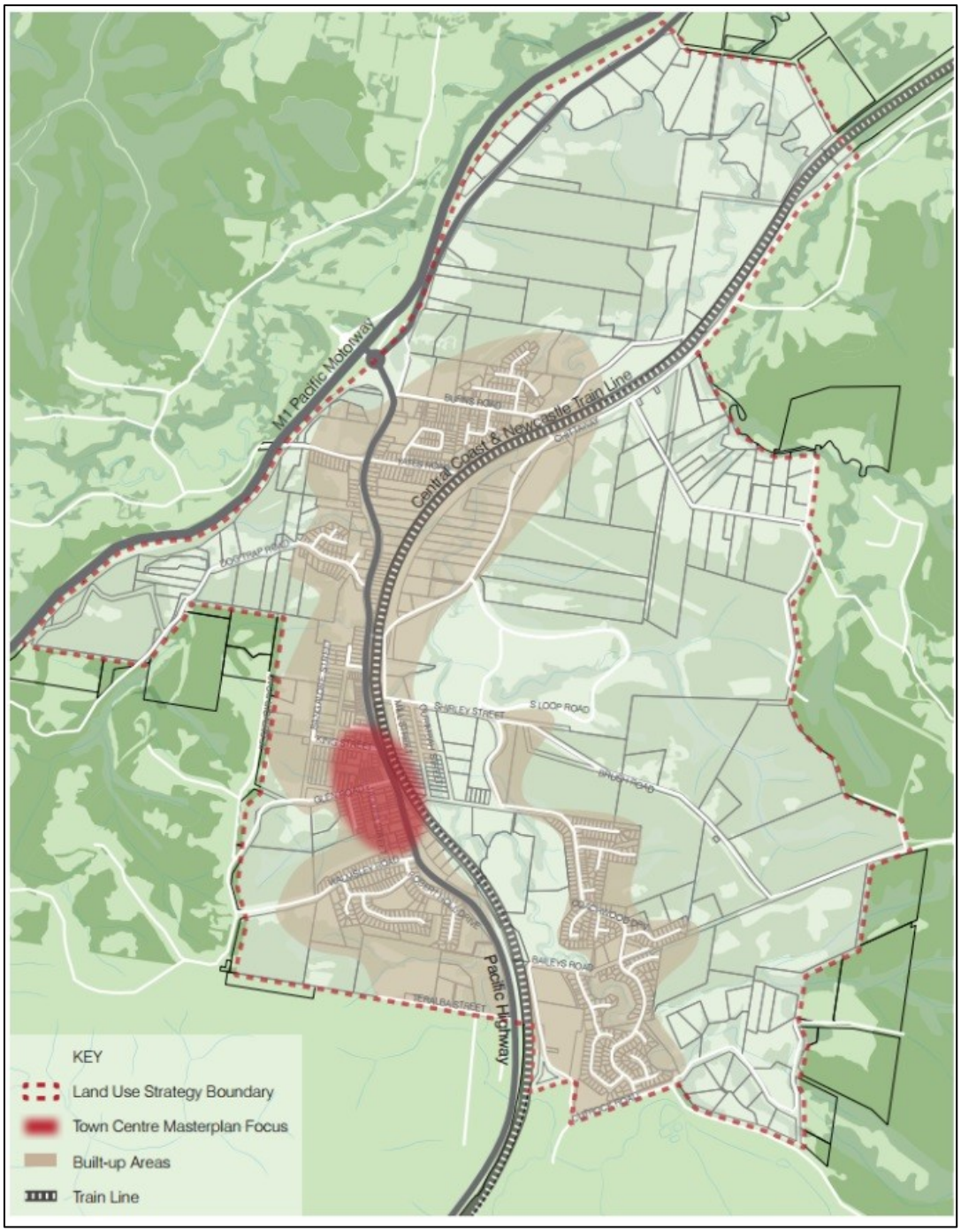
Planners from both Wyong and Gosford Councils were contacted for input into the current study. Details are provided in the section below.

4.2.1. Wyong Council Planners and Ourimbah Masterplan and Land Use Review

The Ourimbah Masterplan and Land Use Review is currently being undertaken by Wyong Council's planners and consultants. The Masterplan was at final draft stage (Reference 13) at February 2017. The aim of this Masterplan project is to develop a vision to guide investment in the use and development of land and infrastructure over the next 20 years for the region identified in Image 1. This Masterplan is hoped to facilitate both growth and connectedness as Ourimbah is a location where motorway, highway and railway converge, connecting it to regional destinations and national markets. Connectedness is about using this physical infrastructure to link frequently visited locations such as the town centre, train station and University campus.

The Masterplan proposes that the existing creek crossing on Burns Road be replaced by a flood free access bridge that will cross Ourimbah Creek and the Main Northern Railway Line. The Masterplan indicated that the cost of this bridge would be in excess of $20 million (Council liaison with RMS indicates that the cost of this bridge would be approximately $100 million). The proposed bridge would solve many of the risk issues associated with the current Burns Road crossing (see Section 2.3), however due to the significant cost and potential long term implementation plan a number of other solutions to minimise risk at this location have been investigated.

Image 1: Ourimbah Master Plan Study Area



This FRMS&P recommends that the Ourimbah Masterplan carefully considers flood behaviour and affectation determined by the Flood Study and this FRMS&P.

4.2.2. Gosford Council Planners

Gosford Council planners were contacted for input into this FRMS&P. It was noted that various Plan items from the 'Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2' Study (WMAwater 2014, Reference 10) have had applications for funding made to OEH and are currently awaiting funding for implementation. OEH however considered it was premature to fund any of these projects separate from a complete review of the Ourimbah Creek Floodplain Risk Management Study, which is now currently being undertaken. These items

include:

- Voluntary purchase of 14 properties in Tall Timbers Estate and 6 in Mannings Road, Narara;
- Emergency Pedestrian Access Route - Stage 1 - Tall Timbers to Mannings Road, Narara;
- Emergency Pedestrian Access Route - Stage 2 - Mannings Road to pedestrian overbridge opposite Teralba Street, Narara; and
- Emergency Pedestrian Access Route - Stage 3 - Tall Timbers to McDonalds Road, Narara.

4.2.3. The University of Newcastle

The University of Newcastle Ourimbah Campus is situated on the eastern side of Bangalow Creek and services over 1,000 students on a daily basis. Liaison with University staff indicated that the campus has a number of flood related concerns. The University reportedly closes multiple times per year due to issues associated with flooding and storms. Additionally, flooding of two carparks was noted as a key concern with significant implications for risk to life.

The University enquired about the possibility of an early flood warning system, however as described in Section 9.3.3.3, the available warning time is inadequate for emergency response.

Various potential flood risk mitigation measures have been investigated, namely:

- Improving flood access (Section 9.3.1) – This reduces the risk associated with flooded access roads;
- Option FM4 and FM5 (Section 9.2.1.4 and 9.2.1.5) – Levee or filling to protect the northern lower carpark for events up to the 1% AEP event;
- Installation of a stream gauge on Bangalow Creek (Section 9.3.3.2) – can be used for flood warning, albeit only short warning times are available; and
- Recommendation to prepare a Flood Plan for the University to assist in emergency response (Section 9.3.4.4).

4.2.4. Local Land Services (LLS)

Greater Sydney LLS is responsible for the Ourimbah Creek catchment and have been consulted as part of this study. Specifically, LLS was contacted for assistance in regards to questionnaire respondents (see Section 4.1) who reported erosion and degradation of the creek channel on private land. These residents were referred by WMAwater to LLS and were advised to make a submission to obtain funding for bank stabilisation as per that recommended by LLS.

4.2.5. Manly Hydraulics Lab (MHL)

Manly Hydraulics Laboratory (MHL) has the capability to design, build, operate, and maintain flood warning systems. Flood warning systems provide near real-time information to support the management of flood prone land and infrastructure. Various organisations, including RMS, NSW Police, State Emergency Service (SES), Local Government, and the Bureau of Meteorology use MHL flood warning systems.

Flood warning systems combine the services of MHL's automated data acquisition systems to collect environmental data; with MHL's automated messaging and alarming service. When high water level or rainfall threshold conditions are encountered, an automated alarm is issued, and notifications are sent to recipients in various formats (email, SMS, web services, and social media integration).

MHL have been contacted to provide a preliminary pricing for installation of a flood warning system by installation of rainfall and stream gauges. Preliminary pricing for each gauge type are:

- Rainfall Gauge - $13,000 installation, plus $2,000/annum maintenance; and
- Stream Gauge - $20,000 installation, plus $2,000/annum maintenance.

Some savings can be made if both a rainfall and stream gauge are installed at the same location, particularly in ongoing maintenance costs.

4.2.6. Roads and Maritime Services (RMS)

RMS was contacted as part of the current study for the following reasons:

1. **Early Warning Notification of Road Closures -** The potential for utilising RMS Variable Messaging System (VMS) or addition of new signage on the Pacific Motorway and Highway at Ourimbah to provide early notification of road closures on Burns Road, Chittaway Road and Shirley Street due to flooding.

2. **Tuggerah Street Upgrade –** RMS are currently upgrading the Pacific Highway between Ourimbah Street and Parsons Road. As part of this upgrade, the existing Tuggerah Street exit is also proposed for upgrading. WMAwater has recommended that the concept design of this exit be revised to provide flood free access to Tuggerah Street for events up to the 1% AEP event. No formal response has been received however Council has advised that RMS are not in favour of raising Macdonalds Road too high to make it flood free in a 1% AEP flood event as it will have adverse flood impacts to adjoining properties which cannot be adequately mitigated. RMS has advised that it is also the responsibility of Council as it is a local road.

3. **RMS Stream Gauges –** Council have noted that RMS has installed a stream gauge on Cut Rock Creek (in the Lisarow Swamp) to record base flow for the above mentioned upgrade of the Pacific Highway. WMAwater has sought permission for Council to take over ownership of this gauge.

Two letters addressed to RMS detailing the above are presented in Appendix F.

WMAwater has received two official responses for the above listed questions and are waiting on a third. RMS responses are summarised below:

Early Warning Notification of Road Closures

Liaison with RMS re the Pacific Motorway/Highway VMS, indicated that whilst it is possible to use the VMS for this purpose, it is not recommended as RMS would prioritise RMS warning messages over those of warning of flooded road closures. Accordingly, it could not be guaranteed that notification of flooded roads would be displayed to commuters. In place of the VMS, RMS noted that they are open to discussion with Council about the possibility of installing signage within the RMS owned road easements.

Tuggerah Street Upgrade by Cardno

A joint meeting between Council, WMAwater, RMS and Cardno to discuss the feasibility of the RMS raising the proposed Tuggerah Street exit ramp was held in October 2016. A case was made as to why the road should be raised with RMS agreeing to investigate this option. RMS has not provided a response.

RMS Stream Gauge

RMS will allow Council to take over ownership of the RMS stream gauge which could potentially be used as a flood warning gauge (see Section 9.3.3.2).

4.2.7. Transport for NSW: Kangy Angy New Intercity Fleet Maintenance Facility

In May 2014 the NSW Government announced the New Intercity Fleet Program to replace the ageing trains carrying intercity customers from Sydney to the Central Coast, Newcastle, the Blue Mountains and the Illawarra. The program includes a purpose built fleet maintenance facility proposed at Kangy Angy to service and maintain the new trains. At the time of this FRMS&P, Transport for NSW was placing on public display 'A Review of Environmental Factors and concept design' (Reference 14) for the proposed facility. A community notification providing further project details is presented in Appendix C.

As part of the development of the maintenance facility, Transport for NSW is developing a concept design for the site in Kangy Angy, which includes a new alternative access road aimed to link Enterprise Drive to Orchard Road, offering flood free access for residents north of the Main North Line railway.

Currently, properties on the northern side of the Main North Line railway have road access via Turpentine Road. This road is frequently flood affected causing property isolation and was a key area of resident concern as identified in the Flood Study (see Section 2.3) and again from liaison with the Ourimbah Residents Association (see Section 4.2.8). The proposed link road will provide flood free access to these properties thus greatly improving local resident access during flood.

The access road would be accessed from Enterprise Drive via a new intersection with Old Chittaway Road. From the intersection with Enterprise Drive, the access road would start to ramp up to a curved viaduct structure over the Main North railway. The access road would be designed in accordance with the requirements of Central Coast Council and, in addition to the proposed traffic lanes would include other elements such as a shared user path, anti-throw

screens and appropriate lighting.

The proposed New Intercity Fleet Maintenance Facility review of environmental factors report (June 2016, Reference 14) indicated that a link road is to be constructed that crosses the Main Northern Railway Line which allows access to the region during times of flood. It was noted even with the construction of the link road, properties to the west of the proposed facility on Turpentine and Ourimbah Roads could still be isolated during flood as the intersection of Orchard and Ourimbah Roads is flooded by in excess of 2 m during the 20% AEP event. A submission was made to Transport for NSW as part of this FRMS&P requesting that flood access issues be fully considered as part of the proposed rail facility design. Further details are presented in a letter addressed to Transport for NSW contained in Appendix F.

The most recent Facility design plans (June 2016, Reference 14) indicate that a flood access road is proposed which will allow flood access to these isolated properties. The addition of the flood access route will allow flood access to properties to the west of the Facility and is a good outcome for Council and the community. This proposal is supported from a risk management perspective.

The community consultation process highlighted that some local residents are opposed to the Kangy Angy facility (see Section 4.1) due to perceived flood impacts, however the current study makes clear that this facility will not impact on peak flood levels for events up to and including the 1% AEP as the facility is situated outside of the flood extent. However one issue raised by local residents is the increased runoff due to less infiltration as a result of covering the present pervious surface with an impervious surfaces (building roofs and hard stand areas). This issue is addressed below.

Removal of natural vegetation and the sealing of pervious surfaces with hard stand areas or building roofs will increase the volume of runoff into the adjoining creek systems. However the magnitude of the increase is impossible to accurately estimate based on the limited information provided to date. It would depend upon:

- if on-site detention or water re-use storage tanks are provided in the facility;
- if the runoff from buildings exits directly to the creek system or is made to pass through what is known as a Water Sensitive Urban Design feature (WSUD). WSUD features are specifically designed to reduce, as far as possible, the amount of increased runoff from entering the creek system and at the same time ensure water quality is maintained. It is noted that detention basins are proposed as part of the design.

In summary, it is likely that even with the most comprehensive design there will be some increase in runoff into the creek systems. However this will only be noticeable in frequent events which occur several times every year. In large flood events the increase in volume of runoff will make insignificant affect on the peak flow and thus the peak flood levels. This is because the total area of site (not all of which will be impervious surfaces) is only 50 hectares or 0.5 km^2 (or 0.3% of the total catchment area of Ourimbah Creek). These and other water quality, groundwater and flooding issues have been addressed in the New Intercity Fleet Maintenance Facility Project - Submissions Report (Reference 15).

4.2.8. Ourimbah Residents Association

Liaison with the Ourimbah Residents Association indicated that the main issue of concern is the flooding of access roads. It was noted by Ourimbah Residents Association that road access issues, coupled with a significant risk to motorists entering floodwaters, was historically occurring multiple times per year and had resulted in numerous emergency rescue operations (twice in 2015 alone) of people attempting to drive through floodwaters.

The following roads were highlighted by Ourimbah Residents Association as key areas of concern. Analysis of these flood affected roads is presented in Section 6.4:

- Burns Road – busy access road from the Pacific Motorway to Gosford, The Entrance and the University;
- Howes Road – leading to the isolation of a number of residential properties;
- Turpentine Road – leading to the isolation of Ourimbah and Orchard Roads including a number of residential properties;
- Chittaway Road – busy access road; and
- Shirley Street – access road.

Many of the above mentioned issues could potentially be addressed by improving flood access which is described in Section 9.3.1.

A number of management options listed below (with respective sections in this Study) were suggested by Ourimbah Residents Association for consideration in the current study:

- Creek clearing and maintenance (see Section 9.2.6);
- Road and culverts works for the above listed locations (see Section 9.3.1);
- Installation of larger / more obvious signage highlighting the flood risk for roads susceptible to flooding for the above listed locations (see Section 9.3.2);
- More robust safety railings on Burns Road crossing;
- Automated signage on the Pacific Motorway and Pacific Highway notifying road closures and flood risk (see Section 9.3.2.2);
- Investigating the feasibility of automated boom gates (see Section 9.3.2.2); and
- Manned diversion of traffic when roads are closed to prevent people driving into floodwaters (see Section 9.3.2.3).

4.3. Community Consultation

4.3.1. Public Exhibition of the Draft Ourimbah Creek FRMS in March 2017

Public exhibition of the Preliminary Draft Ourimbah Creek FRMS was undertaken to ensure community support and this included a community workshop at the University of Newcastle Ourimbah Campus in March 2017. Approximately 80 local residents attended and presentations were made by Council Officers and WMAwater. Following this there was a questions and answer session.

4.3.2. Public Exhibition of the Draft Ourimbah Creek FRMS in April 2019

Public exhibition of the Draft Ourimbah Creek FRMS and Plan was undertaken to ensure community support and this included a community workshop at the Central Coast Council (Wyong) offices on 27th March and 2nd April 2019. Approximately 10 local residents attended and were able to discuss issues with representatives from Central Coast Council, WMAwater, SES and OEH. Digital copies of the reports were available on the Council website and hard copies were available at Council Offices and the local library.

11 written submissions were received from local residents and government departments. A summary of the responses are as follows:

- Several submissions required clarification and these were addressed in a response by Council;
- There was one request for a house to be included on Council's House Raising program;
- There was one request for a house to be included on Council's Voluntary Purchase program;
- Six people filled in the on line survey of the recommended floodplain management measures. However as this is an extremely small survey sample the results have not been statistically analysed;
- One resident asked for flood survival / management plans to be required for house owners and education facilities in flood liable areas. In addition requested that flood markers be installed throughout specific problem areas to assist in communication of the flood risk and when to evacuate from the area. These plus other types of emergency warning and community education measures are listed in the study for either investigation or implementation by Council and SES;
- One submission recommended Ourimbah University have flood warning system. Additional gauge and warning for the University recommended is the study;
- Several people asked that the study review approved projects that may affect flooding (such as Oscar Drive, Chittaway Point, Kangy Angy rail facility, Glenning Valley estate). Council advised in response that this suggestion is outside the scope of a FRMS which is to review floodplain management measures to protect existing development. The review of any project on the floodplain is undertaken by Council or the relevant approving authority;
- One submission asked why the study could not update the flood models to account for recent works in the area (Pacific Highway upgrade). Council will update the flood models in the near future to address this issue and to include the updated rainfall data provided in the 2016 edition of AR&R.
- Several submissions supported raising of various roads which are recommended in the study. These are listed in priority order with higher priority firstly given to emergency management;
- Burns Road, Ourimbah was highly mentioned for improved access, flood warning and boom gates. These and various other measures are recommended in the Study.
- All the recommended emergency management measures in the report were supported by the submissions;
- No additional measures were recommended that were not already addressed in the

Study;

- Raising of Macdonalds Road at the intersection of Pacific Highway as part of the main road upgrading works was supported by some submissions. RMS has been consulted as detailed in this study and advised that the full raising of Macdonalds Road and The Ridgeway at the intersection of Pacific Highway is supported by them however it will have a negative impact on flood levels upstream and downstream of the works. Therefore only limited raising is proposed as part of the highway upgrade works;
- Some submissions considered that Council's development and planning regulations were too weak and needed to be strengthened to prevent unnecessary development in areas of the floodplain, particularly those that might cause impacts to existing properties in all floods up to the PMF. They also did not support any development of areas that required emergency evacuation through floodwaters. The study has identified that specific areas of the floodplain require careful consideration for future development and for Council's regulations to be strengthened and to make clear the regulations and conditions;
- Some submissions advised that alternate communication besides the use of mobile phones should be used in a flood emergency as mobile reception is very poor throughout many areas of the catchment and the towers lost power during the June 2007 flood event. Mobile phone towers and reception is improving constantly and is considered still as an appropriate measure to inform residents of impeding danger however the most appropriate communication measure will be considered for each area of the floodplain at the time of investigation;
- One submission recommended that Council or other authorities should be more proactive in managing the waterways of potential blockages during a flood by fallen trees, jetties, boats, boat wash, etc. This is considered impractical however Council has advised that it will consult with the relevant authorities informing them of these concerns and to take action where necessary and possible;
- One submission recommended that evacuation plans be prepared for schools including child care centres. SES and Council have been assisting making schools and child care centres aware of the areas of flood risks and how to prepare and respond to flooding in preparing private flood plans. This education and assistance is recommended in this Study;
- One submission was concerned that recommended options in the study would not be given high priority for early implementation by Council. Council lists all its projects on a forward plan of works. Each project will need to compete with other projects to be undertaken by Council and with the available resources. Therefore it is difficult to include a timeframe for implementation for each recommended action in the study.
- One submission raised concerns that the Pacific Highway main road works through Lisarow may have adversely affected previous Council channel and levee diversion works in Cutrock Creek, immediately downstream of the Pacific Highway. Council staff have advised that they will review the flood modelling undertaken by the RMS once it is handed over to Council to upgrade their flood model and check for any abnormalities.

5. OURIMBAH CREEK FLOOD STUDY SUMMARY

5.1. Aims and Objectives of the Flood Study

The 2013 Ourimbah Creek Catchment Flood Study (Reference 2) was carried out in order to meet the objective of defining the flood behaviour for the 20% AEP, 10%, 2%, 1%, 0.5% AEP events and the PMF in the catchment and to:

- Define flood behaviour in terms of flood levels, depths, velocities, flows and flood extents within the study area;
- Prepare flood extent mapping (for all design events modelled); and to
- Create a modelling system that might be used in the subsequent FRMS&P to test whatever flood mitigation works might be proposed by either the community, OEH, Council or the consultant.

In order to define flood behaviour, the Flood Study developed a hydrologic model (RAFTS), in conjunction with a linked 1D/2D hydraulic model (TUFLOW).

5.2. Flood Study Review

The Flood Study has been reviewed as part of the current study in the following sections. A summary of design results is presented in Section 5.3. Sections 5.4 to 5.6 examine the Flood Study outputs provisional hydraulic categories, preliminary hazard classification and emergency response planning classifications respectively.

5.2.1. Hydrology Overview

The XP-RAFTS software was used to develop a hydrologic computer model of the catchment. XP-RAFTS is a lumped hydrologic software product that is developed by XP Software and is used extensively across Australia for deriving discharge estimates. The following sections provide a summary of how the model was developed, the adopted input parameters and the outcomes of the model calibration and verification.

The review of the Flood Study hydrology indicates that the results and associated hydrologic model are fit for use in the current study.

5.2.2. Sub-Catchment Delineation and Parameters

The catchment was subdivided into 426 sub-catchments based on the alignment of major flow paths and topographic divides. The sub-catchments were delineated with the assistance of the CatchmentSIM software using a 5 metre Digital Elevation Model (DEM). The current study review of the sub-catchment delineation using available ALS/LiDAR data (see Section 3.4.1) indicates that they are suitable for use in the hydrologic model.

XP-RAFTS requires the slope of each sub-catchment for input into the model. The LiDAR data was also used to check individual sub-catchment slopes, with selected model slopes consistent

with the topography of the catchment.

The Flood Study's selected roughness values for the hydrologic model are within the range of those recommended by the revised ARR guidelines (Project 15: Two Dimensional Modelling in Urban and Rural Floodplains). Selected Mannings 'n' values are considered suitable for use in the hydrologic model.

The modelled percentage impervious was examined and compared to that observed via analysis of available aerial imagery (see Section 3.4.1). Selected imperviousness values are considered suitable for use in the hydrologic model.

5.2.3. Hydrologic Model Calibration/Verification

Hydrologic computer models are developed using parameters that are subject to natural variability. Accordingly, the model has been calibrated using rainfall and stream flow data from historic flood events to ensure the adopted parameters are producing reliable estimates of rainfall-runoff behaviour. Calibration is typically completed by routing recorded rainfall through the hydrologic model with modelled flow hydrographs compared to recorded stream flow records where available. Calibration is completed by adjusting model parameters to achieve the best match possible between recorded and model-generated hydrographs.

The following criteria were employed to select events suitable for the purpose of model calibration and verification:

- A minimum of three significant flood events;
- Floods after 1990 preferred as stream flow and rainfall information are more available;
- Events where flood marks are available are preferred so the same events can be used for both hydrologic and hydraulic model calibration.

Based on these criteria, the following events were selected for model calibration and verification:

- February 1992;
- June 2007; and,
- June 2011.

Analysis of the hydrologic model calibration indicates that a reasonable calibration/verification process has been achieved by matching model flows to observed stream gauge data.

Design flows from the Flood Study were also compared to design flows from previous studies (see Section 3.2.1) undertaken in the catchment as well as to flows determined by the Probabilistic Rational Method (ARR87). It was noted that the design flow results from the various methods are similar which gives further confidence in the Flood Study.

5.2.4. Design Rainfall

Design rainfall was derived using standard procedures outlined in ARR87 for events up to and including the 0.5% AEP. It was noted that the Flood Study assumed that the design rainfall was evenly distributed across the entire catchment. However, analysis of the design rainfall for the

region indicates that there is a rainfall gradient with higher rainfalls typically occurring towards the upper part of the catchment. The maximum variation in rainfall intensities was approximately 15% but varies depending on location and event duration.

Analysis of the hydrologic model indicates that the applied design rainfall is approximately equal to the catchment average rainfall. This leads to only minor differences in the applied and 'true' design rainfalls with the applied rainfall typically no more that 5% different to the ARR87 design rainfall at a point. This difference in design rainfall does not lead to significant changes in peak flood level (relative to freeboard) with differences of over 0.1 m uncommon during the 1% AEP event which indicates that the employed methodology is acceptable.

In November 2016 the ARR 2016 design rainfall and temporal patterns were released and in any future studies these should be used.

5.2.5. Critical Duration Analysis

The Flood Study confirmed that flooding in the catchment could occur as a result of a variety of different storm durations. The Flood Study determined that a storm duration of six hours typically produced the worst case flooding conditions across most of the catchment. Longer storm durations (up to 48 hours) tend to produce higher flood levels in the downstream reaches of Ourimbah Creek (e.g., around Chittaway Point).

Given that a range of critical durations were evident across the study area, the Flood Study did not nominate a single storm duration but instead developed a design flood envelope for each design flood event. This involved extracting and comparing peak flood levels, depths and velocities at each TUFLOW model grid cell for each simulated duration and the highest depth, level and velocity at each grid cell was subsequently adopted. It is this 'design flood envelope', comprising the worst case depths, velocities and levels at each grid cell that forms the basis for the design event results. Accordingly, it is important to recognise that the following design flood results are a composite of results from a range of different durations. It is also important to note that the peak flood levels, depths and velocities do not necessarily occur at the same time.

However, upon review of the Flood Study it was noted that the 9 hour duration, a typical critical duration for catchments in eastern NSW, had not been incorporated into the peak flood envelope.

The 9 hour duration was found to be critical at a number of locations, predominantly in the upper reaches and tributaries of Ourimbah Creek, and increases in peak flood level of 0.1 m were not uncommon. However, the majority of locations where increases in peak flood level were experienced were in-bank and not affecting residential properties. Accordingly, the impact of not modelling this event is relatively minor and well within Council's freeboard of 0.5 m and therefore the Flood Study results are suitable for use in the current study.

5.2.6. Design Losses

The Flood Study used continuing losses of 4.0 mm/hr, which is significantly higher than those

recommended in ARR87 (2.5 mm/hr). These losses were determined via hydrologic model calibration and are likely indicative of the predominantly sandy and sandy loam soils in this Ourimbah Catchment. Typically, it is recommended to use design losses as per those recommended in ARR87 unless calibrated rainfall losses are lower. However use of these higher loss values for the 1% AEP 9 hour duration event indicate that the average difference in flow throughout the model is approximately +3% leading to less than 0.1 m difference in peak flood level at the majority of locations. This indicates that the model is generally insensitive to the selected continuing losses.

An initial loss 15 mm has been used in design flood modelling which is within the ARR87 recommended range for the region (10 to 35 mm/hr).

The selected design loss parameters are suitable for use in hydrologic modelling for the current study.

5.2.7. Areal Reduction Factor

Design rainfall information for flood estimation is generally made available in the form of point rainfall intensities. This is true for the design rainfall described in Section 5.2.4. However, most flood estimates are required for catchments that are sufficiently large that design rainfall intensities at a point are not representative of the real average rainfall intensity across the catchment. The ratio between the design values of areal average rainfall and point rainfall, computed for the same duration and AEP, is called the Areal Reduction Factor (ARF). It allows for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.

It was noted that no ARF was used in the development of design flows in the Flood Study, which is contrary to the method recommended in ARR87. The Ourimbah Creek catchment is 160 km² at its outlet which would require an ARF of 0.94 (6% reduction in rainfall intensity) for the 48 hour duration event. However, applying an ARF for the entire catchment would also lead to reductions in rainfall for smaller tributaries upstream, which, due to their smaller catchment area would not require an ARF. The Flood Study method of not applying an ARF to the catchment leads to increased flows in the lower reaches of the catchment and increased flood levels of typically less than 0.2 m in the 1% AEP event, however does not lead to under estimation of peak flows in the upper catchments, as would otherwise occur.

It should be noted that the increased flows in the lower catchment associated with not using an ARF would be negated somewhat by the implementation of the 4.0 mm/hr continuing loss noted in Section 5.2.6.

5.2.8. Hydraulic Modelling Review

The hydraulic model TUFLOW converts applied flow (discharge hydrographs generated by a hydrologic model) into flood levels and velocities. TUFLOW is a finite difference grid based 1D/2D hydrodynamic model which uses the St Venant equations in order to route flow according to gravity, momentum and roughness.

5.2.9. Model Extent and Topography

The Flood Study modelled the catchment using a linked 1D/2D modelling system. Topography was defined using available DEM data (see Section 3.4) with a 4 m grid size adopted for the urbanised areas to the east of the Pacific Motorway where manmade flow obstructions (e.g., roadway embankments, buildings) are more prevalent. A less detailed 8 metre grid size was adopted across the rural areas to the west of the Pacific Motorway. Channels were modelled in 1D with cross sections taken from a mixture of ground survey and the LiDAR data.

5.2.10. Roughness

Various land uses were assigned Mannings 'n' roughness values as part of the Flood Study. The roughness values used in the model are shown in Table 17 of the Flood Study which has been reproduced as Table 7.

Table 7: Flood Study Selected Mannings 'n'

Material Description Mannings 'n'	
Grass	0.035
Grass with isolated trees	0.04
Grass with sparse trees	0.06
Grass with medium density trees	0.08
Dense tree coverage	0.12
Concrete surfaces	0.015
Car Park (with parked cars)	
Depth < 0.3m - water in contact with vehicle tyres only,	Depth < 0.3m = 0.08
Depth > 0.3m - water in contact with vehicle bodies	Depth > 0.3m = 0.50
Roadways	0.02
Waterbodies (e.g. Dams)	0.04
Railway corridor	0.06
Buildings	3
Creek channels	0.030-0.080
Concrete pipes/culverts	0.015

The Flood Study selected roughness values are within the range of those recommended by Chow (1959) and Henderson (1966) as well as the revised ARR guidelines (Project 15: Two Dimensional Modelling in Urban and Rural Floodplains). Selected Mannings 'n' values are considered suitable for use in the hydraulic model.

5.2.11. Hydraulic Model Calibration/Verification

Hydraulic computer models are developed using parameters that are not known with a high degree of certainty and/or are subject to natural variability. This includes catchment roughness as well as blockage of hydraulic structures. Accordingly, the model should be calibrated using flow and flood mark information from historic floods to ensure the adopted parameters are producing reliable estimates of flood behaviour.

The Flood Study calibrated the hydraulic model by routing flows from historic floods through the hydraulic model. Simulated flood levels were extracted from the model results at locations where recorded flood marks were available. Calibration was completed by iteratively adjusting hydraulic model parameters to achieve the best possible match between recorded flood marks and simulated flood levels.

The following criteria were employed to select events suitable for the purpose of model calibration and verification:

- A minimum of three significant flood events;
- Contemporary floods preferred as the currently available topographic datasets are likely to provide a good reproduction of topographic conditions at the time of the floods; and,
- Events also used for hydrologic model calibration were preferred.

Based on these criteria, the following events were selected for model calibration and verification:

- February 1992;
- June 2007; and
- June 2011.

Analysis of the hydraulic model calibration indicates that a good calibration/verification process has been achieved by matching model peak flood levels to surveyed levels. The average difference between the modelled and observed flood levels was approximately 0.1 m for the three events which indicates an excellent hydraulic model calibration. Accordingly, the Flood Study hydraulic model is considered suitable for use in design flood modelling and the current study.

5.3. Flood Study Design Event Results

The hydraulic model was run for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events as well as the PMF, for which a number of maps have been produced displaying the flood affected regions (see mapping included in the Flood Study – Reference 2).

5.3.1. Peak Flows

The Flood Study noted the peak flows for each design event at a number of locations, as shown in Table 8.

Table 8: Peak Design Discharges for Existing Conditions (from Flood Study - Reference 2)

Table 24 Peak Design Discharges for Existing Conditions

Location		XP-RAFTS ID	Peak Discharge (m^3/s)						
			20%	10%	5%	2%	1%	0.5%	PMP
Ourimbah Creek	Lyrebird Lane	1.28	286	353	441	536	625	825	2,820
	Moores Point Rd	1.36	297	369	470	586	688	937	3,350
	Footes Rd*	1.42	312	369	472	600	709	984	3,580
	Palmdale Rd*	1.47	312	371	471	600	709	990	3,620
	Sydney Newcastle Freeway	1.49	336	393	454	534	610	819	2,860
	Main Northern Railway	1.57	486	583	715	832	972	1,320	5,280
	Wyong Road	1.59	499	599	735	857	1,000	1,340	5,410
	Tuggerah Lake#	1.60	492	593	730	853	998	1,340	5,370
Canada Drop Down Creek	Palmdale Rd	89.13	70.2	84.6	110	133	153	212	8,58
	Ourimbah Ck Confluence	89.17	102	122	148	177	211	297	1,320
Kangy Angy Creek	Old Tuggerah Rd	171.02	8.69	10.3	12.6	14.5	16.7	22.7	79.0
	Pacific Hwy	171.06	20.3	24.1	29.4	33.6	38.9	53.0	187
Chittaway Creek	Enterprise Dr	163.05	25.5	30.4	36.9	43.2	50.2	70.0	224
	Old Chittaway Rd	163.07	26.8	32.1	39.2	46.0	53.9	75.3	246
Bangalow Creek	Coachwood Dr	119.08	28.3	33.7	42.5	51.1	59.6	80.0	245
	Cut Rock Ck confluence	119.10	34.1	40.5	51.1	61.9	73.0	98.2	315
	Shirley St	119.14	75.0	88.6	108	128	153	213	746
	Chittaway Rd	119.18	112	134	164	190	220	305	1,140
	Burns Rd	119.20	112	134	164	191	221	307	1,150
	Ourimbah Ck Confluence	119.23	137	166	229	283	346	494	2280
Cut Rock Creek	Detention Basin Outflow	137.03	4.86	5.65	7.17	8.11	9.62	13.9	44.8
	Tuggerah St	128.03	27.9	32.7	41	50	59.3	79.9	263
	Railway Upstream	128.07	38	44.6	55.2	67.3	79.3	108	368
	Teralba St	128.08	39.3	46.1	57.2	68.8	80.9	111	376
	Railway Downstream	128.11	42.1	49.7	61.4	72.9	85.2	117	402
Dog Trap Gully	Pacific Hwy	153.06	26.7	31.8	40.1	48.1	56.2	75.4	286

NOTE: * The peak discharges for Ourimbah Creek at Palmdale Road are lower than at Footes Road for some AEPs. This is associated with some of the flow being diverted from Ourimbah Creek via the Bangalow Creek flood runner and, therefore, bypassing Palmdale Road.
Reductions in peak discharge are also evident downstream of Wyong Road. This is associated with the very flat channel slope along this section of Ourimbah Creek which serves to attenuate the peak discharge.

5.3.2. Flood Depths and Levels

Mapping of peak flood depths and levels is included in the Flood Study. The map set includes the following;

- Peak flood depths and levels for the design flood events (PMF, 0.2EY (20% AEP), 10%, 5%, 2%, 1% and 0.5% AEP);
- Provisional Hazard maps;
- Hydraulic Category maps; and
- Emergency Response Planning Maps.

5.4. Provisional Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (FDM, Reference 1) defines flood prone land to fall into one of the following three hydraulic categories:

- Floodway;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant effect on flood flows, velocities or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities.

The Flood Study defined provisional floodways on the qualitative guidelines presented in the FDM. These guidelines and the adopted criteria to achieve these outcomes are presented in Table 30 of the Flood Study which has been reproduced as Table 9.

The Flood Study went to significant effort to verify the suitability of the delineated floodways by additional checks made in accordance with recommendations outlined in the former DECC (now OEH) *"Floodway Definition"* (Department of Environment & Climate Change, 2007) guideline. This involved blocking sections of the delineated floodways and quantifying the impact that this blockage had on peak flood levels as well as the distribution of floodwaters in the vicinity of the blockage during the 1% AEP flood. The classification of Flood Storage and Flood Fringe were also verified, giving confidence to the hydraulic categories identified in the Flood Study. A review of the hydraulic categorisation is presented in Section 6.1.

Table 9: Flood Study – Qualitative and Quantitative Criteria for Hydraulic Categories (from Flood Study - Reference 2)

Hydraulic Category	Floodplain Development Manual Definition	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	The following criteria were used to provide an initial appraisal of floodway extents. - V x D > 1 m^2/s - D > 0.5 m and - V > 1 m/s Based on this information, floodways were delineated by hand.
Flood Storage	• 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.	Areas that are not floodway and where the depth of inundation is greater than 0.3 metres
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	Areas that are not floodway where the depth of inundation is less than 0.3 metres

NOTES: *Hydraulic categories were only applied to areas subject to inundation (i.e., D > 0m)*
**The adopted criteria were developed specifically for the Ourimbah Creek Catchment only and may not be appropriate for any other areas.*

Whilst Table 9 indicates that filling of flood fringe areas should not have a significant affect on the pattern of flood flows and/or flood levels. This will depend upon the extent and location of the filling. Entirely filling the flood fringe areas will significantly increase flood levels in many locations. Care therefore needs to be exercised if any filling is completed in flood fringe areas to ensure local flows are not redistributed thereby adversely impacting on flood/drainage behaviour across adjoining areas. In this regard, any proposed filling in floodplain areas should be supported by an appropriate flood impact assessment report that demonstrates the filling will not adversely impact on local flood behaviour.

5.5. Provisional Hydraulic Hazard Classification

The Flood Study defined provisional flood hazard categories in accordance with the FDM. Provisional hazards only take account of the hydraulic aspects of flood hazard; depth and velocity (Diagram 1), while true hazard (see Section 6.2) takes into account additional factors such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, duration

of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

The Flood Study established high and low provisional hazard areas for the 1% AEP event and the PMF.

The flood study also undertook preliminary true flood hazard by analysing the provisional hazard mapping in conjunction with the Emergency Response Planning Maps (see Section 5.6). The preliminary true hazard categories reflect consideration of the depth and velocity of floodwaters as well as other factors that influence flood hazard, including the potential for isolation and evacuation difficulties.

Diagram 1: Provisional Hydraulic Hazard Categories

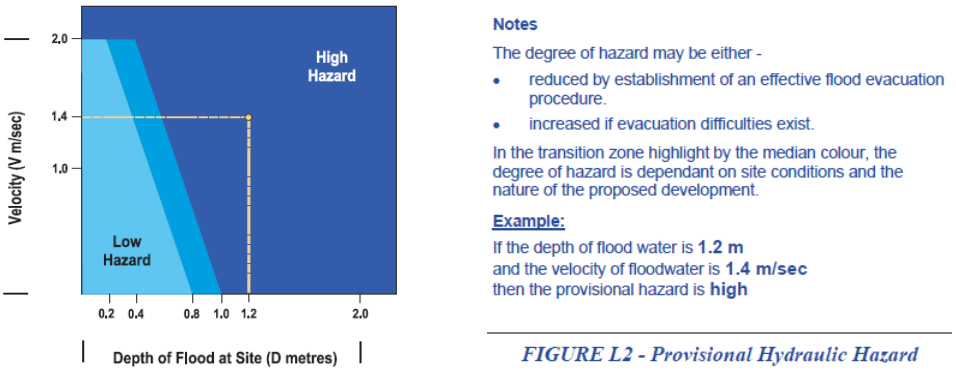


FIGURE L2 - Provisional Hydraulic Hazard Categories

Extracted from The Floodplain Development Manual (Reference 1)

In general, the provisional hazard categories were retained in the preliminary true hazard mapping. However, the "transitional" provisional flood hazard was changed to a high true flood hazard when subject to the following Emergency Response Planning (ERP) classifications (due to the flood liability of the land in conjunction with potential evacuation difficulties):

- Low Flood Island;
- Low Trapped Perimeter Area; and,
- Overland Refuge area on Low Flood Island or Low Trapped Perimeter Area.

A review of the Flood Study's preliminary true hydraulic hazard is presented in Section 6.2.

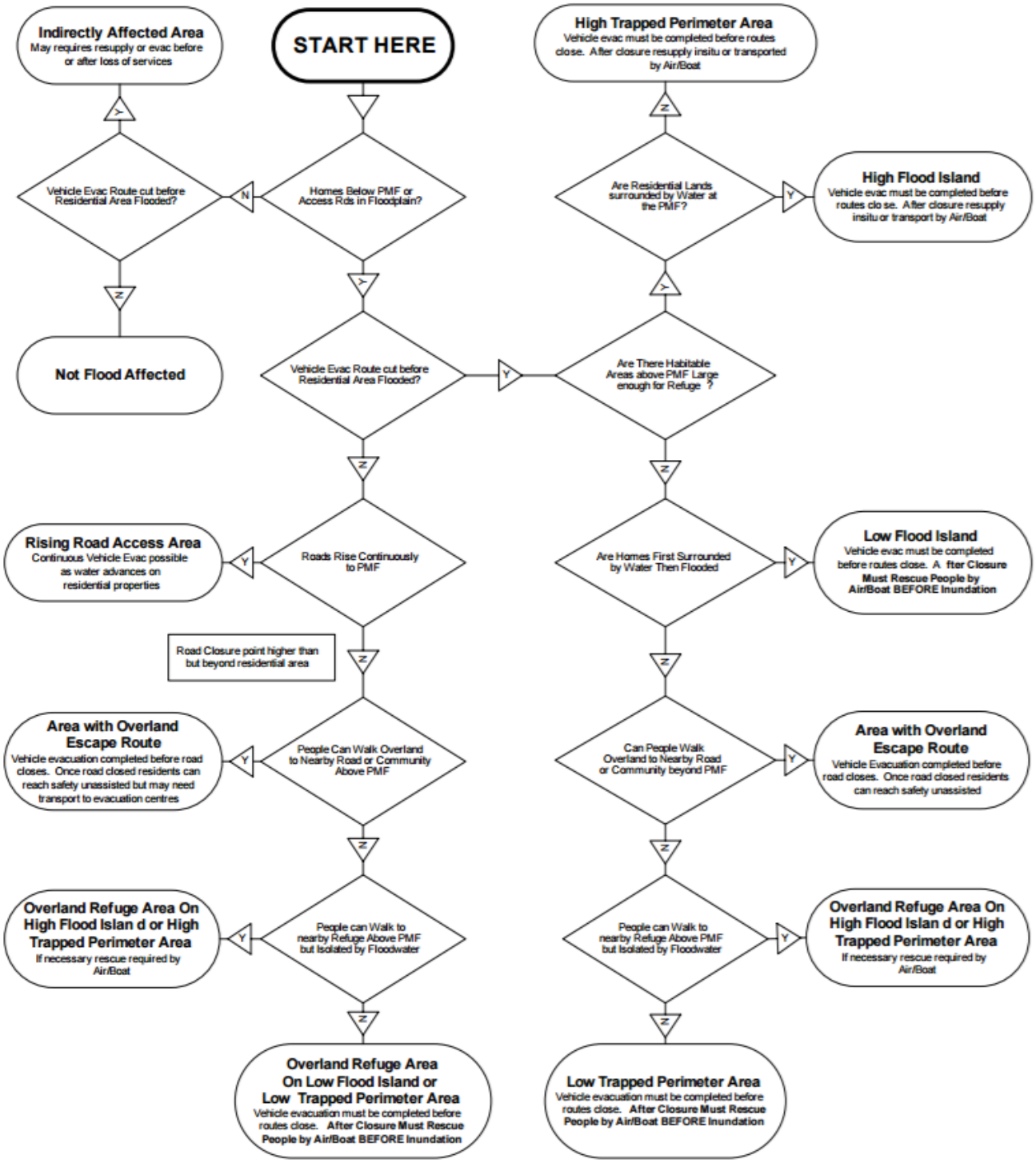
5.6. Flood Study Emergency Response Planning Maps

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 (Reference 16). These ERP classifications 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, 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 10). A flow chart presenting how flood emergency classifications are assigned is presented in Image 2.

Table 10: Emergency Response Planning Classifications of Communities

Classification	Response Required		
	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

Image 2: Flow Chart for Flood Emergency Reponse Classification (Reference 16)



The Flood Study classified each allotment within the catchment based upon the flow chart provided in the ERP guideline for both the 1% AEP and PMF. This was completed in an automated fashion using proprietary software based upon consideration of:

- Whether evacuation routes/roadways get “cut off” and the depth of inundation (a 200mm depth threshold was used to define a “cut” road);
- Whether evacuation routes continuously rise out of the floodplain (based upon roadway alignments provided by Gosford and Wyong Council’s and a 2m LiDAR-based DEM developed for this study);
- Whether an allotment gets inundated during the nominated design flood and whether

evacuation routes are cut or the lot becomes completely surrounded (i.e., isolated) by water before inundation (a lot was considered inundated when there was less than 250 m² of “dry” land area available);

- If evacuation by car was not possible, whether evacuation by walking was possible (an 800 mm depth threshold was used to define when a route could not be traversed by walking).

The Flood Study’s ERP mapping has been examined with the findings presented in Section 6.3.

6. EXISTING FLOOD BEHAVIOUR

6.1. Hydraulic Categorisation

The Flood Study defined the provisional hydraulic categories as per the methods discussed in Section 5.4. The employed methodology and defined hydraulic categories are considered fit for purpose and suitable for use in Council's planning policy. Accordingly, the provisional hydraulic categories are now classified as the true hydraulic categories.

Figures 40 and 41 of the Flood Study present the true hydraulic category mapping for the 1% AEP and PMF events respectively.

6.2. Flood Hazard Classification

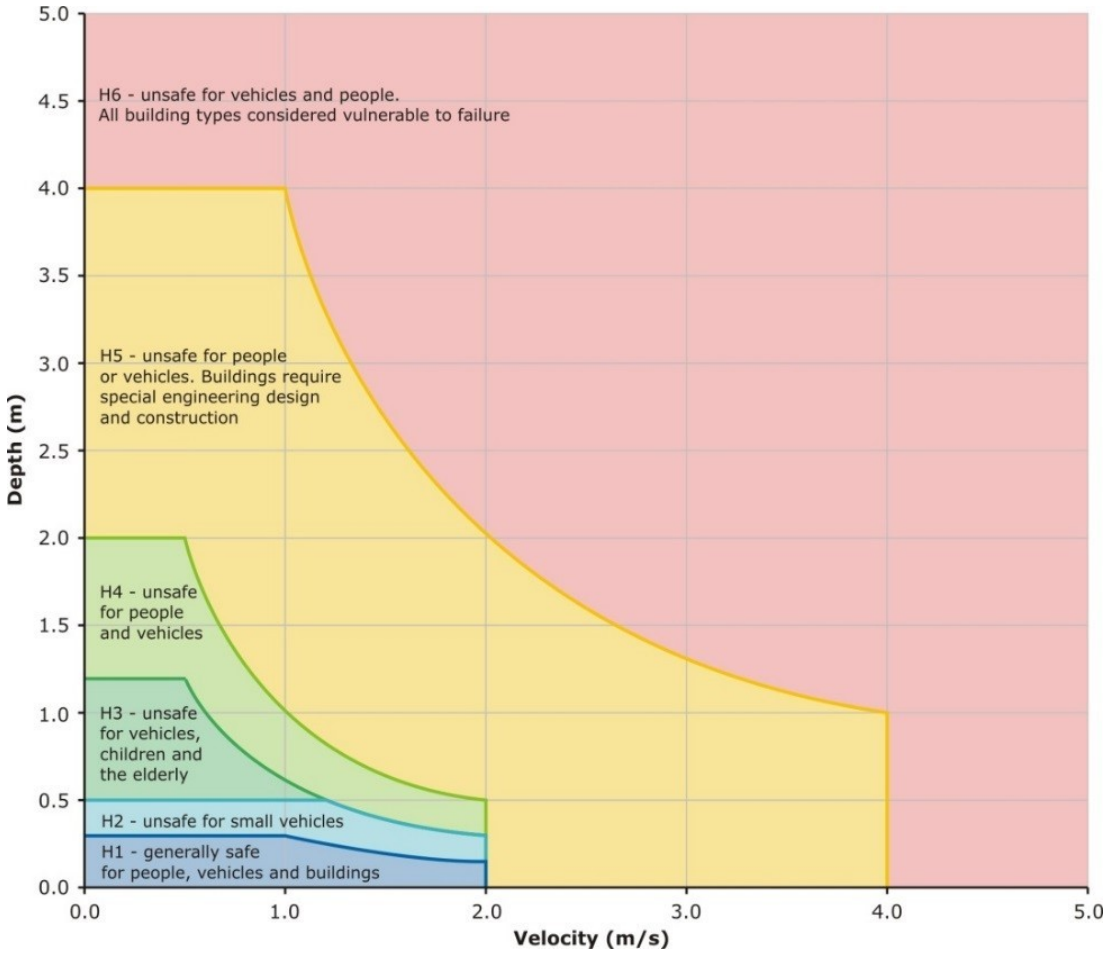
The Flood Study mapped the preliminary True Flood Hazard, classifying the floodplain as 'High' or 'Low' hazard. In recent years there has been a number of developments in the classification of hazard. *Managing the floodplain: a guide to best practice in flood risk management in Australia* (Reference 17) provides revised hazard classifications. These add clarity to the description hazard categories and what they mean in practice. This new methodology for determining hazard has been used in this FRMS&P.

The hazard classifications are divided into six categories (Diagram 2) which indicate the restrictions on people, buildings and vehicles:

- H1 - Generally safe for vehicles, people and buildings,
- H2 - Unsafe for small vehicles,
- H3 - Unsafe for all vehicles, children and the elderly,
- H4 - Unsafe for all people and all vehicles,
- H5 - Unsafe for all people and all vehicles. Buildings require special engineering design and construction, and
- H6 – Unsafe for people or vehicles. All buildings types considered vulnerable to failure.

Figure 4 and Figure 5 present the hazard classifications based on the H1 – H6 delineations for the 1% AEP and PMF events respectively. Under this classification for a 1% AEP event much of the Ourimbah Creek floodplain is classified as H5 which is considered unsafe for all people and all vehicles with buildings requiring special engineering design and construction, and the creek channel and major runners are considered unconditionally unsafe (H6). Cut Rock Creek flood hazard is typically lower with the H5 and H6 uncommon. Other smaller tributaries experience similar flood hazard classifications as that determined for Cut Rock Creek. No residential homes were identified as situated within areas classed as H6, however numerous homes on the floodplain are surrounded by flood hazard with H5 classification.

Diagram 2: Hazard Classifications (Reference 17)



6.3. Emergency Response Planning Classifications

The Flood Study defined ERP classifications as per the methods discussed in Section 5.6. The ERP mapping has been reviewed as part of this FRMS&P and was determined to require significant amendments to the classification delineation. Common issues include:

- Lots classified as 'High Trapped Perimeter Area' that are entirely flood affected;
- Lot classifications of 'Low Flood Island' and 'Low Trapped Perimeter Area' appear to be used interchangeable;
- Lots classified as 'Area with Overland Escape Route' are surrounded by lots classified as 'Low Flood Island'; and
- Other less common issues have also been identified.

The current study utilised methodology consistent with that outlined in Reference 16 to reproduce ERP classification maps for the 5% AEP, 1% AEP and PMF events (as per the Reference 16, SES guidelines). These maps are presented in Figure 6 to Figure 8 respectively.

6.4. Road Inundation and Access

Understanding flood access issues is critical to effective evacuation and flood response planning. The Flood Study modelled peak flood depths (black) and velocities (red) within the Ourimbah Creek catchment which are presented in Table 11 at various road crossing. The

locations of these flooded access roads are presented in Figure 1 (a to l). Examination of Table 11 highlights the flood liability of access roads throughout the catchment with 15 roads noted as unsafe for smaller vehicles during the 20% AEP event.

This is in agreement with findings from the community/stakeholder consultation (see Section 4) which indicates a large amount of road flood liability and risk associated with motorists attempting these crossing during flood. The roads mentioned below were specifically mentioned as part of the consultation process and a summary of their flood liability is provided below:

- Burns Road –20% AEP Hazard category H5, estimated as first flooded in the 2EY event;
- Howes Road – 20% AEP Hazard category H4, estimated as first flooded in the 2EY event;
- Turpentine Road – 20% AEP Hazard category H4, estimated as first flooded in the 2EY event;
- Chittaway Road – 20% AEP Hazard category H4, estimated as first flooded in the 1EY event; and
- Shirley Street – 20% AEP Hazard category H3, estimated as first flooded in the 0.5EY event.

Research undertaken for the revision of ARR shows that vehicles can become unstable in shallow depths of floodwaters (~0.1 m) if velocities approach 3 m/s. Small cars can float in still water depths of only 0.3 m (Reference 18). In addition, once flooding has subsided, structural damage could make access over a bridge unsafe.

Information about the depths and velocities of road inundation and likely timing of road closures can aid flood response planning, and ensure that evacuation occurs in a timely fashion before conditions deteriorate and hinder the evacuation process, requiring rescue boats and helicopters. Additionally, early warning can allow motorists to better plan their route, make informed choices and thus avoid flood affected areas and road crossings.

Refer to Section 9.3.1 for an assessment of measures to improve flood access.

Table 11: Flood Depths and Velocities at Creek Crossings

ID	Location* (Figure 1a to l)	Event Depth (m) and Velocity (m/s)						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1	Tapley Road (CRC)	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	1.1 / 0.4	1.2 / 0.4	1.3 / 0.4	2.2 / 0.6
2	The Ridgeway (CRC)	-	-	-	-	-	-	-
3	Orchard Road (CRC trib)	1.1 / 1.3	1.3 / 1.3	1.4 / 1.5	1.5 / 1.4	1.6 / 1.3	1.8 / 1.6	2.9 / 1.7
4	Macdonalds Road (CRC)	0.4 / 2.0	0.5 / 2.3	0.6 / 1.7	0.7 / 1.6	0.8 / 1.4	1.0 / 1.6	1.7 / 8.0
5	Macdonalds Road 2 (CRC)	0.8 / 0.3	0.9 / 0.3	1.0 / 0.4	1.1 / 0.5	1.1 / 0.6	1.2 / 0.6	1.9 / 1.0
6	Fagans Road (BC trib)	-	-	0.1 / 0.4	0.1 / 0.3	0.1 / 0.3	0.2 / 0.3	0.6 / 1.3
7	Coachwood Drive (BC)	-	0.0 / 2.1	0.3 / 2.3	0.4 / 2.3	0.5 / 2.3	0.5 / 2.3	2.1 / 2.3
8	Pryor Road u/s (BC)	-	-	-	-	-	0.3 / 0.3	2.2 / 0.6
9	Pryor Road d/s (BC)	-	-	-	-	-	-	1.0 / 5.7
10	Coachwood Drive (BC trib)	-	-	-	-	0.1 / 0.1	0.1 / 0.4	0.4 / 0.7
11	Shirley Street (BC trib)	-	-	-	0.1 / 1.0	0.1 / 1.1	0.3 / 1.5	2.3 / 2.2
12	Shirley Street 2 (BC trib)	-	-	0.2 / 0.4	0.3 / 0.7	0.3 / 0.7	0.4 / 0.8	1.4 / 3.6
13	The Boulevard u/s (BC)	0.4 / 0.8	0.3 / 0.3	0.4 / 0.3	0.5 / 0.3	0.5 / 0.3	0.7 / 0.4	2.2 / 1.0
14	The Boulevard d/s (BC)	0.2 / 0.5	0.2 / 0.5	0.2 / 0.6	0.2 / 0.6	0.2 / 0.6	0.2 / 0.7	2.2 / 1.3
15	The Boulevard u/s 2 (BC)	0.6 / 0.2	0.7 / 0.2	0.8 / 0.3	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	3.3 / 0.8
16	The Boulevard d/s 2 (BC)	0.6 / 0.3	0.7 / 0.3	0.8 / 0.3	0.9 / 0.4	1.0 / 0.3	1.2 / 0.4	3.3 / 0.7
17	Shirley Street 1 (BC)	0.9 / 0.3	1.0 / 0.3	1.1 / 0.4	1.2 / 0.6	1.3 / 0.7	1.4 / 0.9	3.9 / 2.6
18	Shirley Street 2 (BC)	-	-	-	-	-	-	0.9 / 6.7
19	Pacific Highway u/s (DTG)	0.6 / 0.9	1.0 / 0.9	1.1 / 1.0	1.3 / 0.9	1.4 / 0.9	1.6 / 1.5	2.7 / 1.8
20	Pacific Highway d/s (DTG)	0.5 / 2.4	0.6 / 2.5	0.9 / 2.4	1.2 / 2.3	1.4 / 2.1	1.6 / 2.3	2.9 / 2.4
21	Chittaway Road (BC)	0.5 / 1.7	0.5 / 1.7	0.6 / 1.7	0.7 / 1.7	0.8 / 1.7	1.0 / 1.7	3.2 / 1.7
22	Chittaway Road 2 (BC)	0.6 / 1.2	0.7 / 1.3	0.7 / 1.3	0.8 / 1.3	0.9 / 1.3	1.1 / 1.3	3.3 / 1.4
23	Burns Road (BC)	1.9 / 1.5	2.1 / 1.7	2.3 / 1.6	2.5 / 1.6	2.6 / 1.5	2.8 / 1.6	4.9 / 3.3
24	Old Chittaway Road (CC)	0.2 / 1.4	0.3 / 1.6	0.4 / 1.7	0.4 / 1.8	0.5 / 1.8	0.6 / 1.9	2.2 / 1.9
25	Enterprise Drive (CC)	-	-	-	-	-	-	1.2 / 3.4
26	Turpentine Road (CC)	1.5 / 0.4	1.6 / 0.3	1.7 / 0.3	1.8 / 0.4	1.8 / 0.4	2.0 / 0.5	1.6 / 3.1
27	Palmdale Road (OC)	0.1 / 0.4	0.2 / 0.8	0.4 / 1.7	0.8 / 1.7	0.9 / 1.7	1.3 / 1.7	4.7 / 1.7
28	Footts Road (OC)	1.8 / 1.5	2.0 / 1.8	2.2 / 1.7	2.5 / 1.7	2.6 / 1.4	3.0 / 1.7	7.0 / 5.4
29	Palmdale Road (CDDC)	0.2 / 0.7	0.2 / 0.7	0.5 / 1.0	0.6 / 1.3	0.8 / 1.4	0.9 / 1.5	3.9 / 2.1
30	Railway (OC)	-	-	-	-	-	-	0.5 / 6.1
31	Wyong Road (OC)	-	-	-	-	-	-	0.5 / 8.0
32	Tuggerah Street (BC)	1.8 / 0.6	2.0 / 0.6	2.2 / 0.6	2.3 / 0.6	2.5 / 0.5	2.7 / 0.6	3.9 / 2.4
33	Tuggerah Street (BC)	0.3 / 0.4	0.4 / 0.3	0.6 / 0.4	0.8 / 0.4	1.0 / 0.4	1.1 / 0.4	2.3 / 0.6
34	Tuggerah Street 2 (BC)	0.4 / 0.3	0.5 / 0.3	0.7 / 0.4	0.8 / 0.6	1.0 / 0.3	1.1 / 0.7	2.3 / 1.6
35	Woodview Avenue (BC)	0.1 / 0.4	0.2 / 0.5	0.2 / 0.6	0.2 / 0.7	0.2 / 0.4	0.2 / 0.3	1.0 / 2.6
36	Pacific Highway (CRC)	-	-	-	-	-	-	-
37	Nr Cassinia Close Lisarow(CRC)	0.2 / 0.7	0.3 / 0.7	0.3 / 0.7	0.4 / 0.6	0.4 / 0.6	0.4 / 0.6	1.2 / 0.9
38	Nr Ridgeway / Pacific Hgw (CRC)	0.3 / 0.7	0.3 / 0.5	0.4 / 0.5	0.5 / 0.6	0.5 / 0.4	0.6 / 0.6	1.3 / 0.8
39	Teralba St (CRC)	0.6 / 0.1	0.7 / 0.1	0.9 / 2.5	1.0 / 1.6	1.1 / 1.3	1.2 / 1.7	2.5 / 0.1
40	Lisarow St (CRC)	0.3 / 0.6	0.4 / 0.5	0.5 / 0.5	0.5 / 0.6	0.5 / 0.7	0.8 / 0.6	2.3 / 0.8
41	Pacific Hwy (CRC)	-	-	-	-	-	-	0.2 / 1.1

* CRC = Cut Rock Creek, BC = Bangalow Creek, DTG = Dog Trap Gully, CC = Chittaway Creek, OC = Ourimbah Creek, CDDC = Canada Drop Down Creek, trib = tributary of.

6.5. Existing Levee Assessment

The following levees in the catchment have been identified:

- Tuggerah Business Park Levee (TBPL); and the
- Main Northern Railway Line Levee.

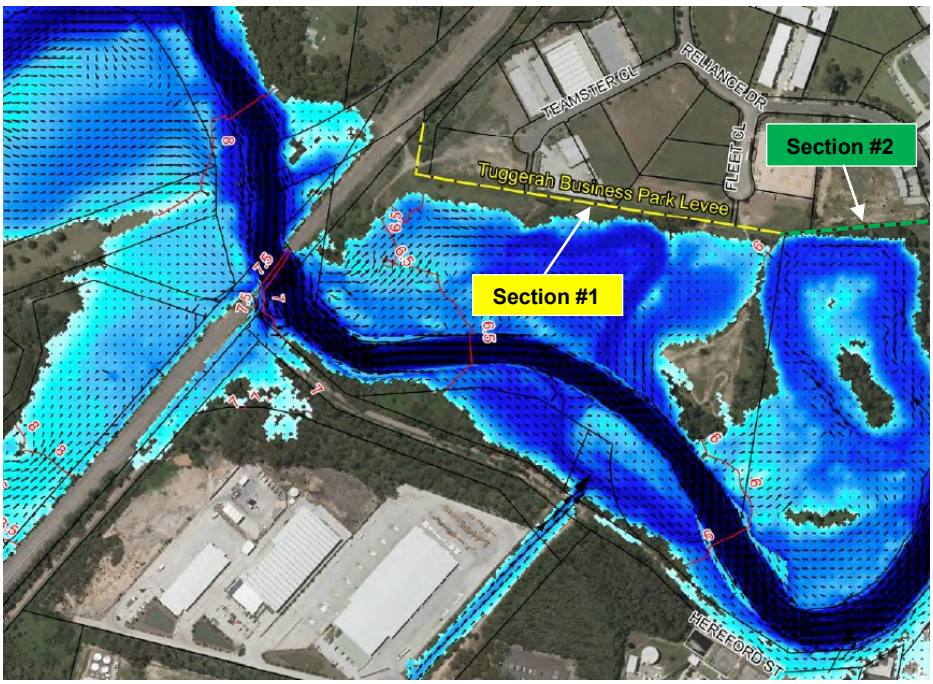
This assessment has been untaken using 2014 LiDAR data (see Section 3.4.1) which has a vertical accuracy of 0.3 m (95% Confidence Interval) and a horizontal accuracy of 0.8 m (95% Confidence Interval). Accordingly, the LiDAR data is only suitable for providing an indicative assessment. Additionally, the structural design of these structures has not been assessed.

Ground survey and a maintenance / geotechnical assessment of these levees is required for a detailed levee assessment and is recommended in Section 9.2.1.7.

6.5.1. Tuggerah Business Park Levee (TBPL)

The TBPL is situated on the northern bank of Ourimbah Creek between the Main North Railway Line and Wyong Road. The levee can be described as being composed of two parts, namely the TBPL East and TBPL West. The TBPL West is situated between the Main North Railway Line near Teamster Close and Reliance Drive near Fleet Close (see Image 3). The TBPL East is situated to the east of the TBPL West and runs parallel to Reliance Drive meeting a drainage channel immediately west of Wyong Road (see Image 4).

Image 3: TBPL West (Reference 2)

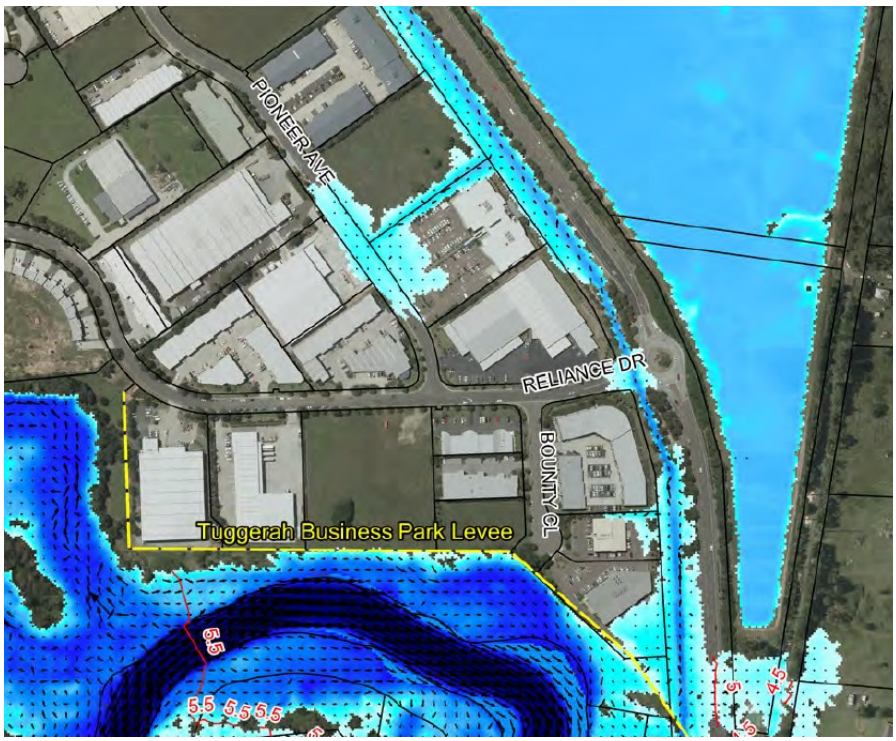


The crest level of the TBPL West levee ranges from 7.5 to 6.8 mAHD (from west to east) between the Railway and Fleet Close (Section #1) which is 0.5 to 1.2 m above the level of the 1% AEP. To the east of Fleet Close (Section #2) the levee crest is poorly defined and ranges from 6.5 to 7.5 mAHD (from west to east) which is 0.9 to 1.9 m above the level of the 1% AEP event. This part of the levee is not overtopped until events larger than the 0.5% AEP.

Sections of the TBPL East levee do not appear to be formalised based on analysis of the LiDAR. The crest level of the levee ranges between 6 to 5 mAHD (from west to east), however it may contain lower sections that cannot be identified via analysis of the LiDAR. Ground survey is required to undertake a more detailed analysis. The Flood Study modelled this levee using a breakline however no information regarding where crest levels were obtained was provided.

1% AEP flood levels bordering the TBPL East levee range from 5.5 to 5.2 mAHD and accordingly there is very little if any freeboard constructed into the design height of this levee. Modelling indicates that the levee is slightly overtopped at its eastern end and that flood waters backwater into the drainage channel bordering Wyong Road. This causes some flooding in the Tuggerah Business Park away from the channel proper (see Image 4).

Image 4: TBPL East (Reference 2)



6.5.2. Main Northern Railway Line Levee

The Main Northern Railway Line levee is located on the western side of the Main Northern Railway line (within the rail corridor), directly west of the Berkeley Vale industrial area (Image 5) and was constructed based on design plan drawn in 1991. The levee is designed to prevent overtopping and subsequent “wash out” of the railway line ballast (Reference 2).

The crest level of the levee ranges from 10.4 to 11.2 mAHD which is at least 0.7 m higher than the 1% AEP flood level. The levee is not overtopped by the 0.5% AEP event, however it is overtopped by the PMF.

Image 5: Main Northern Railway Line Levee

Image provided from Google Maps

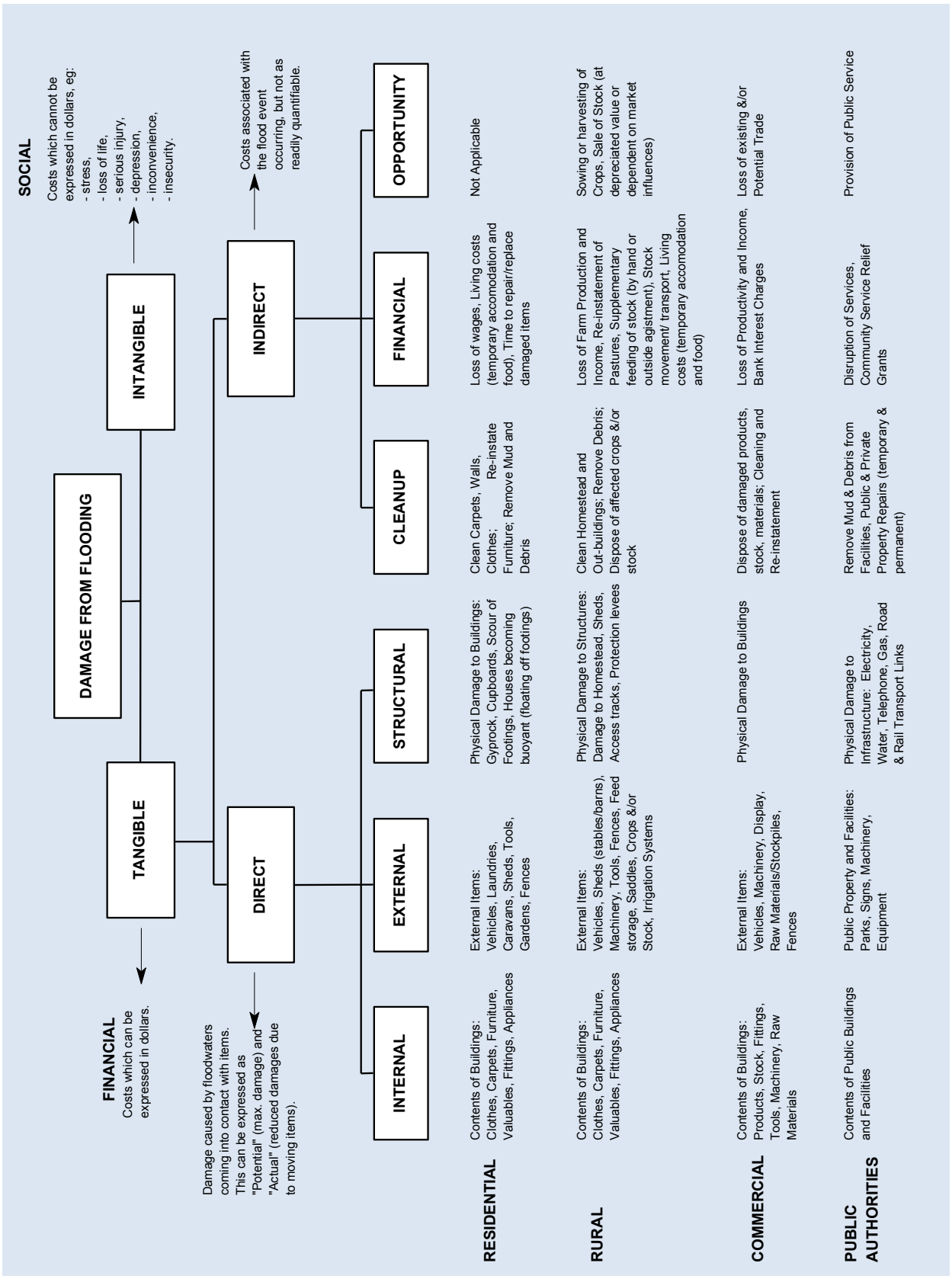
7. ECONOMIC IMPACTS OF FLOODING

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 as 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 Table 12.

Table 12: Flood Damages Categories



7.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 12). 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 damage estimates are also useful when studying the economic effectiveness of proposed mitigation options, however difficulties arise when trying to assess intangible damages such as loss of life. 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, floor level survey and estimates were made (see Section 3.4.2). This was used in conjunction with modelled flood level information from the Flood Study to calculate damages. Damage calculations were carried out for all properties within the PMF extent.

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.

A flood damages assessment had previously been undertaken for areas flood affected by Tuggerah Lakes as part of the Reference 4 study. This included areas of the lower reaches of the Ourimbah Creek catchment typically downstream of Wyong Road (referred to as Management Area TL5 in Reference 4). As a flood damages assessment has already performed for the area downstream of Wyong Road, these damages have not been reassessed in the current study to avoid double counting and overestimating flood damages for the region.

Damages were calculated for residential and commercial\industrial properties, discussed separately below. 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.

7.1.1. Residential Properties

Residential properties suffer damages from flooding in a number of ways. Direct damages include loss of property contents and/or damage to the structure of the property. Indirect damage costs can be incurred when property occupiers live elsewhere while repairs are being made. A flood damages assessment was undertaken for 930 residential properties. Surveyed and estimated floor level data was obtained by the methods outlined in Section 3.4.2. A summary of the flood damages assessment is provided in Table 13 for the Ourimbah Creek catchment. As previously discussed, the damages downstream of Wyong Road have not been assessed to avoid double counting and overestimating flood damages.

Table 13: Residential Flood Damages for Properties Situated Upstream of Wyong Road

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20% AEP	35	3	$ 220,000	$ 6,000
10% AEP	67	13	$ 920,000	$ 14,000
5% AEP	104	19	$ 1,522,000	$ 15,000
2% AEP	119	26	$ 2,279,000	$ 19,000
1% AEP	144	34	$ 2,840,000	$ 20,000
0.5% AEP	180	53	$ 4,481,000	$ 25,000
PMF	633	525	$ 47,039,000	$ 74,000
Average Annual Damages (AAD)			**$ 380,000**	**$ 600**

Table 13 indicates a moderate degree of flood liability for more frequent events with 34 properties (4%) flooded above floor level in the 1% AEP event. During the PMF there are an estimated 525 properties (56%) flooded above floor level indicating a high degree of flood risk and associated flood damages. On average, flooding in Ourimbah Creek, upstream of Wyong Road, cost Council and the community $380,000 per annum.

7.1.2. Non-Residential – Commercial and Industrial

Non-residential land uses in the study area are typically situated bordering the Pacific Highway with a large business/industrial hub bounded by Enterprise Drive, Wyong Road and the Main North Line Railway in the lower reaches of the catchment.

Non-residential properties are affected either directly by flood damage or indirectly by loss of business due to restricted customer and/or employee access. Costs vary significantly dependent on the type of activity;

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

A summary of the flood damages assessment for commercial and industrial properties is provided in Table 14 for the Ourimbah Creek catchment. Table 14 indicates relatively limited flood liability for non-residential properties.

Table 14: Estimated Non-residential Flood Damages for Ourimbah Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
20% AEP	5	3	$ 268,000	$ 53,500
10% AEP	7	3	$ 372,000	$ 53,100
5% AEP	12	3	$ 395,000	$ 32,900
2% AEP	13	4	$ 531,000	$ 40,800
1% AEP	22	6	$ 752,000	$ 34,200
0.5% AEP	44	29	$ 3,252,000	$ 73,900
PMF	170	168	$ 38,429,000	$ 226,100
Average Annual Damages (AAD)			**$ 226,000**	**$ 1,300**

7.1.3. Critical Infrastructure and Vulnerable Facilities

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; gas supply; telephone supply; electricity supply including transmission poles/lines, sub-stations and underground cables; rail; roads and bridges including traffic lights/signs; and costs to employ emergency services and assist in cleaning up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise;

- Clean-up costs;
- Erosion and siltation;
- Drain cleanout and maintenance;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts;
- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

There are two electrical sub-stations in the catchment which are described below along with their flood affection.

Ourimbah Zone Sub-station - is situated at 4 Yates Road, Ourimbah. Analysis of the design results indicates that the sub-station is flood free for events up to and including the 0.5% AEP

event. The substation is flooded by depths of approximately 1 m in the PMF event.

Berkeley Vale Zone Sub-station - is situated at 14 Apprentice Drive, Berkeley Vale. Analysis of the design results indicates that the sub-station is flood free for events up to and including the 0.5% AEP event. The substation is flooded by depths of approximately 2 m in the PMF event.

A sewage treatment plant is situated on Ibis Road off Wyong Road. This area is situated outside of the study area so specific flood liability cannot be described.

On site sewage systems are still present on some of the older residential lots, most notably at Tall Timbers. Inundation of these systems presents a significant health hazard for residents or the SES / Police / RFS who may enter flood waters during the event or as part of the clean up operation. In addition in a very large flood event it is possible that the reticulated sewage system may fail and discharge effluent into floodwaters.

The study area has a number of schools and learning centres which are listed below along with their flood liability.

Table 15: Flood Affected Schools in Ourimbah Creek Catchment

Name	Address	Yard First Flooded	Above floor flooding
Lisarow Public School	17 Macdonalds Rd, Lisarow	20% AEP	PMF
Ourimbah Public School	121 Pacific Hwy, Ourimbah	0.5% AEP	0.5% AEP
Central Coast Rudolf Steiner School	45 Catamaran Rd, Fountaindale	PMF	Not flooded
Chittaway Bay Public School	Chittaway Rd, Chittaway Bay	PMF	PMF
Newcastle University Ourimbah Campus	The Boulevard	20% AEP	PMF

Flooding to schools, and to similar institutions, would have different impacts depending on the time of day and obviously during school hours response would be more critical due to the number of persons on the site. It is important that the schools have effective flood plans implemented (see Section 9.3.4).

In addition to the above there are a number of other private and public properties/facilities that are vulnerable to flooding (e.g child care, aged care centres).

7.2. 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. As well as 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.

Flood affectation to many of the critical infrastructure and vulnerable facilities (Section 7.1.3) may also result in significant intangible damages. For example, damage to service supply (water, sewage) will affect households as will the temporary closure of schools or child care facilities as repairs are carried out. The flood affectation to these facilities will not necessarily occur at the site of the facility. Thus just because the facility is not directly affected by flooding does not mean that flooding will not have a bearing on the facilities activities and the resulting community. For example, with schools, child care, aged care, universities the main issue is with access to the facility and this may be some distance from the building.

With service infrastructure (sewer, water, electricity) the main facility will likely not be directly affected by floodwaters but the supply will be affected by say fallen trees hitting power lines or closure of the sewer system as floodwaters are entering the system in the flooded area. Many of these affectations to the critical infrastructure and vulnerable facilities are variable and will not necessarily occur in all floods or at the same locations. It is only through review of past floods that the true affectation to critical infrastructure and vulnerable facilities can be addressed.

8. CURRENT PLANNING INSTRUMENTS AND LEGISLATION

8.1. National Provisions – Building Code of Australia

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

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event. The Standard provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event. Flood hazard areas are identified by the relevant State/Territory or Local Government authority.

The BCA is produced and maintained by the Australian Building Codes Board (ABCB), and given legal effect through the *Building Act 1975,* which in turn is given legal effect by building regulatory legislation in each State and Territory. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must therefore be read in conjunction with that legislation.

8.2. State Provisions

8.2.1. EP&A Act 1979

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

8.2.2. Ministerial Direction 4.3

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

> *(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and*
>
> *(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.*

Various clauses within Direction 4.3 provide additional legislation in regards to development on the floodplain. This includes restrictions that do not allow for development in the floodway, flood impacts on adjoining properties, and development intensification within the flood planning area.

8.2.3. 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.

8.2.4. Planning Circular PS 07-003

Planning Circular PS 07-003 provides advice on a package of changes concerning flood-related development controls for land above the 1% AEP flood and up to the Probable Maximum Flood (PMF).

Councils can make an application to the DoP for exceptional circumstances for the inclusion of a Floodplain Risk Management Clause in the LEP, as per Planning Circular PS 07-003. This can be useful for areas where there are significant increases in flood risk associated with increased flood magnitude above the 1% AEP event. Some Councils, where this is an issue, choose to prohibit sensitive land uses below the PMF.

Both Gosford and Wyong Council LEPs have Floodplain Risk Management Clauses allowing for flood related development controls to be applied up to the level of the PMF. In both LEPs, these

controls only restrict sensitive development types.

8.2.5. Section 10.7 (formerly Section 149) Planning Certificates

Section 10.7 Planning Certificates are issued in accordance with the EP&A Act 1979. They contain information on how a property may be used and the restrictions on development. A person may request a s10.7 certificate to obtain information about his or her own property but generally a s10.7 certificate will be requested when a property is to be redeveloped or sold. When land is bought or sold the Conveyancing Act 1919, requires that a Section 10.7 Planning Certificate be attached to the Contract for Sale.

Most councils' Planning Certificates are issued under Section 10.7 (2) and 10.7 (5) of the EP&A Act 1979. A separate request can be made for a Section 10.7 (2) Certificate which confirms whether complying development may be carried out under the State Environmental Planning Policy 2008 (Exempt and Complying Development). Information to be disclosed on a Section 10.7 (2) Planning Certificate is specified under the Environmental Planning and Assessment Regulation 2000 (Schedule 4) and includes the following where relevant:

- Names of relevant planning controls i.e SEPP's, LEP's, REP's, DCP's;
- Declared State Significant Developments;
- Zoning and land uses under the planning control;
- Critical habitat;
- Heritage Information;
- Land reserved for acquisition;
- Coastal Protection;
- Mine subsidence;
- Road widening and road realignment;
- Council and other public authority policies on hazard risk restrictions (including flooding);
- Section 94 Contributions Plans.

8.3. Local Provisions

Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments are used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. 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 control development on flood prone land. 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 9.4.7).

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 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.

Wyong Shire Council's LEP was adopted in 2013, and Gosford City Council in 2014. Both were prepared under the Standard Instrument LEP program.

8.3.1. Central Coast Council Merger – Integration of Flood Controls

The May 2016 merger of Wyong and Gosford Councils will require the integration of Councils' planning polices, including the LEPs and DCPs. Advice on how the integration of these planning policies is best achieved is outside of the scope of the current study. It is recommended that Council engage a specialist planning consultant to prepare advice for integration of the Wyong and Gosford LEP/DCP.

The following sections describe the plans/policies adopted by the respective Councils prior to the amalgamation.

8.3.2. Wyong Shire Council Local Environment Plan 2013 (WLEP 2013)

Clause 7.2 of WLEP 2013 relates to flood planning and states:

7.2 Flood planning

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

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

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

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

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

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

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

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

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

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

Clause 7.3 relates to flood risk management and states:

7.3 Floodplain risk management

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

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood.

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) air strips,
(b) air transport facilities,
(c) child care centres,
(d) correctional centres,
(e) educational establishments,
(f) electricity generating works,
(g) emergency services facilities,
(h) group homes,
(i) helipads,
(j) home-based child care,
(k) hospitals,
(l) hostels,
(m) public utility undertakings,
(n) respite day care centres,
(o) (Repealed),
(p) seniors housing,
(q) sewerage systems,
(r) water supply systems.

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

8.3.3. Gosford City Council Local Environment Plan 2014 (GLEP 2014)

Clause 7.2 of GLEP 2014 relates to flood planning and is the same as that presented in Wyong Council's LEP. GLEP2014 also includes the same 7.3 Floodplain Risk Management clause, however it is slightly different, stating:

7.3 Floodplain risk management

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

(a) in relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding in events exceeding the flood planning level,

(b) to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

(2) This clause applies to land between the flood planning level and the level of a probable maximum flood, but does not apply to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood plus 0.5 metre freeboard..

(3) Development consent must not be granted to development for the following purposes on land to which this clause applies unless the consent authority is satisfied that the development will not, in flood events exceeding the flood planning level, affect the safe occupation of, and evacuation from, the land:

(a) caravan parks,

(b) correctional facilities,

(c) emergency services facilities,

(d) group homes,

(e) hospitals,

(f) residential care facilities,

(g) tourist and visitor accommodation.

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

8.3.4. Wyong Shire Council Development Control Plan 2013

Chapter 3.3 of the Wyong Shire Council DCP deals with floodplain management. The stated objectives are:

- *To minimise the risk to human life and damage to property by controlling development on flood prone land*
- *To apply a performance and merit based approach to all development decisions taking into account ecological, social, engineering safety and environmental considerations to ensure development is appropriate and sustainable*
- *To ensure that the development or use of floodplains waterways and riparian corridors does not adversely impact upon aesthetic, recreational and ecological values*
- *To ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods*
- *To promote flood compatible building design that considers requirements for the development of flood prone land and does not adversely impact on adjoining properties*
- *To establish guidelines for the development of flood prone land that are consistent with the NSW Flood Policy and NSW Floodplain Development Manual (2005) and as updated by the associated Floodplain Risk Management Guides*

The DCP stipulates development controls based on the risk precinct (four precincts defined by flood risk) and land use, provided in a matrix replicated in part below. These consider planning aspects such as minimum floor levels, structural considerations, emergency access and egress requirements, impacts of the development on others, etc.

Proposed Land use	Precinct 1 FPL to PMF	Precinct 2 Below FPL	Precinct 3 Flood Storage and Flow Paths (up to 10% AEP)	Precinct 4 High Hazard (up to 50% AEP)
1 Single Dwelling Houses		1, 9	2, 5, 7	
2 Agriculture & Recreation		2	2, 5, 7	
3 Sheds / Garages / ancillary Residential		1	2, 5, 7	
4 Commercial and Industrial Uses		2, 6		
5 Medium to High Density Residential				
6 Critical or Sensitive Facilities	3			
7 Land Subdivision	4			
8 Tourist Development				
9 Caravan parks - short-term sites		6	5, 6	
10 Permissible Earthworks		8		

Flood related development controls do not apply

Flood related development controls apply (refer to numbered prescriptive criteria below)

If the proposal is to be pursued further, a performance based assessment is to be provided demonstrating that the proposed development is compatible with the flooding characteristics of the site (refer to Section 3.2 and Appendix C of the DCP).

In addition, the DCP stipulates general requirements for fencing, car parking, fill, on-site sewer management, and storage of hazardous substances. Appendix B of the DCP provides a table of flood compatible materials based on the building component.

8.3.5. Gosford City Council Development Control Plan 2013

Section 6.7.7.6 provides details of the flood targets for the LGA, with the objectives stated as:

- *To reduce private and public losses resulting from floods.*
- *To enable safe access or evacuation of people to the existing public road network during flooding.*
- *To maintain the existing flood regime and flow conveyance capacity.*
- *To avoid significant adverse effects on the floodplain environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of any river bank or watercourse.*
- *To limit land uses to those compatible with flow conveyance function and flood hazard.*

A Flood Control Target Matrix (partially shown below) is provided which stipulates varying controls based on land use. Additional information is also provided for subdivisions, parking and fencing. The chapter also states that:

> *'If the subject land falls within the area of an existing Floodplain Risk Management Plan then the development must comply with specific conditions of the plan.'*

Table 4 Flood Control Target Matrix

Development	Development Types					
Control Targets	Pools & Spas	Residential Buildings (Rural)	Residential Buildings (Urban)	Group homes, seniors housing, emergency facilities	Commercial, Industrial	Subdivisions (Urban & Rural)
Floor levels	-	B	B	A	B	-
Flood Impacts	C	C	C	C	C	C
Subdivisions	-	-	-	-	-	D
Access & Parking	-	E	-	F	E	E
Fencing	-	G	G	G	G	G

9. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to manage flood risk and reduce flood damages. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the Ourimbah Creek catchment.

It should be noted that cost estimates have been provided for the various options outlined below. These cost estimates are indicative only and typically only provide an order of magnitude estimate for the comparison of various options.

9.1. 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 (denoted as 'Option FM', Section 9.2)** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical. On site detention is used to mitigate the increase in peak flow from a site resulting from changing the land type from pervious cover to impervious cover. However it is not possible to reduce flood levels in a large river system such as Ourimbah Creek through on site detention.

- **Response modification measures (denoted as 'Option RM', Section 9.3)** 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.

- **Property modification measures (denoted as 'Option PM', Section 9.4)** 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.

Table 16 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 Ourimbah Creek catchment and have not been recommended.

Table 16: Floodplain Risk Management Measures

Flood Modification	Property Modification	Response Modification
Levees	Land zoning	Community awareness
Temporary defences	Voluntary purchase	Flood warning
Channel construction	Building & development controls	Evacuation planning
Channel modification	Flood proofing	Evacuation access
Major structure modification	House raising	Flood plan / recovery plan
Drainage network modification	Flood access	
Drainage maintenance		
Retarding basins		

Figure 1a to l indicates where localised management measures have been considered in detail and described in the various sections below.

9.2. Flood Modification Measures Considered

All flood modification measures investigated in detail are listed below.

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);
- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3)
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5);
- Option FM6 – Canntree Road Levee (Section 9.2.1.6);
- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7);
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1);
- Option FM9 – Lees Bridge Widening (Section 9.2.5.1);
- Option FM10 – Footts Road Weir Removal (Section 9.2.5.2);
- Option FM11 – Upstream Pacific Motorway Vegetation Management Area (Section 9.2.6.1);
- Option FM12 – Sohier Park Vegetation Management Area (Section 9.2.6.2);
- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1);
- Option FM14 – Combined Channel and Basin (Section 9.2.8).

9.2.1. Levees and Filling

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water

behind the levee.

Localised levees or bunding can be applied around individual properties. Such measures are considered minor property adjustments and are discussed in Section 9.4.3.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis for erosion or failure. Although a levee can keep out flood waters, flooding can occur within the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed using hydraulic modelling techniques so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event, wave action from passing vehicles or watercraft and effects of wind.

OPTIONS CONSIDERED

The community consultation questionnaire (see Section 4.1) indicated that residents were interested in the implementation of levees or filling at various locations in the catchment including:

- Option FM1 – East Chittaway Point Levee (Section 9.2.1.1);
- Option FM2 – Bangalow Creek Levees (Section 9.2.1.2);
- Option FM3 – Mill Street Industrial Area Levee (Section 9.2.1.3);
- Option FM4 – University Lower Carpark Levee (Section 9.2.1.4);
- Option FM5 – University Lower Carpark Filling (Section 9.2.1.5)
- Option FM6 – Canntree Road Levee (Section 9.2.1.6).

Details for each of the above listed levees are provided in the following sections. Additionally, the survey and maintenance of existing levees is discussed in:

- Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance (Section 9.2.1.7).

9.2.1.1. Option FM1 – East Chittaway Point Levee

Levees situated adjacent and parallel to Ourimbah Creek at Chittaway Point were investigated on both the southern and northern sides of the Creek. Levees were found to be not suitable for flood mitigation at Chittaway Point for a variety of reasons:

- Flooding in Chittaway Point can be due not only to Ourimbah Creek but elevated levels in Tuggerah Lake. Levees would need to be designed to stop both sources of flooding and would therefore be required to protect from flooding from two directions requiring long ring levees;
- As both sides of floodplain would be denied by the levees, increases in peak flood level upstream and in the channel would be significant and the required design height of the

levees would need to be approximately 2 m above surrounding ground level. If constructed out of compacted earth the base width of the structure would be between 10m and 20m, thus requiring a considerable amount of space. Though this could be reduced if a concrete wall or similar narrower "wall" type structure was created;

- The total length of both levees would be +10 km, largely constructed on private land;
- Due to the height and length of the levees and the need for acquisition of private land, the cost of construction of the levees would be extremely expensive (estimated to be in the order of +$150 million); and
- Many land holders may not wish to have a levee constructed in their backyard due to the impact on views and a reduction in the amenity provided by Ourimbah Creek.

Due to the significant cost of construction and the impact on resident's views and the amenity of Ourimbah Creek, consideration of Option FM1 has not been investigated further.

9.2.1.2. Option FM2 – Bangalow Creek Levees

Option FM2 examined various levee alignments in Bangalow Creek as recommended by respondents as part of the community questionnaire. No suitable location for implementation of a levee was identified in this area for the following reasons:

- Properties are widely distributed, meaning that any benefit created by a levee only benefits a small number of properties;
- The majority of properties in this area are not flooded over floor until the PMF event which indicates relatively minor flood affectation;
- The wide distribution of properties and low flood affectation indicate that any expensive works, such as a levee (+$2 million) would have a poor Benefit/Cost (B/C) ratio; and
- Leveeing the Bangalow Creek floodplain would lead to significant increases in peak flood levels in surrounding areas which can impact on properties situated outside of the levee.

No suitable location to construct a levee on Bangalow Creek was identified. Accordingly, Option FM2 has not been investigated further.

9.2.1.3. Option FM3 – Mill Street Industrial Area Levee

The community questionnaire indicated that community members were interested in investigating the construction of a ring levee surrounding the Mill Street industrial area. The model results indicate that a levee with an average height of 1 m (inclusive of a 0.5 m freeboard) would provide protection in the 1% AEP event.

Option FM3 was modelled for the 1% AEP event with the peak flood level impacts presented in Figure D 1. The modelled Option FM3 ring levee removes flood affectation for the Mill Street industrial precinct, however causes increased flood levels on the floodplain (up to 0.3m upstream). Minor increases in flood level affect residential properties on Bristowe Close to the south-east. However the majority of the affectation is within the heavily vegetated riparian corridor where there is no development. The levee does not "block" the flow path as much as expected as there is already a significant impediment due to the existing buildings and the long

axis of the levee is aligned parallel with the flow path.

The other major problem with this levee is access to each property across the levee. A 1.5m high levee requires a 1:6 grade for vehicle access with say a 2m wide crest. Thus 20m extent of land is required for access. This is impossible to achieve for each of the six individual properties. Possible solutions could be to allow only one access point and each property would provide an access easement for the other properties and/or reduce the levee with construction of a solid concrete wall.

The Option FM3 levee provides benefits to industrial properties whilst causing minor increases in flood affectation for residential properties. As the levee only protects non residential properties it is likely that significant owner funding will be required as the state government's program is more focussed on residential mitigation measures. This measure should be presented to the property owners and their support obtained before further investigation of Option FM3 is investigated further.

This levee would become a flood free island protecting the property inside. However this could potentially increase the risk to life if owners decided to stay within the leveed area and either had to be rescued or chose to attempt to evacuate themselves.

9.2.1.4. Option FM4 – University Lower Carpark Levee

As part of the Stakeholder consultation, the University of Newcastle (see Section 4.2.3) noted that the two lower carparks at the Ourimbah Campus are frequently flood affected. The issue of flooding of the southern carpark near Shirley Street could potentially be addressed by raising The Boulevard which could also improve flood access to the University. Further details are presented in Section 9.3.1.4.

To mitigate flooding of the northern carpark a levee could be constructed to protect parked cars and to remove the risk of people trying to rapidly exit the carpark during times of flood. Option FM4 modelled the construction of a levee to protect the northern carpark. A levee with an average embankment height of 2.5 m above surrounding ground level (inclusive of 0.5 m freeboard) and a length of 200 m could be used to achieve flood protection in the 1% AEP event. A significant issue with this option is the width of an earthen levee would exceed 15m. An alternative might be a concrete wall.

Option FM4 was modelled for the 1% AEP event with the peak flood level impacts presented in Figure D 2. The modelled levee alignment protects the carpark and produces no adverse effects on the surrounding floodplain.

An indicative construction cost of the levee is $200,000 (may be more if a concrete wall construction) which would be funded by the University of Newcastle. A smaller design event could be selected to inform the design height of the levee to save on the cost of construction. A levee should only be constructed in conjunction with monitoring of creek levels, using the proposed gauge described in Section 9.3.3.2. Levees do have the potential to increase flood risk if they become overtopped. Failure of a 2.5 m levee would pose a significant risk to life to

anyone in the carpark at that time. If the design height of the levee is approached, university security should be notified to man the carpark, and the carpark closed, once a threshold is reached. There is also the risk of levee failure before overtopping occurs.

A B/C ratio for this measure and for filling (Section 9.2.1.5) is impossible to accurately estimate as this requires data on the likelihood of cars being left in the car park during a flood as most are removed once the owners become aware of the flood risk. Cars are also insured for damage in floods if comprehensively insured.

A more reasonable approach to reducing flood affectation of the carpark may be to raise the entire carpark. This is discussed in Section 9.2.1.5.

9.2.1.5. Option FM5 – University Lower Carpark Filling

Option FM5 has been examined with the aim of achieving the same objective as Option FM4, i.e. the protection of the lower University carpark. Filling of the carpark, rather than a levee, would remove the risk of levee overtopping failure as well as issues with internal drainage.

Modelling of this option indicates that raising of the carpark will have no impacts on peak flood levels on the surrounding floodplain. The level to which the carpark is raised could again be based on a trade-off between cost of construction and the level of flood protection.

To achieve 1% AEP flood immunity the carpark would need to be raised by 2.5 m (assuming 0.5 m freeboard) which would require approximately 13,000 m³ of fill. The estimated cost of construction is $400,000.

Option FM5 is recommended for further investigation through detailed costing and design as it would reduce the risk to life and damages to vehicles. However whilst the impacts of filling are minimal, filling of the floodplain is generally not supported as approval for this amount of filling may establish a precedent for approvals for other floodplain filling activities. This filling also does not address the cumulative effect of filling adjoining areas of the floodplain which might increase flood levels above allowable limits. The assessment of the cumulative effect of filling floodplains is required under Council's development controls. This is one of the reasons why Council has previously rejected applications by the University to fill the land. This issue would need to be resolved initially before further detailed investigation is undertaken. A possible solution is to raise the main carpark to above the 1% AEP flood level and only raise the lower/overflow carpark to a lower level flood event thereby reducing the amount of filling. Appropriate warning signs could indicate the level of flood risk to each carpark.

9.2.1.6. Option FM6 – Canntree Road Levee

Examination of the design results indicates that in events larger than the 1% AEP floodwaters overtop Wyong Road to the north of Lees Bridge, creating a new flow path through the area to the east of Canntree Road. This breakout affects numerous residential properties as well as a proposed development site and is subject to high hazard flows (H5 and H6, see Section 6.2) in the PMF. Areas of these hazard classifications pose a significant risk to life and structures in a

large flood event. A levee at this location could potentially prevent floodwater from overflowing Wyong Road and Canntree Road and affecting the land north of Oscar Drive.

The implementation of a levee to stop flow passing through this area has been investigated. The Option FM6 levee was modelled and extends 250 m north from the Wyong/Geoffrey Road roundabout. The levee was designed for the 0.5% AEP event and was required to be on average 1.0 m higher than the Wyong Road crest height (1.6 m above surrounding ground level) including 0.75 m freeboard. An indicative cost of construction is $250,000 assuming that the levee does not require works to be undertaken on Wyong Road. The reduction in AAD associated with Option FM6 is $2,000, indicating a B/C ratio of 0.1.

Figure D 3 presents the impact on peak flood levels with implementation of Option FM6 for the 0.5% AEP event. Option FM6 ameliorates 0.5% AEP flood affectation for properties downstream, however leads to significant increases in flood levels (up to 0.2 m) and flood affectation upstream.

The construction of the levee described above does not provide protection from a full range of design events, with floods larger than the 0.5% AEP still posing a risk to properties downstream. To protect these properties up to the level of the PMF, a levee with an embankment 4 m above surrounding ground level would be required. A levee to the PMF would remove the high velocity flows for all events in the area thus significantly reducing risk to life, however would not ameliorate flood affectation due to flooding of the area by Ourimbah Creek flows downstream of Lees Bridge. An indicative cost of construction for a levee designed to not be overtopped in the PMF is $750,000, however there would be no reduction in AAD as downstream properties would still be flooded. The reduction in flood hazard and associated risk to life cannot be monetised.

Due to the increased flood affectation for properties upstream of Wyong Road and the poor B/C ratio, Option FM6 is not recommended and has not been considered further.

There is the potential that land downstream may be developed as a residential subdivision and this levee has been suggested for flood protection. Whilst this may be cost effective for the land developer it raises the question whether a levee should be used for this purpose. In general levees are constructed to mitigating existing flood damages and risk to life but not to support new development in the floodplain. For this reason some councils in NSW have a policy that new developments must meet the pre-levee design flood levels for construction and development approval.

9.2.1.7. Option FM7 – Tuggerah Business Park Levee and Railway Levee Survey and Maintenance

The existing Tuggerah Business Park and Main Northern Railway Line Levees (see Section 6.5.1) require ground survey to identify low points that reduce the protection afforded by the levee. It is recommended that once the low points are identified maintenance to formalise the levee be undertaken as well as development of a levee management plan.

RECOMMENDATIONS

► Undertake detailed costing and design of filling the University of Newcastle Ourimbah Campus lower carpark (Option FM5, see Section 9.2.1.5).

► Undertake ground survey and maintenance works for existing levees within the catchment (Option FM7, Section 9.2.1.7) and development of a levee management plan.

9.2.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding.

DISCUSSION

Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the ability of a workforce to install. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times.

RECOMMENDATIONS

► In the Ourimbah Creek catchment, demountable defences are not suitable to be used to reduce flood risk and inundation, due to the lack of suitable locations for their placement and insufficient available warning time (see Section 9.3.3).

9.2.3. Channel / Floodway Construction

DESCRIPTION

Channels or floodways can be an effective way to transfer and confine flow in a flooding situation and can aid in reducing peak flood levels, extents and duration.

DISCUSSION

Locations for potential drainage and diversion channels were investigated as potential mitigation measures. Option FM8 was identified and found to provide some benefit in terms of reduced flood levels.

9.2.3.1. Option FM8 – Baileys Road Diversion Channel

Option FM8 investigated the construction of a 1.5 m deep by 16 m wide diversion channel parallel and to the east of Main Northern Railway Line, aimed at diverting a portion of flow north from Cut Rock Creek before it crosses west through the Pacific Highway towards Lisarow Street. The invert of the diversion channel was modelled at approximately 1.8 m below the creek top of bank.

Option FM8 was modelled for the 1% AEP event with the peak flood level impacts presented in

Figure D 4. Option FM8 reduces 1% AEP peak flows through the Lisarow Street area and upstream at the Tall Timbers estate (key areas described in the Brief, see Section 2.3). The reduction in flow leads to a decrease in peak flood level of up to 0.3 m, however widespread increases in peak flood level are experienced downstream of the diversion channel.

An indicative cost of implementation of Option FM8 is $400,000, with the Option providing little in terms of reductions to AAD (B/C < 0.1). The concept design modelled the Option FM8 channel in the rail easement, however liaison with Transport for NSW indicated that this is not feasible. The location of Baileys Road does not allow enough room for construction of the channel outside of the rail easement.

For the reasons described above, Option FM8 is not feasible and has not been investigated further.

RECOMMENDATIONS

► No channel construction works are proposed.

9.2.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/drainage system. This includes a range of measures from straightening, concrete lining, removal / augmentation of structures, dredging and vegetation clearing. Channel modifications may reduce flood levels at the location of the works but need careful planning to ensure that the flood risk is not exacerbated downstream.

DISCUSSION

The community consultation questionnaire highlighted a desire by members of the community for the investigation of increasing channel capacity by straightening and widening creek channels throughout the study area. In particular, numerous residents noted various works to modify the conveyance characteristics of the entrance to Tuggerah Lakes. Modification of the entrance has been examined in numerous previous studies and shown to be ineffective in reducing property flood affectation (see Section 3.2.4). Further investigation of this issue is outside the scope of the current study.

Considering the above, the following locations were identified where channel straightening could be implemented to increase conveyance:

- Cut Rock Creek downstream of Burns Road;
- Cut Rock Creek downstream of Teralba Street; and
- Canada Drop Down Creek downstream of Palmdale Road.

These locations were modelled to investigate the impacts of undertaking channel straightening works. It was found that channel modification is unsuitable for reducing flood affectation for a variety of reasons, including:

- Modelled reductions in peak flood levels were minor (< 0.2 m) and did not benefit developed land;
- The benefits associated with localised decreases in flood level were offset by increases in flood levels in areas downstream; and
- The environmental cost of modifying these natural channels is significant and is generally not able to be achieved due to stringent environmental policies.

Due to the reasons described above, channel straightening was found to be not feasible and has not been pursued further.

RECOMMENDATIONS

► Channel modification measures were shown to provide little benefit to developed land and led to increased flood affectation in the downstream. Additionally, environmental impacts are likely to be significant. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.5. Major Structure Modification

DESCRIPTION

Hydraulic controls such as bridges or major culverts on significant waterways can affect upstream flood levels due to backwatering effects. By increasing hydraulic conveyance, flood levels upstream of a structure can be decreased. Generally the most effective way of increasing hydraulic conveyance is by increasing the cross-sectional area (normal to the flow direction). This is often done by widening a bridge or raising the deck level.

DISCUSSION

Specific structures noted by Council and the community have been investigated in the following sections.

The addition and modification of various structures could potentially be implemented to improve flood access. Some preliminary concept designs have been investigated in Section 9.3.1. These structures have generally been designed such that roads can be raised to provide better flood access whilst having minimal impact on design flood levels. Accordingly, the structures investigated as part of the improved flood access roads are not described further in this section as they are not considered as flood modification measures (see Section 9.1).

9.2.5.1. Option FM9 – Lees Bridge Widening

As described in Section 9.2.1.6, events larger than the 1% AEP flood overtop Wyong Road to the north of Lees Bridge creating a new flow path through the area to the east of Canntree Road. This breakout affects residential properties and is categorised as high hazard flow (H5 and H6, see Section 6.2) in the PMF.

In an attempt to reduce the flow passing through this area, Lees Bridge, the existing bridge at the Wyong Road crossing of Ourimbah Creek was investigated. Option FM9 investigated

doubling the width of the existing bridge to 160 m by removing the approach embankments. It was thought that by increasing the conveyance capacity of Lees Bridge, upstream flood levels would be lower, leading to less flow breaking out and flowing through the area to the east of Canntree Road.

Figure D 5 presents the impact on peak flood levels with implementation of Option FM9 for the 0.5% AEP event. Option FM9 significantly reduces peak flood levels upstream of Lees Bridge which stops flow from overtopping Wyong and Canntree Roads to the north, thus reducing flood risk and affectation in this area. However, downstream of Lees Bridge peak flood levels are increased and a number of previously non flood affected properties become flood affected.

Due to the increased flood affectation for properties downstream of Lees Bridge, Option FM9 is not recommended and has not been considered further.

9.2.5.2. Option FM10 – Footts Road Weir Removal

The community questionnaire (see Section 4.1) noted that the weir at Footts Road was of concern to residents. To investigate the impact that the weir has on peak flood levels, the 20% AEP and 1% AEP flood events were modelled with the weir removed. It was found that removing the weir has no impact peak flood levels for either event. The weir potentially impacts on peak flood levels for events smaller than the 20% AEP, however these events have not been investigated as part of this FRMSP.

No changes to the Footts Road weir are recommended as the structure does not affect peak flood levels from the 20% AEP and larger.

RECOMMENDATIONS

► No modifications of existing major structures were identified as suitable for flood mitigation in the study area. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.6. Drainage Maintenance

DESCRIPTION

Maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce the risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. For natural channels, such as those situated in the Ourimbah Creek catchment, environmental legislation, land ownership and funding limits any opportunities for creek clearing and vegetation management.

DISCUSSION

The community questionnaire (see Section 4.1) highlighted the community's concerns about creek channel maintenance in relation to both structure and creek channel blockage.

Structure Blockage

Blockage of structures throughout the Ourimbah Creek catchment has been mentioned by the community questionnaire respondents. Structure blockage can be improved with the introduction of maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. These policies aim to ensure that assets will perform when they are needed. Alternatively the implementation of trash racks or bollards (to prevent cars or large debris entering creeks) upstream of structures could be considered by Council to keep structures free of debris. The cost of trash racks or bollards varies greatly depending upon the nature of the structure. An indicative cost is $5,000 to $20,000 per item and examples are provided in Image 6. The concept is to direct debris above the culvert or over the road in the second example below. In the latter the pedestrian railing is held by bolts which are designed to shear under the force of debris and water and so collapse preventing damage to the railing and allowing quick re-installation.

Image 6: Example of Structures to Reduce Blockage of a Culvert

Creek Channel Maintenance

Clearing of the creek channel to increase flow conveyance was also recommended by the community. This was investigated using the hydraulic model with the channel roughness reduced to simulate channel clearing through vegetation management. The Mannings 'n' values of the creek channel reduced by 0.03 may be achievable through vegetation management. It was found that peak flood levels reduced by up to 0.5 m, however peak flood levels downstream of the Pacific Motorway generally increased by ~0.1 m.

Large scale clearing of the creek channel is not possible, however isolated areas of channel maintenance could be achieved. Two locations were identified where vegetation management could provide significant reductions to upstream peak flood levels:

- Option FM11 - Upstream Pacific Motorway vegetation management area; and
- Option FM12 - Sohier Park vegetation management area.

Details of both of these investigated vegetation management Options are presented in the following sections.

9.2.6.1. Option FM11 – Upstream Pacific Motorway Vegetation Management Area

The Option FM11 area is situated on Ourimbah Creek upstream of the Pacific Motorway and required the maintenance of 20 hectares of densely vegetated land, represented by the red polygon in Image 7.

Image 7: Option FM11 - Modelled Extent of Vegetation Management (Mannings reduced)

Image source: Google Earth

The 10% and 1% AEP events were modelled with the reduced roughness implemented and the results were compared to the design results. It was found that channel clearing and vegetation management associated with Option FM11 is not suitable as a mitigation option for the following reasons:

- Increased peak flood levels downstream were found to adversely affect residential properties;
- Areas which experienced significant decreases in peak flood levels were typically still flooded by depths in excess of +2 m, even in the 20% AEP event;
- Little benefit was experienced in terms of reductions in over floor flood liability;
- The environmental cost of clearing a natural channel is significant;
- Clearing of native vegetation is generally not able to be achieved due to environmental policies;
- Vegetation management would need to be ongoing and would have significant long term annual costs (+$25,000 / year);
- OEH noted that this area has an ongoing vegetation regeneration program which is in conflict with clearing vegetation; and
- Much to this land is private property and Council does not have the right to undertake these works.

9.2.6.2. Option FM12 – Sohier Park Vegetation Management Area

Option FM12 modelled the impact of creek clearing and vegetation management of Bangalow Creek near Sohier Park. Option FM12 required the maintenance of 3 hectares of densely vegetated land, represented by the red polygon in Image 8.

Image 8: Option FM12 - Modelled Extent of Vegetation Management (Mannings reduced)

Image source: Google Earth

The 1% AEP event was modelled with the reduced roughness implemented and the results were compared to the design results. It was found that whilst decreases in peak flood level of up to 0.2 m were achieved, no properties benefited from these works. Council also noted that much of this land is private property and Council does not have the right to undertake these works without the negation of land purchase or an easement.

Due to the issues highlighted above, Option FM12 is not recommended for implementation.

RECOMMENDATIONS

► Large scale clearing of the creek channel for flood mitigation purposes is not recommended due to a lack of significant benefits achieved and due to significant economic and environmental costs.

► Previously Gosford City Council introduced vegetation and silt management schemes throughout its completed flood mitigation works. These should be maintained and expanded where possible. However it is acknowledged that these schemes are costly for Councils to operate and must be continued forever to be effective. These schemes are welcomed by the residents.

9.2.7. Retarding Basins

DESCRIPTION

Retarding basins work by storing and controlled release of runoff after the event peak. These measures are appropriate for use in controlling flooding by mitigating the effects of increased

runoff caused by development and can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to alleviate existing flood problems.

DISCUSSION

Retarding basins can significantly reduce peak flows and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Large retarding basins can be a safety hazard. Appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

The community questionnaire respondents (see Section 4.1) requested that retarding basins be examined for various locations in the study area. Retarding basins were typically not found to be suitable for flood mitigation in the catchment for the following reasons:

- Local topography was not suitable for construction of a basin (the majority of locations fell into either of these two categories);
    - If the floodplain is too narrow and steep, a basin's embankment must be excessively high in order to achieve enough volume behind the embankment to attenuate the flood peak; or
    - If the floodplain is too wide, the basin wall must be excessively long (i.e. the width of the floodplain) to form a basin.
- The basin volume must be large enough such that it can attenuate flows for the upstream catchment. Basins with a large upstream catchment area must be very large to have enough volume to attenuate the flood peak. This can lead to an excessively large area of new flooded land within the basin; and
- The location of a basin should not be such that increased flood levels affect sensitive land uses (i.e. residential properties) within the basin.

Taking the above into account, only one location (Option FM13) was trialled to test suitability for implementation of a basin.

9.2.7.1. Option FM13 – Cut Rock Creek Basin

Option FM13 modelled the implementation of a basin on Cut Rock Creek in the area situated upstream of Cutrock Road. The existing road alignment currently acts as a basin with the road forming a barrier leading to the attenuation of flows that do not over top the road. The Option FM13 basin raises the existing road alignment by 1.5 m on average (including 0.5 m freeboard) over a length of 750 m. The existing culverts under Tuggerah Street (2 x 1.05 m Ø and 1 x 0.9

m Ø) and Cutrock Road (2 x 1.2 m Ø) were not modified.

Option FM13 was modelled for the 1% AEP event with the impact on peak flood levels presented in Figure D 6. Option FM13 reduces 1% AEP peak flood levels by up to 0.1 m downstream of the basin which benefits properties at the Tall Timbers estate and on Lisarow Street (key areas mentioned in the Brief for analysis, see Section 2.3). However, these benefits are minor when considering over floor flood affectation as the majority of properties in these areas are not flooded over floor until events larger than the 0.5% AEP.

An indicative cost of implementation of Option FM13 is estimated to be $4.8 million. The reduction in AAD associated with Option FM13 is $1,000, indicating a B/C ratio of less than 0.1. Due to the low B/C ratio Option FM13 is not recommended, however this basin also serves to improve flood access (see Section 9.3.1) by providing flood free access in the 1% AEP event for areas to the east of Cut Rock and Bangalow Creeks. Raising of this section of road to improve flood access may be beneficial as a risk mitigation method and is examined further in Section 9.3.1.2.

A preliminary concept design for Option FM13 is contained in Appendix E.

RECOMMENDATIONS

► Retarding basins were not found to be suitable for flood mitigation in the study area.

► However, Option FM13 has been considered for further investigation in combination with Option FM8 (see Section 9.2.3.1) to examine if this could achieve improved reductions in peak flood levels downstream. The combined Option FM13 / FM8 is investigated as Option FM14 in Section 9.2.8.

9.2.8. Option FM14 – Combined Channel and Basin

DESCRIPTION

Various flood mitigation measures were investigated to reduce flood affectation in the Ourimbah Creek catchment. No single flood mitigation works was found to be suitable and accordingly combinations of the previously mentioned Options have been investigated. Option FM14 was investigated as the combination of two options, namely:

- Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1); and
- Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1).

DISCUSSION

Option FM14 aimed to reduce flood affectation of properties at the Tall Timbers estate and for Cut Rock Creek between the Pacific Highway and Teralba Street (key areas mentioned in the Brief for analysis, see Section 2.3). A preliminary concept is provided in Appendix E (Figure E 2).

The reduction in peak flood level associated with modelling of Option FM14 for the 1% AEP event is presented in Figure D 7. Results indicate that the combination of these Options significantly reduces flood levels. However, these benefits are generally minor when

considering over floor flood affectation as the majority of properties in these areas are not flooded over floor until events much larger than the 0.5% AEP.

Table 17 presents the benefits that Option FM14 provides in terms of reduced property flood affectation (yard and above floor) and the associated reduction in damages. Property yard inundation is significantly reduced with implementation of this Option with 16 fewer yards inundated during the 1% AEP event, however as noted, reductions in over floor flood liability is limited.

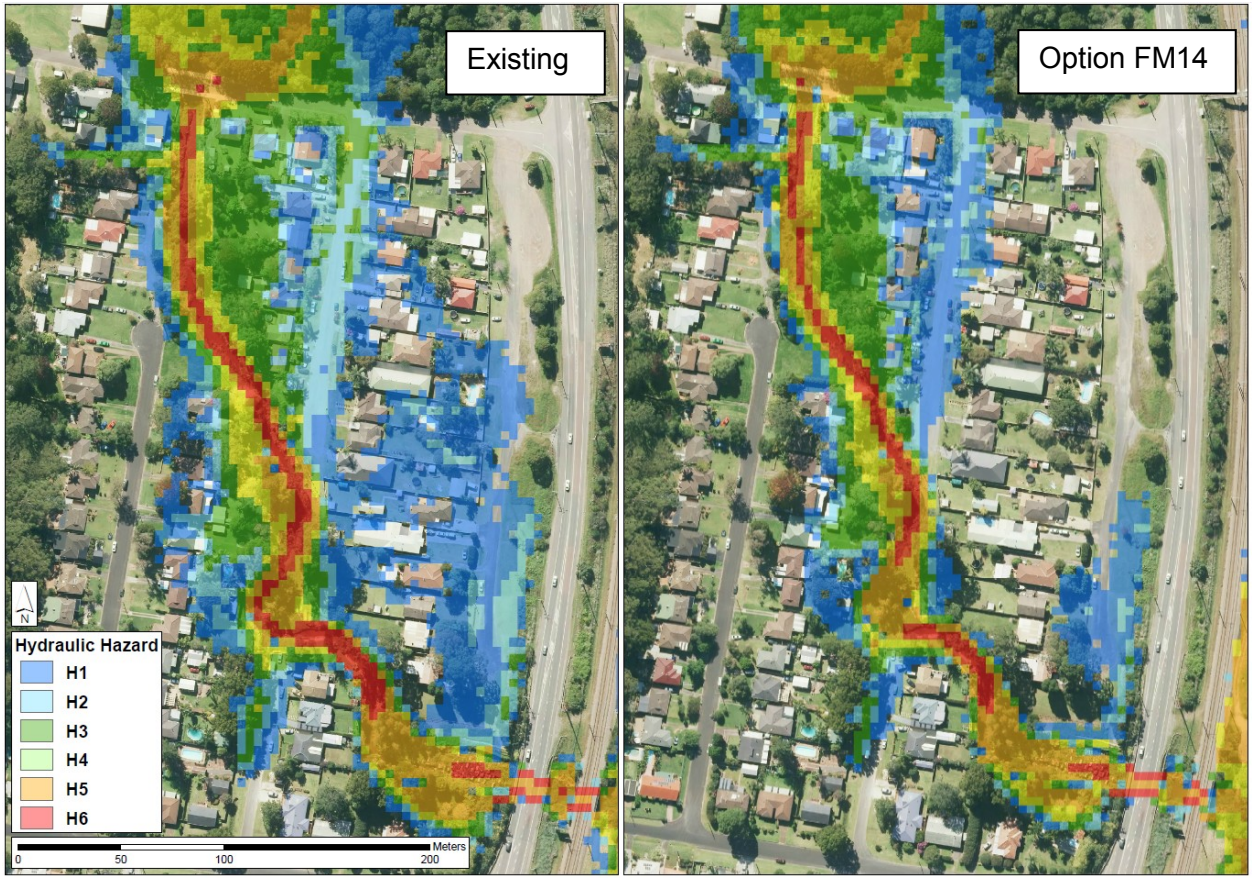
Table 17: Option FM14 – Reduction in Property Flood Affectation and Flood Damages

Event	No. Properties No Longer Flooded	No. of Properties No Longer Flooded Over Floor	Reduction in Damages for Event
20% AEP	2	0	$ 4,000
10% AEP	9	0	$ 24,000
5% AEP	13	0	$ 53,000
2% AEP	11	1	$ 67,000
1% AEP	16	1	$ 208,000
0.5% AEP	24	3	$ 331,000
PMF	-	-	$ 0
Average Annual Damages (AAD) Reduction			**$ 9,000**

The damages assessment was undertaken to determine the B/C ratio for implementation of Option FM14. An indicative cost of implementation of the Option FM14 is estimated to be $5.0 million, with the Option expected to provide a $9,000 reduction in AAD. By estimating the expected damages for the next 50 years assuming implementation of this Option a B/C ratio of 0.1 has been calculated indicating that the option is financially unfeasible.

Whilst Option FM14 was found to not provide a monetary benefit, it does provide a reduction in risk to life. The Option FM13 embankment would significantly improve flood access (see Section 9.3.1) and implementation of the Option significantly reduces flood levels and velocities in the area surrounding Lisarow Street (a key area mentioned in the Brief for analysis, see Section 2.3). This region is currently flooded during events smaller than the 20% AEP and experiences high hazard flows (H3 and H4 classifications, see Section 6.2) during the 1% AEP flood restricting safe flood access. With implementation of this Option, flood depths outside of the channel proper are less than 0.1 m for events up to and including the 5% AEP flood. Flood hazard is also substantially ameliorated with existing 1% AEP flood hazard classifications reduced to predominantly H1 allowing safe evacuation for both pedestrians and vehicles. The reduction in flood hazard is presented in Image 9.

Image 9: Reduction in 1% AEP Hazard with Implementation of Option FM14



An analysis of flood impacts indicates that as with Option FM8, increases in peak flood level at residential properties are experienced downstream of the diversion channel.

RECOMMENDATIONS

► The increases in peak flood level to properties, coupled with the high cost of construction and low B/C ratio make Option FM14 (combination of Option FM13 – Cut Rock Creek Basin (Section 9.2.7.1) and Option FM8 – Baileys Road Diversion Channel (Section 9.2.3.1)) unfeasible.

9.3. Response Modification Measures Considered

Response modification measures aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, through improvements to emergency management capabilities, evacuation and planning, and through better flood-educated communities.

Fourteen road crossings have been investigated as indicated in Section 9.3.1 together with the following other response modification measures:

- Automatic Road Closures and Boom Gates (Option RM15) (Section 9.3.2.1);
- Warning Signs (Option RM16 and RM17) (Section 9.3.2.2);
- Camera Fines (Option RM18) (Section 9.3.2.3);
- Potential Gauges for Flood Warning (Options RM19 and RM20) (Section 9.3.3.2);
- Opportunities for Increasing Available Warning Time (Options RM21 and RM22) (Section 9.3.3.6);

- Opportunities for Reducing Required Warning Time (Options RM23 and RM24) (Section 9.3.3.7);
- Shelter-in-place Feasibility Assessment (Option RM25) (Section 9.3.3.8);
- Flood Emergency Management Planning (Options RM26, RM27, RM28) (Section 9.3.4);
- Create a SES Flood Intelligence Card for Lees Bridge (Option RM29) (Section 9.3.4.3);
- Emergency Response Plans (Options RM30 and RM31) (Section 9.3.4.4);
- Community Flood Education (Option RM32) (Section 9.3.5).

9.3.1. Improved Flood Access

DESCRIPTION

As described in Section 3.1 with details provided in Section 6.4 and on Table 11 (locations shown on Figure 1a to l), flooding of key access roads is a major concern for the study area. Flooded roads pose a significant risk to life and hinder effective emergency response. Improving flood access can significantly improve a community's response to flooding.

DISCUSSION

Improving flood access was considered throughout the catchment but was found to be unsuitable for many areas due to the following reasons:

- Many of the access roads would need to be raised in excess of 2 m over a very long distance to significantly improve flood access. For example, to provide flood free access on Ourimbah Creek Road, the road would need to be raised by 1 to 3 m for over 5 kilometres to achieve flood free access in the 20% AEP event;
- In many locations, large increases in flood levels associated with road raising can affect residential properties. Access roads in and out of Chittaway Point (Geoffrey and Chittaway Roads) as well as Palmdale Road are locations where road raising would lead to significant impacts on peak flood levels. Culvert and bridge design could ameliorate this, however implementation of sufficient structures would greatly increase costs; and
- Road construction and design would be highly expensive.

The Cut Rock Creek and Bangalow Creek floodplains were found to be most suitable for improvements to flood access roads.

Raising of key access roads could potentially improve flood access and increase the safety and trafficability of access roads to allow safe access and egress for residents to their homes. Access to the University of Newcastle Ourimbah Campus could also be improved. Improvements to flood access roads at key locations could potentially address many of the issues highlighted as part of the key stakeholder engagement and outlined in Section 2.3.

The following roads have been investigated for flood access improvements, with details for each of these locations provided in the ensuing sections:

- Option RM1 – Tuggerah Street at the Pacific Highway (Section 9.3.1.1);
- Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park (Section 9.3.1.2);
- Option RM3 – Coachwood Drive North of Mahogany Close (Section 9.3.1.3);
- Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus (Section

9.3.1.4);

- Option RM5 – Chittaway Road near Burns Road (Section 9.3.1.5);
- Option RM6 – Howes Road, Link Road (Section 9.3.1.6);
- Option RM7 – Orchard Road, Link Road (Section 9.3.1.7);
- Option RM8 – Tall Timbers, Link Road (Section 9.3.1.8);
- Option RM9 – Burns Road Bridge (Section 9.3.1.9);
- Option RM10 – Burns Road Raising and Culvert Upgrades (Section 9.3.1.10);
- Option RM11 – Elmo Street near Footts Road (Section 9.3.1.11);
- Option RM12 – Tapley Road (Section 9.3.1.12);
- Option RM13 – Macdonalds Road near Indigo Place (Section 9.3.1.13);
- Option RM14 – Pacific Highway at Dog Trap Gully (Section 9.3.1.14).

9.3.1.1. Option RM1 – Tuggerah Street at the Pacific Highway

The Macdonalds Road exit of the Pacific Highway experiences significant flood affectation and would benefit from improving flood access (refer Image 10).

Image 10: Tuggerah Street at the Pacific Highway (Option RM1)

RMS are currently planning for the upgrading of the Pacific Highway between Ourimbah Street (at the north end) and Parsons Road roundabout (at the southern end). The Jacobs (2014) study (Reference 12) indicates that a proposed Highway exit ramp to Tuggerah Street is to replace an existing exit ramp to Macdonalds Road. WMAwater have examined flood affectation of the proposed exit based on the above mentioned report and make the following comments:

- The exit is flooded in the 0.5EY (2 year) event and potentially more frequent events not modelled as part of the study.
- In the 20% AEP flood the exit experiences depths > 0.5 m and velocities of ~1 m/s. This is a flood hazard classification of H3 (see Section 6.2) which means that it is unsafe for all vehicles.
- In the 1% AEP flood the exit experiences depths > 1.8 m and velocities >1.5 m/s, placing flooding of the proposed exit in the H5 flood hazard classification. This poses an extreme risk to motorists.

As discussed in Section 4.2.6, WMAwater has contacted RMS in relation to this exit ramp to request that the access road be made flood free in the 1% AEP event. A letter addressed to RMS outlining this request is presented in Appendix F. The feasibility of RMS raising the proposed exit ramp was also discussed in October 2016 at meeting with engineers from Council, WMAwater, RMS and Cardno. A case was made as to why the road should be raised with RMS agreeing to investigate this option.

Pending a response from RMS, WMAwater have developed a preliminary concept design and costing for improving flood access at this location. The concept design allows for flood free access at this location during a 1% AEP flood event. The concept design details are presented in Appendix E (Figure E 1) and involve road raising and additional culverts. An indicative cost estimate for these works is $1.4 million. As an alternative a flood free footbridge could be provided however this would involve people being outside during a flood event and this introduces other safety issues. This could be further investigated if RMS do not upgrade the Macdonalds Road exit ramp as part of the Pacific Highway upgrade.

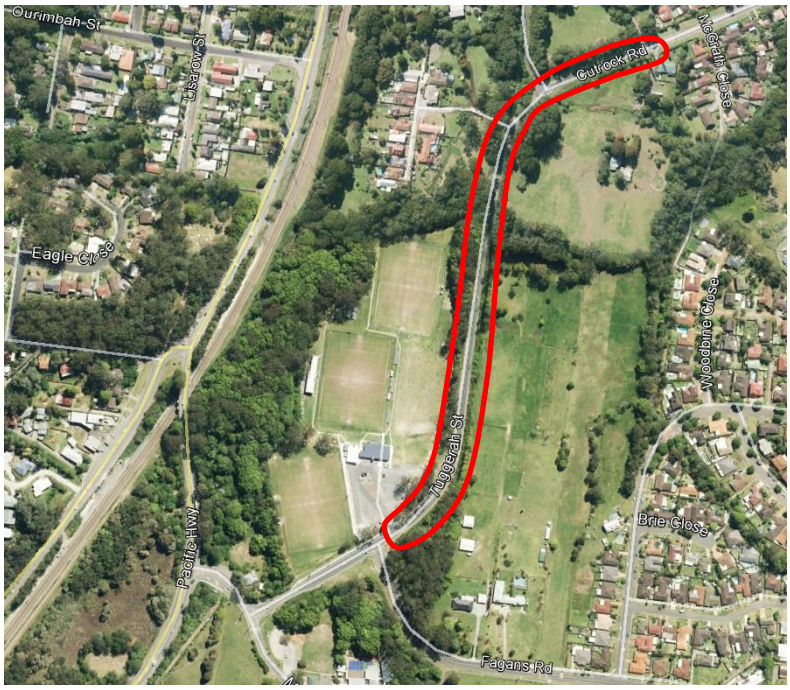
Upgrading this route would improve access in times of flood to the Lisarow Primary School.

9.3.1.2. Option RM2 – Tuggerah Street and Cutrock Road near Pluim Park

Tuggerah Street north of Fagans Road and Cutrock Road west of McGrath Close is currently flooded by H2 hazard flooding in the 20% AEP, making it unsafe for smaller vehicles to use this road during this event. In the 10% AEP event, H3 flood hazard is experienced on these roads making the route unsuitable for vehicles of any kind.

Raising this section of Tuggerah Street has the potential to improve trafficability for urban areas to the east of Cut Rock Creek and to the University. Additionally, Option RM2 (refer Image 11) could potentially provide access to Tall Timbers Estate if implemented with Option RM8 (see Section 9.3.1.8).

Image 11: Tuggerah Street at the Pacific Highway (Option RM2)



WMAwater have developed a preliminary concept design and costing for improving flood access at this location aimed to allow flood free access in the 1% AEP event by incorporating the Option FM13 basin (Section 9.2.7.1) into this design. If a storage basin at this location is not the preferred option, additional culverts could be incorporated into the design such that design flood levels are not significantly affected with raising of this section of Tuggerah Street. These features could be examined in detail should improvements to flood access at this location be found to be feasible. A preliminary concept design is presented in Appendix E and involves road raising and additional culverts. An indicative cost estimate for these works is $4.8 million.

9.3.1.3. Option RM3 – Coachwood Drive North of Mahogany Close

Coachwood Drive to the north of Mahogany Close (refer Image 12) is currently first flooded in the 5% AEP event with the 2% AEP event classified as H3 flooding at this crossing making it unsafe for vehicles of any kind. Raising of this road and the addition of culverts could be implemented to improve flood access.

Image 12: Coachwood Drive north of Mahogany Close

WMAwater have developed a preliminary concept design and costing for improvements to flood access works aimed to allow flood free access at this location during a 1% AEP flood event. The preliminary concept design details are presented in Appendix E (Figure E 3). An indicative estimate for these works is $900,000.

9.3.1.4. Option RM4 – The Boulevard at the University of Newcastle Ourimbah Campus

Shirley Street to the north of Brush Road and The Boulevard to the south of North Loop Road (refer Image 13) is currently first flooded by the 20% AEP event with H2 classification flood hazard experienced indicating a potential risk for smaller vehicles. During events exceeding the 10% AEP, a flood hazard classification of H3 is experienced meaning the vehicle access is unsafe for all vehicles. Raising of this road and the addition of culverts could be implemented to improve flood access at this location.

Image 13: The Boulevard at the University of Newcastle Ourimbah Campus

WMAwater have developed a preliminary concept design and costing for improved flood access works aimed to allow flood free access at this location during a 1% AEP flood event. The preliminary concept design details are presented in Appendix E (Figure E 4) and involve road raising and additional culverts. An indicative cost estimate for these works is $5 million.

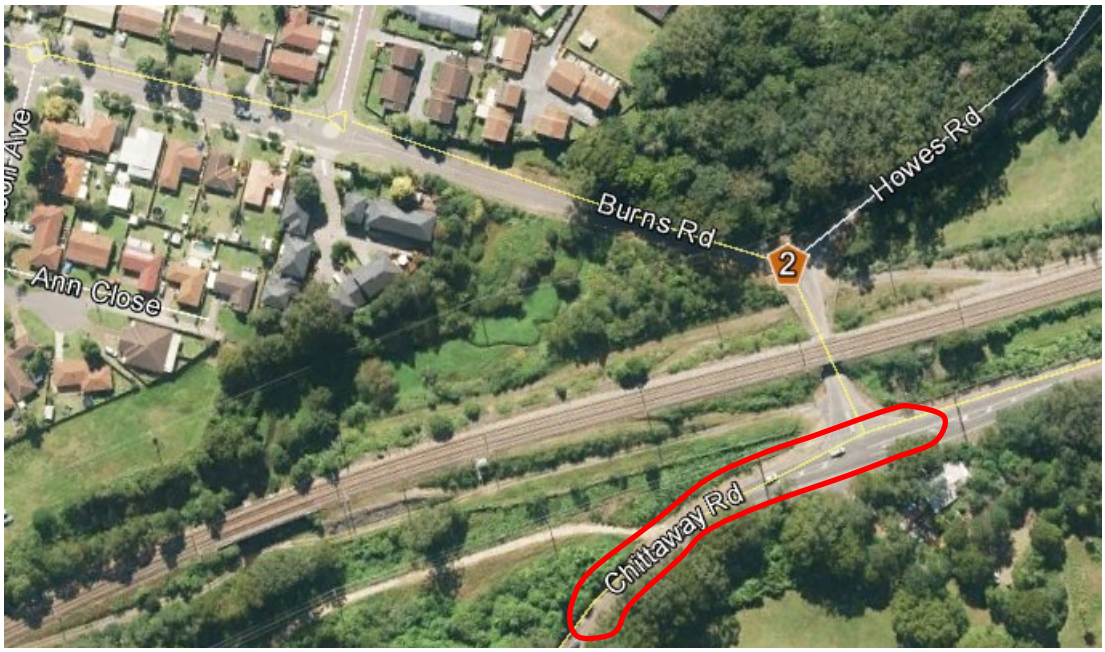
An additional benefit of the described road raising works is the protection afforded for the carpark west of South Loop Road. Implementation of these works would lead to this carpark being flood free during the 1% AEP event.

9.3.1.5. Option RM5 – Chittaway Road near Burns Road

Chittaway Road near its intersection with Burns Road (refer Image 14) is currently first flooded in the 5% AEP event with a H1 flood hazard classification indicating that the road is still trafficable during this event. The 2% AEP event experiences a flood hazard classification of H2

indicating that vehicle access is unsafe for smaller vehicles. The 1% AEP event experiences H3 flood hazard classification. Road raising works at this location could be implemented to improve flood access.

Image 14: Chittaway Road near Burns Road



WMAwater have developed a preliminary concept design and costing for road raising works aimed to allow flood free access at this location during a 1% AEP flood event. The preliminary concept design details are presented in Appendix E (Figure E 5). An indicative cost estimate for these works is $500,000.

In addition flood warning and awareness measures discussed in Sections 9.3.2, 9.3.3 and 9.3.4 should also be considered for this location.

9.3.1.6. Option RM6 – Howes Road, Link Road

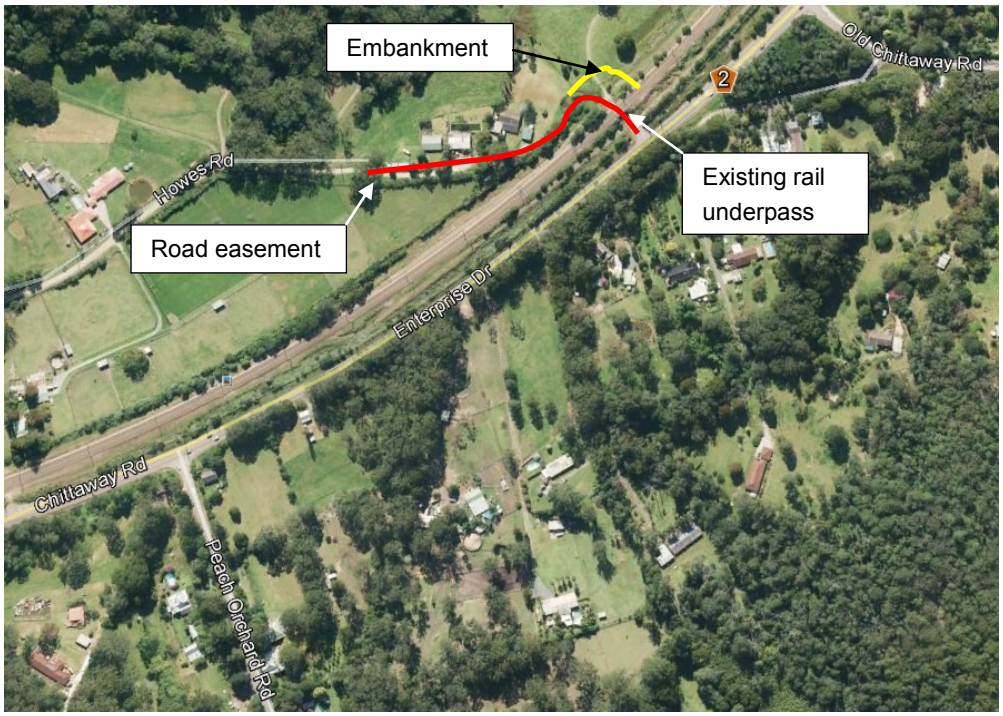
Stakeholder consultation noted that properties on Howes Road are frequently isolated due to flooding (see Section 4.2.8). Access to Howes Road is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths exceed 1 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable. Howes Road services four properties which are frequently isolated during floods.

Due to the frequency at which Howes Road becomes flooded, improved flood access is a priority. Providing pedestrian access to these properties during times of flood does not significantly reduce their risk exposure. Emergency vehicle access would not be improved and there are few facilities within walking distance of these properties.

Improved flood access to Howes Road could be achieved by leveeing an existing rail underpass south of Old Chittaway Road to exclude floodwaters, and allowing for a road easement. Discussion with Transport for NSW indicated that allowing access along the rail easement

during times of flood is not possible and accordingly negotiation with local residents would be required to provide for a road easement through private land. Image 15 presents the location of the suggested levee embankment and road easement.

Image 15: Howes Road, Link Road



WMAwater have developed a preliminary concept design for levee embankment and road easement works. The preliminary concept design details are presented in Appendix E (Figure E 6). An indicative cost estimate for these works is $500,000. However costs could increase significantly at the design stage after discussions with the relevant land owners (easement or land take costs) and possible geotechnical issues and service relocations.

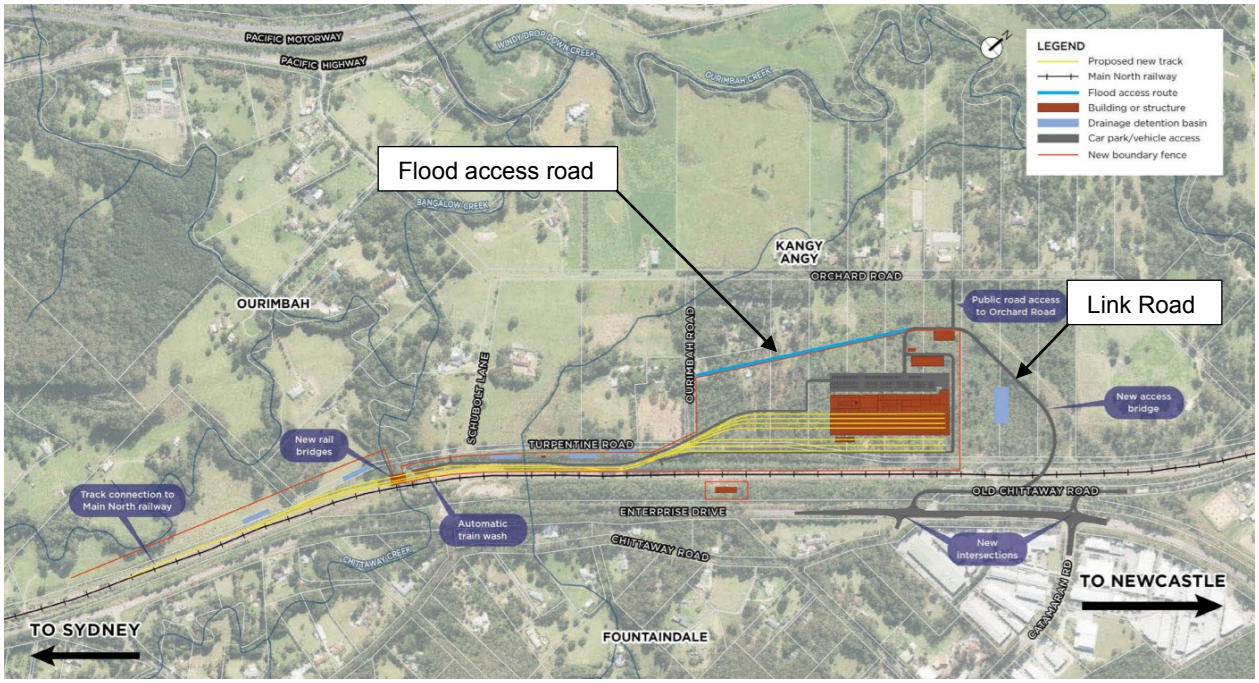
9.3.1.7. Option RM7 – Orchard Road, Link Road

The stakeholder consultation noted that properties on Orchard, Turpentine and Ourimbah Roads are regularly isolated due to flooding of access roads (see Section 4.2.8). Due to the frequency at which these properties become isolated, improved flood access is a priority.

The proposed New Intercity Fleet Maintenance Facility (see Section 4.2.7) review of environmental factors report (June 2016, Reference 14) indicated that a link road is to be constructed that crosses the Main Northern Railway Line which allows access to the region during times of flood. It was noted even with the construction of the link road, properties to the west of the proposed facility on Turpentine and Ourimbah Roads could still be isolated during floods as the intersection of Orchard and Ourimbah Roads is flooded by in excess of 2 m during the 20% AEP event. A submission was made to Transport for NSW as part of this FRMS&P requesting that flood access issues be fully considered as part of the proposed rail facility design. Further details are presented in a letter addressed to Transport for NSW contained in Appendix F.

The most recent Facility design plans indicate that a flood access road is proposed which will allow flood access to these isolated properties. Image 16 presents the proposed concept design and flood access route. The addition of the flood access route will allow flood access to properties to the west of the Facility which is a critical outcome for Council and the local community. WMAwater support this proposal and Transport for NSW should note the importance of the proposed access road.

Image 16: New Intercity Fleet Maintenance Facility (Reference 14) – Flood Access Road



9.3.1.8. Option RM8 – Tall Timbers, Link Road

A key area of flood risk identified in the Brief (see Section 2.3) is the Tall Timbers Estate. The Tall Timbers access road is frequently flooded in minor storm events (potentially multiple times a year) however the fourteen houses have floors above the 0.5% AEP event. Thus the main issue is the risk to life with using the private access road. The duration of overtopping of the access road will vary considerably depending upon the nature of the rainfall event but could last from less than 1 hour to up to 6 hours, this duration could increase if the culverts beneath the road become blocked by debris. Image 17 displays the potential location of link road between Tuggerah Street and the Tall Timbers Estate.

Image 17: Tall Timbers Estate and Access Road

The WMAwater 2014 study (Reference 10) found that raising the existing access road was not a suitable method of risk mitigation due to a number of reasons described in the Reference 10 report and summarised in Section 3.2.5. The Reference 10 report found that Voluntary Purchase was the option most suitable for mitigation of flood risk for these properties and Council has applied for funding as part of the Floodplain Risk Management Program.

However, the raising of Tuggerah Street and Cutrock Road near Pluim Park as described in Section 9.3.1.2 may provide an incentive for raising the existing access road to the Tall Timbers Estate due to the possibility of linking the Tall Timbers estate to flood free access even in larger events thus significantly ameliorating flood risk. Should raising of Tuggerah Street be found to be feasible, then raising of the Tall Timbers access road may be preferred to voluntary purchase for mitigation of flood risk at this location.

The cost of raising the Tall Timbers access road was examined in the Reference 10 study and was estimated to cost $1 million for a low level crossing. To further raise the road to above the 1% AEP level the indicative cost of construction is estimated to be $3 million. The Tall Timbers Voluntary Purchase scheme (see Section 9.4.2) which Council have applied for funding from the Floodplain Risk Management Program is estimated to cost $5.6 to $8 million (Reference 10). Accordingly, raising of the Tall Timbers access road may be a more financially competitive method of managing flood risk than the proposed voluntary purchase scheme. However as mentioned previously, numerous other issues associated with raising this road are noted in the Reference 10 study.

9.3.1.9. Option RM9 – Burns Road Bridge

As noted in the Brief and again in the community consultation, the Burns Road crossing of Ourimbah Creek is a particularly high hazard area subject to frequent high risk flooding. Due to

the nearby placement of the Main Northern Railway Line, road raising cannot be used to increase flood free access at this location.

This location would significantly benefit from the construction of a rail overbridge which would allow access from the northern side of Ourimbah Creek to Chittaway Road by going over the Main Northern Railway Line. Council have discussed this issue with RMS and note that there are two locations where such a bridge may be possible; Burns Road and Yates Road. RMS has advised that a preliminary cost estimate for such a bridge is ~$100 million, and accordingly may not be feasible in the short term. However, funding for this option may be available via a State Government grant or election commitment. RMS may prefer to use Yates Road as the primary location for construction of the rail overbridge.

From a flood mitigation perspective the construction of a bridge to replace the Burns Road crossing of Ourimbah Creek is recommended. However, due to the significant cost and potential long term implementation plan a number of other solutions to minimise risk at this location have been investigated and are described in Section 9.3.2.

9.3.1.10. Option RM10 – Burns Road Raising and Culvert Upgrades

Due to the potential long term timeframe for implementation of Option RM9, Option RM10 has been investigated to assess the feasibility of improving flood access at Burns Road in the short term. Option RM10 (refer Image 18) examines raising Burns Road (between Nellie Road and Howes Road) to the level of Burns Road railway underpass invert (13.3 mAHD) and replacing the existing culverts (2 x 2.6 m x 2.4 m RCBC) with a bridge structure to maximise conveyance.

Image 18: Burns Road Raising and Culvert Upgrades

The implementation of Option RM10 is likely to improve flood access in events much smaller than the 20% AEP, however will provide little benefit in events larger than the 20% AEP event where flow is distributed across the floodplain and flood depths exceed 1 m and velocities exceed 1.5 m/s (H5 Hazard classification). Level of service estimates cannot be made as events smaller than the 20% AEP have not been modelled as part of the current study. Regardless of the size of the bridge structure under Burns Road, Burns Road will still be unpassable during events larger than the 20% AEP.

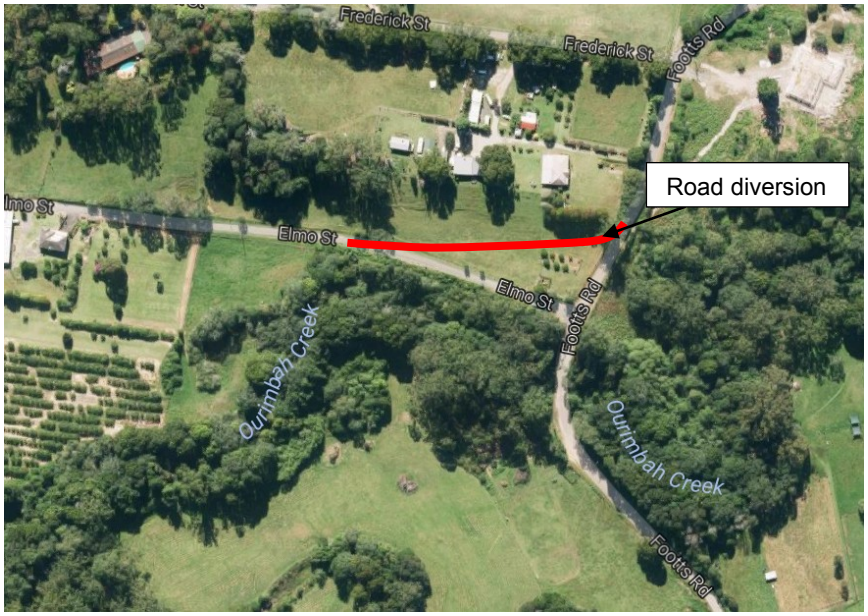
The estimated cost of implementation of Option RM10 is $3 million which is significant, particularly as the Option will be obsolete if Option RM9 is implemented. Accordingly, Option RM10 is not recommended and instead a number of other solutions to minimise risk at this location have been investigated as outlined in Section 9.3.2.

9.3.1.11. Option RM11 – Elmo Street near Footts Road

Elmo Street near Footts Road (refer Image 19) is significantly affected during flood. Access along Elmo Street is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths exceed 2 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable. Due to the frequency at which the road becomes flooded, improved flood access is a priority.

Relocation of approximately 120 m of Elmo Street away from areas frequently flood affected could be implemented to improve flood access at this location.

Image 19: Elmo Street near Footts Road – Road Diversion



The adjusted alignment of Elmo Street would require the road to be diverted onto privately owned land. As part of the detailed design, a land-swap could potentially be negotiated with the adjacent landowner. An indicative cost estimate for these works is $250,000.

9.3.1.12. Option RM12 – Tapley Road

Tapley Road south of The Ridgeway (refer Image 20) is significantly affected during flood. The road provides access for approximately 50 rural properties and is cut about once every two years. Alternative access is available via Maidens Brush Road (unsealed) towards Wyoming.

Access along Tapley Road is first flooded by events much smaller than the 20% AEP event. During the 20% AEP event flood depths of 1 m and velocities exceed 1.5 m/s which leads to a H5 Hazard classification posing extreme risk to motorists and rendering the road unpassable.

Due to the frequency at which the road becomes flooded, improved flood access is a priority.

Image 20: Tapley Road – Road Raising and Culvert Upgrades

For implementation of Option RM12 the raising of ~50 m of road and the enlargement of existing culverts is required. An indicative cost estimate for these works is $80,000.

9.3.1.13. Option RM13 – Macdonalds Road near Indigo Place

Macdonalds Road near Indigo Place allows access to Lisarow Public School and several rural properties (refer Image 21). The road is untrafficable in events as small as the 20% AEP. Due to the frequency at which the road becomes flooded, improved flood access is a priority.

Image 21: Macdonalds Road near Indigo Place – Road Raising and Culvert Upgrades

Option RM13 examines implementation of the raising of ~40 m of road and the enlargement of existing culverts. An indicative cost estimate for these works is $150,000.

9.3.1.14. Option RM14 – Pacific Highway at Dog Trap Gully

The Pacific Highway crossing of Dog Trap Gully (refer Image 20) can be significantly affected during floods with depths of up to 0.6 m experienced in the 20% AEP event. Flooding of this key access road would create major traffic disruption.

Design flood modelling assumed 50% culvert blockage which would affect the frequency and depth of flow over the Pacific Highway. To reduce the amount of blockage, debris control structures should be installed upstream of the structure.

Image 22: Pacific Highway – Installation of Debris Control Structures

An indicative cost estimate for implementation of Option RM14 is $50,000.

RECOMMENDATIONS

► Investigate the feasibility of improving flood access at various roads (Options RM1 to RM14) and implement when funding becomes available.

► Investigate implementation of Option RM8 (Tall Timbers link road, Section 9.3.1.8) as an alternative to voluntary purchase for Tall Timbers Estate.

9.3.2. Road Closures, Early Notifications and Creek Crossing Deterrents

DESCRIPTION

As noted throughout this report, frequent flooding of access roads is one of the largest contributors to flood risk in the catchment. A list of flooded access roads is presented in Section 3.1, 6.4 and on Figure 1a to l. To mitigate risk associated with motorists using flooded roads, road closures and early notification of these closures, warning signs, depth mark indicators and notification of alternate access routes are recommended.

DISCUSSION

9.3.2.1. Automatic Road Closures and Boom Gates (Option RM15)

Due to the flash flood nature of the Ourimbah Creek catchment (see Section 9.3.3.3), early warning time for road closures are typically not available. Whilst some roads have depth indicators (refer Image 23) many motorists ignore them. Currently, road closures are only implemented by Council and RMS once they have been notified of flooding of an access road. This means that the road is flooded well before it is closed, thus greatly increasing flood risk. In

response to the limited available warning times, automatic road closures are recommended through either of the following methods:

1. Automated warning signs and boom gates (refer Image 23) that signal (using telemetry technology) once a trigger level has been reached at a nearby gauge. This would significantly reduce the time taken to close roads by negating the need for Council and SES personnel to travel to the road closure site. Cost per gate including telemetry technology is estimated to be $20,000 not including the cost of the gauge (see Section 4.2.5 for gauge installation costs).

2. Prototype flood gates or barriers which self-deploy during periods of high flow. The flood gates / barriers are locked in the open position at low-lying crossings and are designed to automatically unlock and close road access when floodwaters reach a pre-set depth. In flood situations the gates provide a highly visual barrier to warn motorists and discourage attempts to cross flooded waterways. When water recedes to an acceptable level the flood gate is deactivated by Council officers to allow vehicle access to the crossing. The cost per gate is estimated to be $60,000. It is presumed that the gates can be accessed by emergency vehicles should that be required to rescue people.

Image 23: Examples of Warning Signs, Boom Gates and Depth Indicators

(photo courtesy of David Bagnall)

Specific roads that are recommended for installation of automatic boom gates are listed below in order of their benefit in the reduction of flood risk:

- Burns Road, Ourimbah (gates near the Nelle Road and Chittaway Road intersections);
- Shirley Street, Ourimbah (gates near the Mill Street and The Boulevard intersections);
- Chittaway Road, Ourimbah (gates near the Brownlee Street and The Boulevard intersections);

- Footts Road Bridge, Ourimbah (gates near the Ourimbah Creek Road and Frederick Street intersections); and
- Tuggerah Street, Lisarow (gates near the Macdonalds Road and Baileys Road intersections).

The appropriate gauges used to provide warning of an impending flood and to inform trigger levels for each of the roads mentioned above are presented below:

- The Burns Road, Shirley Street and Chittaway Road boom gates require the installation of a stream gauge near the University between Shirley Street and Chittaway Road. MHL can assist in the installation and maintenance of this gauge and determination of trigger levels as per that outlined in Section 4.2.5. This stream gauge could also be used by the University to notify of potential flooding of the lower carpark (see Section 9.2.1.4).
- The existing Ourimbah Creek at US Weir gauge (211013) could be used to provide warning and trigger levels for proposed boom gates at the Footts Road crossing; and
- If improved flood access for the Pacific Highway Tuggerah Street exit is not found to be feasible (see Section 4.2.7), thought should be given to installing automatic boom gates and warning signs at the proposed exit. The Council owned gauge at Tall Timbers or the RMS Lisarow wetlands gauges (see Section 9.3.3.2) could be used to provide warning of an impending flood. Alarming these gauges could also be used to notify Council, SES and RMS when roads are cut.

In addition to the installation of automatic boom gates, flashing warning signs that initiate once a trigger level is exceeded should also be implemented at these locations. To further reduce risk, flood affected roads should not only be closed at the affected creek crossing, but also warning signage be implemented at the turnoff to the affected road. Early notification and warning of closed creek crossings would allow motorists to select another route thus avoiding the creek crossing entirely.

There are possible negative consequences of constructing boom gates (vandalism, failure to obey, provokes frustration if not raised immediately after the event) and these would need to be canvassed prior to implementation. Possibly a trial could be undertaken but given the relative infrequency of flooding this may take a long time to complete.

An assessment of the implementation of Automatic Road Closures and Boom Gates as a flood risk mitigation option is detailed in the Management Plan with the reference name Option RM15.

9.3.2.2. Warning Signs (Option RM16 and RM17)

The large number of flood affected roads in the Ourimbah Creek catchment (see Section 6.4) makes closing all roads during times of flood difficult. Additionally, residents who live in areas to which access roads are frequently flood affected may resent road closures, particularly if they are in a large vehicle which is able to cross the flood affected road even once a trigger level has been exceeded (trigger levels would need to be set relatively low to ensure that smaller vehicles could safely pass). Roads which are not key access roads and only service a small local community, may not need to be closed in times of flood as local resident's often understand the flood risk associated with their local road. Instead of road closures, automatic flashing warning

signs (triggered by the gauges described in Section 9.3.2.1 and Image 23) and early notification of flooded roads are recommended. Early notification of road closures allow the community to make early informed decisions in regards to route selection during times of flood.

Automatic Warning Signs and Depth Indicators (Option RM16)

Specific locations that are recommended for installation of automatic warning signs and depth indicators are listed below in order of their benefit in the reduction of flood risk:

- Burns Road Ourimbah Creek crossing;
- Turpentine Road at the Main North Railway Line;
- Palmdale Road Ourimbah Creek crossing;
- Pacific Highway near Dalgety Road;
- Geoffrey Road (near Church Road)
- Elmo Street (near Footts Road);
- Chittaway Road (between Aston Wilde Avenue and Oberon Road);
- Chittaway Road (near Lakedge Avenue); and
- Old Chittaway Road (near Enterprise Drive).

Automatic flashing warning signs are estimated to cost approximately $20,000 per location not including the cost of the gauge (see Section 4.2.5 for gauge installation costs), and depth indicators are estimated to cost $5,000 per location.

An assessment of the implementation of Automatic Warning Signs and Depth Indicators as a flood risk mitigation option is detailed in the Management Plan with the reference name Option RM16.

Early Notification of Road Closures (Option RM17)

The early notification of road closures are particularly beneficial as it allows motorist to select another route thus avoiding a flooded creek crossing entirely. Specific locations that are recommended for installation of early notification of road closure signs are listed below:

- Pacific Motorway to the north and south of Pacific Motorway/Highway interchange – used to divert traffic away from Burns Road during times of flood;
- Pacific Highway near Parsons Road (north bound lanes) – used to provide early notification of road closures at Tuggerah Street, Shirley Street, Chittaway Road and Burns Road;
- Pacific Highway north of Burns Road (south bound lanes) – used to provide early notification of road closures at Tuggerah Street, Shirley Street, Chittaway Road and Burns Road.

WMAwater contacted RMS to investigate if the Pacific Motorway/Highways VMS could be used as a means of early notification of road closures. Liaison with RMS indicated that whilst it is possible to use the VMS for this purpose, it is not recommended as RMS would prioritise RMS warning messages over those of flooded road closures. Accordingly, it could not be guaranteed that notification of flooded roads would be displayed to commuters. In place of the VMS, RMS noted that they are open to discussion with Council about the possibility of installing signage within the RMS owned road easements. Additional signage is estimated to cost approximately

$25,000 per sign not including the cost of the gauge (see Section 4.2.5 for gauge installation costs).

An assessment of the implementation of the Early Notification of Road Closures as a flood risk mitigation option is detailed in the Management Plan with the reference name Option RM17.

9.3.2.3. Camera Fines (Option RM18)

As a further deterrent for motorists that insist on using the Burns Road crossing during times of flood, a flood camera could be installed which photographs vehicles using the crossing when the road is closed. Fines and demerit points may increase the incentive not to use this crossing at times of flood. The Queensland State Government have implemented this strategy with some success in a number of LGAs in Queensland.

A flood camera and associated fines could potentially reduce the number of motorists using Burns Road during times of flood and significantly reduce risk to life. Flood cameras could also be installed at other locations where motorists often ignore road closures.

The implementation of a flood camera is estimated to cost $75,000. Revenue raised by fines could be used to pay for the operational costs of the camera.

RECOMMENDATIONS

► Implementation of automatic boom gates (RM15) to close identified high risk roads during times of flood (see Section 9.3.2.1).

► Implementation of automatic warning signs (RM16 and RM17) at various identified locations (see Section 9.3.2.2).

► Council/RMS liaise with the aim of implementing early notifications of road closure signage (RM16 and RM17) on the Pacific Motorway and Pacific Highway (see Section 9.3.2.2).

► Council and the SES undertake a feasibility assessment for installing a flood camera (RM8) on Burns Road (see Section 9.3.2.3).

9.3.3. Flood Warning and Emergency Response Strategies

9.3.3.1. General Considerations

Early evacuation is the NSW SES's preferred emergency response for flooding. This reflects the understanding that the safest place to be in a flood is well away from the affected area (Reference 19). Evacuation should be the primary strategy where the available warning time and resources permit (Reference 19). The alternative to evacuating is shelter-in-place which is to shelter in a building within the floodplain.

The SES contends that sheltering in a building that does not have a habitable floor level above the level of the PMF is not low risk and does present a number of concerns:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building has been designed to withstand the forces of floodwater, buoyancy and debris in

a PMF);
- Isolation, with possible loss of power, water and sewerage;
- People's unpredictable behaviour (e.g. drowning if they change their mind and attempt to evacuate through flooded roads);
- People's mobility (not being able to reach the highest part of the building);
- People's safety (fire and accident); and
- People's health (pre-existing condition or sudden onset e.g. heart attack).

Accordingly, where sufficient warning time for safe evacuation is available, early evacuation from the floodplain is recommended.

9.3.3.2. Potential Gauges for Flood Warning (Options RM19 and RM20)

Various rainfall and stream gauges situated in the catchment have the potential to provide real-time rainfall and river level recordings. These gauges have been described in the Flood Study and are listed below:

- Rainfall Gauges:
  - Kulnura - #561078;
  - Peats Ridge (Waratah Road) - #61351;
  - Lisarow at Fagans Road - #561079;
  - Mardi Dam at Old Maitland Road - #561082; and
  - Narara - #561085.
- Stream Gauges:
  - Ourimbah Creek at US Weir - #211013;
  - Ourimbah Creek DS of Bangalow Creek - #211015;
  - Ouirmbah Creek at Lees Bridge - #211425;
  - Lisarow at Fagans Road - #242464;
  - Tall Timbers private access road gauge; and
  - Lisarow Swamp RMS gauge for Pacific Highway Upgrade.

Typically real-time rainfall and stream gauge information can be used for flood warning, however as discussed in Section 9.3.3.3, even rainfall gauges cannot be used to provide enough warning time for the safe evacuation of the majority of residents due to the flash flood nature of Ourimbah Creek catchment. However as discussed throughout this report, the frequent flooding of access roads is one of the largest contributors to flood risk in the study area. To minimise the risk associated with motorists entering floodwaters, automatic road closures are recommended using boom gates and telemetry technology. Stream gauges can be used to provide reliable information about the depth of flooding above a road crossing allowing closure of this road.

Each of the stream gauges listed above can be linked to automatic boom gates or warning signs as well as to notify Council, RMS and the SES once a predefined threshold has been exceeded. This would allow these agencies to act and perhaps send personnel to man the flood affected creek crossing or notify RMS so that warning messages could be displayed on the VMS.

For example, the Tall Timbers Estate access road gauge was recommended for installation as part of the Reference 10 study. The gauge was installed in 2014 approximately 20 m upstream

of the Tall Timbers Estate access road and continuously records water level and provides automatic warning via telemetry methods to local residents if various thresholds are exceeded. Specifically, warnings are issued when flood levels at the private access road to the Tall Timbers Estate:

- Exceed a height that is 0.25 m below the road crest height;
- Exceed 0.25 m above the road crest height; or
- Are receding.

An assessment of the feasibility of use of these gauges to assist in flood risk management is detailed in the Management Plan with the reference name Option RM19.

Additional Gauges Recommended for Installation (Option RM20)

An additional gauge is recommended for installation on Bangalow Creek at the University of Newcastle Ourimbah Campus (The University Gauge). This gauge would be required for triggering the proposed automatic boom gates on Burns Road, Shirley Street and Chittaway Road and could also be used by the University to notify of potential flooding of the lower carpark (see Section 9.2.1.4). An assessment of the installation of a gauge at the University as a flood risk mitigation option is detailed in the Management Plan with the reference name Option RM20. It is proposed that the installation and responsibility for maintenance of the gauge would be undertaken by the University.

9.3.3.3. Evacuation Feasibility Assessment - Available Warning Time

The feasibility of evacuation from each of the Ourimbah Creek Flood Precincts (see Section 3.1) has been evaluated. The first consideration is available warning times.

Available warning times for flooding due to Ourimbah Creek and its tributaries are short due to the small catchment sizes. Accordingly, these catchments are classified as 'flash flood' catchments where the provision of an effective flood warning service is problematic.

Several challenges to an effective flood warning service have been identified for flash flood catchments (References 20 and 21):

- Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models.
- For flash floods, there is little time to develop reliable flood warnings and for effective dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness and readiness.
- A reliance on rainfall triggers increases the frequency of false alarms.
- The use of water level triggers may not allow sufficient time for response.

For these reasons, the BoM traditionally has not issued specific flood predictions for flash flood catchments. But it does provide more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding:

- General weather forecast. This may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours' notice.

- Flood Watch. This is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours' notice that flooding is possible based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.
- Severe Weather Warning. This is issued for synoptic scale events when torrential rain and/or flash flooding (or other hazardous phenomena) are forecast.
- Severe Thunderstorm Warning. This is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation.

NSW SES may issue Local Flood Advices for locations like Ourimbah not covered by BoM Flood Warnings. For example, during intense rainfall events (e.g. June 2016), notification of SES warnings listed above were made on the Wyong and Gosford SES units Facebook page and on the NSW SES Twitter account.

To add further difficulty to understanding and calculating available warning time, the Ourimbah Creek catchment is composed of numerous smaller tributaries (see Section 9.3.4) which significantly impact on warning times. For example the peak flood level recorded at the Ourimbah Creek at US Weir gauge (211013) can often occur after the peak flood level achieved at the Pacific Motorway situated 7 to 8 km downstream. This is due to the addition of flows from Canada Drop Down Creek immediately upstream of this location. A similar situation arises on the Ourimbah Creek floodplain between the Pacific Motorway and Wyong Road (see Section 3.1) where peak flood levels are impacted by contributions from Bangalow Creek and thus the flood peak can again occur prior to that recorded at Gauge #211013. Again, predicting the timing of peak flood levels relative to a particular upstream location is difficult due to the contribution of flows from various sources.

Due to the difficulties described above (short flood travel times and poor correlation of timing and flood levels at different locations) using stream gauges (see Section 9.3.3.2) to provide warning of an impending flood event is not suitable. Instead design rainfall has been analysed to investigate if rainfall gauges could be used to provide advanced warning of an impending flood event.

The available warning time for various locations within the study area from the time of peak rainfall for various durations is presented in Table 18. These timings have been extracted from the Flood Study hydrologic model for the 1% AEP event. Other design events of varying AEP were also examined. However differences in the timing of peak flood levels did not vary significantly with the exception of the PMF which was slightly quicker (4 hours to Wyong Road).

Table 18: Available Warning Time to Flood Peak From Recorded Rainfall Above a Threshold

Location	Creek	2 Hour Event (hours)	9 Hour Event (hours)	48 Hour Event (hours)	Estimated Available Warning Time
Stream Gauge (#211013)	Ourimbah	4.9	4.2	11.5	4.5
Pacific Motorway	Ourimbah	5.4	4.0	11.1	4.5
Kangy Angy	Ourimbah	5.1	4.1	11.3	4.6
Wyong Road	Ourimbah	5.9	5.0	12.0	5.4
Tall Timbers Gauge	Cut Rock	2.8	2.1	9.0	2.4
University of Newcastle	Bangalow	2.7	2.1	8.9	2.3
Burns Road	Bangalow	2.7	2.1	9.2	2.3

The warning times presented above are short, particularly in the context of flooded roads which are a key issue of concern in the study area (see Section 6.4). In the majority of cases key access roads would already be flooded when notification of an impending flood event is issued and typically 1 to 2 hours should be removed from the Estimated Available Warning Time (see Table 18) to determine the time available to evacuate before vital roads are flooded and road access is lost.

9.3.3.4. Evacuation Feasibility Assessment - Required Warning Time

There is no formal BoM flood warning for the Ourimbah Creek catchment as the response time is too short. Thus at present residents are made aware of potential flooding through the following methods;

- BoM weather warnings;
- the media (radio, internet, TV);
- own interpretation of the local weather conditions based on historical knowledge;
- SMS texts (for some residents only).

Any additional warning will improve the potential for residents to further minimise damages and the risk to life. Gosford City Council received a grant from OEH to undertake a Storm and Flood forecasting study for its LGA which is intended to improve and convey warning to customers and the community. Flood warning apps have already been developed in Australia and overseas (UK) to provide information about potential flooding. In Australia these will be developed further by the BoM and / or other authorities and are recommended as an efficient and cost effective means of conveying flood information.

For evacuation to be feasible, the available warning time must exceed the required warning time (see Section 9.3.3.3). The required warning time may be assessed by protocols set out in Reference 22 and since formalised in a *Guide for Using the SES Timeline Evacuation Model Standard Tool*. Calculations for this assessment for the four Flood Precincts described in Section 3.1 and displayed in Figure 1 are set out in Table 19. The time required for the evacuation of all flood affected properties during the PMF was assessed.

Using the NSW SES Timeline Evacuation Model tool suggests that between 5 and 49 hours (see Table 19) would be required to fully evacuate the various Flood Precincts (Section 3.1) in the catchment. This is including standard allowances for warning acceptance, warning lag and

traffic safety factors (see Table 19), however this does not include allowances for mobilisation of NSW SES personnel, for the decision to issue an Evacuation Order or for dissemination of the Evacuation Order, which adds to the time required.

The calculations presented in Table 19 are based on a number of assumptions, and the results are very sensitive to the number of doorknocking teams available. The area is serviced by the Wyong and Gosford SES units (see Section 9.3.4). If flooding is threatening in the Ourimbah catchment, it will very likely be threatening in other local catchments as well (for example the Wyong River), and it is unclear how many volunteers would be available for doorknocking in the Ourimbah Creek catchment. Accordingly, it has been assumed that only two teams (eight total for the four Flood Precincts) will be available for door-knocking for each of the Flood Precincts identified in Section 3.1. A method of rapid dissemination (e.g. SMS alerts when water reaches a pre-determined level or rainfall exceeds a predefined threshold) could avoid the need for doorknocking, but experience indicates that personal engagement through doorknocking is a more effective means of persuading people to act and is an appropriate basis for assessing warning delivery time (Reference 22).

The SES recommends allowances of one hour for people to accept a warning, another hour for people to prepare to evacuate and another hour (depending on the number of vehicles) for traffic safety. Examination of Table 19 indicates that even assuming a method of rapid dissemination could be employed, to avoid the need for doorknocking (thus removing the Warning Delivery time, see Table 19), required warning times range between 3 and 6 hours to evacuate the various risk precents of the Ourimbah Creek catchment during a PMF event (see Table 19).

Table 19: Evacuation Timeline Model Calculation for Flood Precincts Defined in Section 3.1

Time required to evacuate	D/S Wyong Rd	Pacific Motorway to Wyong Rd	U/S Pacific Motorway	Cut Rock & Bangalow Creeks	Data source
Number of vehicles					
Residential					
Number of dwellings	1041	62	45	412	WMAwater
Vehicles per dwelling	2	2	2	2	Census
Residential vehicles	2082	124	90	0	Calculated
Commercial					
Number of business premises	6	132	0	29	WMAwater
Vehicles per business	10	10	10	10	Estimate
Commercial vehicles	60	1320	0	290	Calculated
Total vehicles (TV)	2142	1444	90	290	Calculated
Evacuation route					
Number of lanes (various routes)	2	8	1	3	Maps
Evacuation route capacity (RC) (veh/hr)	800	3200	400	1200	SES
Warning Delivery (WD)					
# properties at 5 minutes per home assuming 2 teams	44	8	2	18	SES
Evacuation timing (hrs)					
Warning acceptance factor (WAF)	1	1	1	1	SES
Warning lag factor (WLF)	1	1	1	1	SES
Travel time (TT) =TV/RC	3	0.5	0.2	0.2	Calculated
Traffic safety factor (TSF)	1	1	1	1	SES
Total time required to evacuate (TR) = WAF+WLF+TT+TSF+WD	**49**	**12**	**5**	**22**	**Calculated**
BoM forecast time	0	0	0	0	BOM
Warning Time to Road Access Cut	3	2	2	1	Calculated
Total time available (TA)	**3**	**2**	**2**	**1**	**Calculated**
Time = TA – TR	**-46**	**-10**	**-4**	**-21**	Calculated

9.3.3.5. Available and Required Warning Time - Conclusion

Examination of Table 19 indicates that rainfall is not suitable for providing warning of an impending flood event for any of the Flood Precincts within the catchment as the available warning is less than the time available to evacuate.

Issuing evacuation orders in many cases may actually exacerbate risk by requiring people to leave their homes leading to an increased risk of motorists attempting to traverse floodwaters. All of the Flood Precincts described in Section 3.1 have access roads that are cut during events less than the 20% AEP event by flood hazards of H2 classification (see Section 6.2) and greater as described in Section 6.4. A map presenting the Flood Precincts and flooded access roads is presented in Figure 1a to l.

9.3.3.6. Opportunities for Increasing Available Warning Time (Options RM21 and RM22)

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast rainfall has an even greater degree of uncertainty associated with estimating flood affectation. Evacuations based on uncertain triggers 'may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable' (Reference 19). Frequent false alarms could lead to a situation where warnings are ignored by most of the community.

Opportunities for increasing available warning time are limited for the majority of the catchment, however two options have been considered:

- Option RM21 - in some areas potential benefits to available warning time could be achieved by increasing mobile phone reception. Areas to the west of the Pacific Motorway, particularly along Ourimbah Creek Road, have limited mobile phone coverage. Improvements to telecommunications infrastructure could increase mobile service coverage and potentially allow for the rapid dissemination of SES warnings and evacuation orders; and
- Option RM22 - provide accessible real-time flood information (such as a flood portal) and help residents to interpret this information by providing design flood heights for gauges as well as estimated flood depths at their properties. Additionally, flood level triggers for various gauges could be established which could be set up to issue phone messages or SMS directly to subscribers.

Options RM21 and RM22 have been detailed in the Management Plan. However, again is should be noted that the increases in available warning time associated with these Options would be limited due to the reasons described in Section 9.3.3.3. Additionally, any associated warning messages/evacuation orders could potentially exacerbate risk by increasing the chance of motorists entering flood waters.

9.3.3.7. Opportunities for Reducing Required Warning Time (Options RM23 and RM24)

Opportunities to reduce the required warning time can also be considered. The Flood Warning manual (Reference 23) also makes the point that especially in catchments which have limited warning times, there is value in setting up warning messages before flooding occurs. The NSW SES could draft a series of messages for various scenarios, which would enable more rapid broadcast and dissemination during a flood emergency. The preparation of flood warning messages is examined as Option RM23.

An important question is how the people affected by flooding can best be given the appropriate information. The potential for restricted road access (see Section 6.4) and the large number of properties means that door-knocking may be too slow to reach everyone in time. An automated telephone dial-out system could be implemented for residents of the Ourimbah Creek floodplain. The ability of such a system to quickly reach a large number of subscribers is often beneficial for mitigating flood risk. The setup of a telephone dial-out system is examined as Option RM24.

However, as mentioned previously, implementation of such a system would still not allow enough time to safely evacuate the floodplain. Instead these warnings could be used to inform residents of flood risk and road closures and request that residents stay in their homes.

The preparation of flood warning messages and setup of a telephone dial-out system for the rapid dissemination of flood information as a flood risk mitigation option is detailed in the Management Plan with the reference names Option RM23 and RM24.

9.3.3.8. Shelter-in-place Feasibility Assessment (Option RM25)

Shelter-in-place has been investigated as Option RM25 as a possible means of risk mitigation for the study area. As noted in Section 9.3.3.1, the SES has a number of concerns about this approach. Consideration of the safety of sheltering-in-place in the Ourimbah Creek floodplain is investigated in this section. Recommended planning controls to facilitate a shelter-in-place policy are examined in Section 9.4.7. Shelter-in-place is a last resort measure and evacuation should be undertaken at the earliest opportunity when it is safe to do so.

Response modification measures aim to reduce risk to life and property in the event of flooding. This includes provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people living on the floodplain:

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

As described in Sections 9.3.3.3 to 9.3.3.5, the evacuation potential of the Ourimbah Creek catchment in the event of flooding is limited. Accordingly, it was concluded that safe evacuation is not possible for a large number of properties within the catchment, and in some instances may actually exacerbate risk by increasing the chance of motorists entering flood waters. This conclusion is in accordance with the Australasian Fire and Emergency Service Authorities Council (2013, Reference 24) guideline which states that evacuation is the most effective strategy, provided that evacuation can be safely implemented. Additionally, a review of flood fatalities in Australia has found that the large majority of fatalities occurred not in the home, but outside when people have entered flood waters (38% of women and 43% of men - Reference 25).

A key issue with shelter-in-place is whether floor levels are sufficiently high to be above the level of the PMF and what hazard classification is experienced at the property for various events. These characteristics vary greatly between each of the Flood Precincts described in Section 3.1 with a summary for each precinct provided below.

Downstream Wyong Road

For the Flood Precinct downstream of Wyong Road (see Figure 1a to l), the majority of properties are two storey buildings. Additionally, the difference in peak flood level between the PMF and the FPL is relatively minor. Accordingly, the majority of residents have access to habitable floor space above the level of the PMF either within their home or at a neighbours

place. Flood hazard in the region is typically H3 classification which poses no risk to the structural integrity of buildings. Shelter-in-place is therefore relatively low risk for these properties. A number of issues do exist with the long duration of flooding in Tuggerah Lake and issues with sewerage and effluent release, however the associated risk with these issues are assumed to be less than motorists attempting to crossing flood waters.

Residents of properties in this Flood Precinct are recommended to shelter-in-place during a flood event unless properties have rising road access to above the level of the PMF in which case early evacuation is recommended. Examination of the PMF Emergency Response Classification map (Figure 8) can be used to determine which properties have rising road access.

Ourimbah Creek Floodplain from Upstream of the Pacific Motorway to Wyong Road

For the two Flood Precincts described in Section 3.1, *Ourimbah Creek Upstream of Pacific Highway* and *Ourimbah Creek Floodplain between Pacific Highway and Wyong Road* (see Figure 1) the difference between the FPL and the PMF ranges between 2.5 to 4 m which means that typically even for two storey buildings the second storey habitable floor level is often below the level of the PMF. Additionally, numerous properties are situated in areas of H5 hazard classification in the 1% AEP and H6 classification in the PMF. These hazard classifications can impact on the structural integrity of the building (see Section 6.2) making them potentially unsuitable for shelter-in-place.

Properties that were determined to have an unacceptable level of risk based on the criteria outlined in Section 9.4.2 have been proposed for voluntary purchase. Residents of properties in this region not eligible for voluntary purchase are recommended to shelter-in-place, acknowledging that residual risk is unabated for events approaching the magnitude of the PMF. However this residual risk is significantly less than the risk associated with evacuation due to the increased chance of motorists entering flood waters during events with a much higher probability of occurrence. Properties that have rising road access to above the level of the PMF and to an evacuation centre (see Section 9.3.4) are recommended to evacuate early.

If various improvements to flood access are implemented (see Section 9.3.1), it is recommended that properties with rising road access evacuate early to local SES evacuation centres (see Section 9.3.4). Additionally, in the long term this risk could be reduced through planning constraints implemented through Council's LEP and DCP (see Section 9.4.7).

Cut Rock and Bangalow Creek Floodplains

For the Cut Rock Creek and Bangalow Creek Flood Precinct (see Figure 1) the difference between the FPL and the PMF is typically less than 2 m, however the majority of homes are single storey dwellings which have no habitable floor space above the level of the PMF. Flood hazard in the region is typically H3 classification in the 1% AEP which poses no risk to the structural integrity of buildings, however this increases to H5 classification in the PMF.

Residents of properties in this region are recommended to shelter-in-place as a last resort, acknowledging that residual risk is unabated for events approaching the magnitude of the PMF. However this residual risk is significantly less than the risk associated with evacuation due to the

increased chance of motorists entering flood waters during events with a much higher probability of occurrence. Properties that have rising road access to above the level of the PMF and to an evacuation centre (see Section 9.3.4) are recommended to evacuate early.

If various improvements to flood access are implemented (see Section 9.3.1), it is recommended that properties with rising road access evacuate early to local SES evacuation centres (see Section 9.3.4). Additionally, in the long term this risk could be reduced through planning constraints implemented through Council's LEP and DCP (see Section 9.4.7).

9.3.3.9. Emergency Response Recommendations

Due to the short available warning times and the various other factors described in the previous sections, the provision of an effective flood warning service for flooding in the Ourimbah Creek catchment is difficult. Issuing evacuation orders in many cases may actually exacerbate risk by requiring people to leave their homes leading to an increased risk of motorists attempting to traverse floodwaters.

Shelter-in-place is the recommended emergency response for all areas of the catchment unless properties have rising road access to above the level of the PMF in which case early evacuation is recommended. The Wyong Local Flood Plan (LFP - Reference 26 see Section 9.3.4) already recommends shelter-in-place for a number of areas within the catchment. Further investigation of this option would need to be undertaken by the SES as they are the responsible authority for evacuation.

An assessment of the feasibility of a Shelter-in-place policy as a flood risk mitigation option is detailed in the Management Plan with the reference name Option RM25.

RECOMMENDATIONS

► Option RM19 (Section 9.3.3.2) – investigate the suitability of existing gauges to be used for flood warning.

► Option RM20 (Section 9.3.3.2) - installation of a stream gauge on Bangalow Creek near the University of Newcastle Ourimbah Campus.

► Option RM23 (Section 9.3.3.7) - prepare a suite of flood warning messages (NSW SES).

► Option RM24 (Section 9.3.3.7) - construct and maintain a telephone dial-out system for the rapid dissemination of flood information and instructions (NSW SES).

► Option RM25 (Section 9.3.3.8) - implement a shelter-in-place strategy (NSW SES).

9.3.4. Flood Emergency Management Planning (Options RM26, RM27, RM28)

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification.

The NSW SES is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. This role is undergirded by flood planning and NSW SES maintains the Wyong and Gosford Local Flood Plans (References 26 and 27).

Residents living in and proprietors working on the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Wyong Shire Local Flood Plan (Wyong LFP - Reference 26) is a sub-plan of the Wyong Shire Local Emergency Management Plan and the Gosford City Local Flood Plan (Gosford LFP - Reference 27) is a sub-plan of the Gosford City Local Emergency Management Plan. Volumes 1 of the Wyong and Gosford LFPs were endorsed in June 2013 and February 2014 respectively. These LFPs outline responsibilities and procedures for preparing for, responding to and recovering from floods within their respective LGAs. Both LFPs provide information for areas within the Ourimbah catchment, albeit this information is limited. A review of both Flood Plans is presented in the ensuing sections, along with a recommendation to encourage key floodplain exposures to create their own specific Flood Plans.

It is recommended that both the Wyong and Gosford LFPs be updated. This option is detailed in the in the Management Plan with the reference name Option RM26. Some recommendations for these updates are presented in Sections 9.3.4.1 and 9.3.4.2. Furthermore, relocation of the Wyong evacuation centre is recommended with the reference name Option RM27.

Additionally it is recommended that the Wyong and Gosford SES units are resourced appropriately so that they can perform a flood rescue function in Flood Precincts *Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road* and *Ourimbah Creek Floodplain Upstream of Pacific Motorway* (see Section 3.1) at short notice. This option is detailed in the Management Plan with the reference name Option RM28.

9.3.4.1. Wyong LFP

Clause 3.5 of Volume 1 of the LFP lists two operations centres in the Wyong LGA:

- NSW SES Wyong Operations Centre is located at Levitt Street, Wyong, 2259;
- The Wyong Shire Emergency Operations Centre is located at Arizona Road, Charmhaven;

An extreme flood in the region would inundate access roads (see Section 6.4) from both of these operations centres to the catchment thus hindering SES response. This risk should be noted in the LFP.

Clause 3.8 of the Wyong LFP indicates that the following problem areas in the catchment are monitored during flood:

- Geoffrey Road, Chittaway;
- Burns Road, Ourimbah;
- Ourimbah Creek Road;
- Shirley Street, Ourimbah and the University car park;

- Turpentine Road, Ourimbah.

Clause 3.18 lists the following relevant evacuation centres:

- Ourimbah Lisarow RSL Club, Pacific Highway, Ourimbah (near Dog Trap Road).

This building is flooded in a PMF event and is not easily accessible during smaller floods due to flooded access roads. Accordingly, it is recommended that the evacuation centre be moved to a location off the floodplain and additional centres should be added to increase accessibility during flood. The following locations could be investigated by the SES for use as evacuations centres:

- Residents in areas downstream of Wyong Road on the southern side of Ourimbah Creek – buildings on Blade Close, including Kimnastix, Sico South Pacific etc.
- Residents on the northern side of Ourimbah Creek – Tuggerah Westfield.
- Residents on the eastern side of Cut Rock and Bangalow Creeks – University of Newcastle Ourimbah Campus, Science buildings.
- Residents Ourimbah Creek upstream of Wyong Road and the western side of Cut Rock and Bangalow Creeks – Central Coast Youth Club.

Relocation of the Wyong evacuation centre from the Lisarow RSL to one of the locations listed above should be considered and has been detailed in the Management Plan with the reference name Option RM27.

Annex A describes the 'flood threat' and provides some details for Ourimbah Creek, however additional information based on the current study could be added. In particular the Flood Precincts described in Section 3.1 could be defined in the LFP, similar to that presented in Figure 1. Additionally, design flood maps for the catchment could be included to display flood affectation and extent.

Annex B describes 'the effects of flooding on the community' and notes the following key areas of flood affectation (Wyong LFP, 2013):

- *'Bangalow Creek - The flood liable area of Bangalow Creek affects the car park of the University Campus and some older properties in Shirley Street which have been surrounded by water a number of times in the past';*
- *'University Campus - The University Campus has a flood management procedure adopted since about 2000 and the campus was closed in a minor event in 2003. The risk is that large numbers of students trying to enter or leave the University may try to cross the floodplain along Brush Road to get to the railway station or highway by foot or by car';*
- *'Enterprise Drive - Enterprise Drive, the arterial road into that area, may be extended through the Ourimbah Floodplain in the foreseeable future and would tend to worsen some flood problems around Sohier Park, Ourimbah. However the road designers are aware of that problem and there have been specific allowances made, so the design will include large culverts or bridge structures to minimise the effects from that arterial road connecting from Enterprise Drive through to the Central Coast Hwy south of the Shire boundary';*
- *'Overflow from Ourimbah Creek into Wyong River - In a flood larger than 100 year ARI it*

is estimated that Ourimbah Creek would commence to overflow near the Railway into the catchment of Tuggerah Creek and Mardi Creek (through the Tuggerah Business Park and Bryant Drive area) then through the Pioneer Dairy area and into Wyong River. If the flood were large enough, Wyong Road might be cut';

- *'Access to Orchard Road Area - The access to the Orchard Rd rural residential area is via a railway underpass at Turpentine Rd off Enterprise Drive. The underpass becomes inundated at an early stage in Ourimbah Creek floods (or less commonly by floods in the local watercourse which is Chittaway Creek). Residents of the area can then get pedestrian and vehicular egress along a transmission easement to railway land and then Chittaway Road to another underpass of the railway at Ourimbah Creek. However this second underpass also gets cut at later stages of Ourimbah Creek floods. The Orchard Rd area is then inaccessible except by crossing the railway which normally is prohibited.'*

In addition to the above the following should be noted in Annex B and addressed during flood events:

- Sohier Park – A number of flooded properties from the 10% AEP event and potential for large numbers of people attending sporting events. The area becomes isolated;
- Howes Road – number of properties frequently isolated;
- Chittaway Point – large number of properties isolated during floods;
- Burns Road – frequently flooded high risk access road;
- Ourimbah Creek Road - frequently flooded high risk access road; and
- Palmdale Road - frequently flooded high risk access road.

Annex E provides a 'template evacuation warning message for Wyong Shire'. This message is not consistent with the recommended evacuation response of shelter-in-place for areas in the Ourimbah Creek catchment. A template for a warning message to provide information on shelter-in-place is recommended.

Annex F describes the 'evacuation arrangements for the Wyong Shire Council area' and notes the following evacuation arrangements for the region described as Sector F:

- *'Ourimbah township is very low-lying and is inundated in moderate to severe flood events. The township will commence inundation when Bangalow Creek (not gauged) breaks its banks. The remaining parts of this sector can experience flash flooding resulting from heavy rainfall in the catchment. Properties along Ourimbah Creek Road can be isolated when rising water levels in the creek flow across the road. The strategy for these areas is for residents to shelter in place'*.

This is in agreement with recommendations in the current study. The same recommendation should be made for other areas of the catchment and described in the four Flood Precincts (see Section 3.1).

It is recommended that NSW SES give consideration to appropriately resourcing the Wyong SES unit so that it is able to respond efficiently to any urgent demands for rescue, particularly for areas on the Ourimbah Creek floodplain upstream of Wyong Road. This will help ensure that any residents that follow the shelter-in-place recommendations made in this report are able to be evacuated if required during a flood event. Any improvements to the Wyong's SES units

rescue capability should be reflected in the LFP (probably in the relevant annex of Volume 2).

9.3.4.2. Gosford Local Flood Plan (LFP)

Clause 3.6 of Volume 1 of the LFP lists two operations centres in the Gosford LGA:

- The NSW SES Gosford Operations Centre is located at Erina Works Depot, Pateman Road, Erina, NSW, 2250; and
- The Gosford City Emergency Operations Centre is located at Woy Woy Road, Kariong.

An extreme flood in the region would likely flood access roads thus hindering SES response. This risk could be noted in the LFP. No operations centre is situated in the Ourimbah Creek catchment and the SES may wish to consider this due to the large number of people that are flood affected in the region.

Clause 3.15 of the Gosford LFP lists roads that are flooded within the LGA. This list should be updated to include those listed in Table 11.

Clause 3.18 lists the Gosford RSL Club as the relevant evacuation centre. This is the closest recommended evacuation centre to the catchment, which is some distance away and may not be easily accessible during times of flood. Accordingly, the following replacement locations could be investigated by the SES for use as evacuations centres:

- Residents on the eastern side of Cut Rock and Bangalow Creeks – University of Newcastle Ourimbah Campus, Science buildings; and
- Residents of Ourimbah Creek upstream of Wyong Road and the western side of Cut Rock and Bangalow Creeks – Central Coast Youth Club, Niagara Park.

Annex A describes the 'flood threat' however provides no information specific to the Ourimbah Creek catchment. Information relating to flood affectation of Tall Timbers Estate, Mannings Road and the Lisarow Street area should be defined in the LFP. Additionally, design flood maps for the catchment could be included to display flood affectation and extent.

Annex B describes 'the effects of flooding on the community' and notes Macdonalds Road, Lisarow is monitored during flood. In addition to the above the following should be noted in the LFP and addressed during flood:

- Cut Rock Creek between Pacific Highway and Teralba Street;
- Pluim Park;
- Tall Timbers Estate; and
- Mannings Road.

Annex E provides a 'template evacuation warning message for Gosford Shire'. This message is not consistent with the recommended evacuation response of shelter-in-place for areas in the Ourimbah Creek catchment. A template for a warning message to provide information on shelter-in-place is recommended.

The following Annexes are recommended for inclusion in the Gosford LFP:

- Evacuation arrangements for shelter-in-place; and

- List of schools and other flood risk uses.

9.3.4.3. Create a SES Flood Intelligence Card for Lees Bridge (Option RM29)

The NSW SES could create a Flood Intelligence Card (FIC) for the existing Lees Bridge gauge (#211425, see Section 9.3.3.2) which would provide a list of consequences and actions for a corresponding gauge height. The FIC should be updated using the findings from the Flood Study and observations of historic events.

Creating a FIC for the Lees Bridge gauge is recommended and detailed in the Management Plan with the reference name Option RM29.

9.3.4.4. Emergency Response Plans (Options RM30 and RM31)

As well as updating the Wyong and Gosford LFPs, there would be benefit in NSW SES and Council encouraging and helping key floodplain exposures to prepare and update their own flood emergency response plans. The process of preparing plans would in itself be an important part of raising awareness and preparedness, and could be linked to a Business FloodSafe breakfast (see Section 9.3.5). Among the higher priorities for flood plans are:

- Newcastle University Ourimbah Campus;
- Lisarow Public School;
- Ourimbah Public School;
- Chittaway Bay Public School;
- Pluim Park; and
- Bill Sohier Park.

It is recommended that Council and the SES assist the above listed sites to create Emergency Response Plans (Option RM30) as well as work with affected residents to prepare private emergency response plans (Option RM31). These options are detailed in the Management Plan.

SUMMARY

Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations. NSW SES has the lead role in planning for and responding to floods. There is a need to update the Wyong and Gosford LFPs and create Flood Plans for key floodplain exposures. Best practice teaches that people will respond more effectively when households and businesses are also engaged in planning to respond to floods which can be achieved through community flood education (see Section 9.3.5).

RECOMMENDATIONS

- ► Option RM26 (Section 9.3.4) - Review and update the Wyong and Gosford LFPs to include information pertinent to the Ourimbah Creek catchment, drawing on flood intelligence from the Flood Study (Reference 2) and this FRMS&P (NSW SES); relocation of the Wyong evacuation centre is recommended with the reference name Option RM27.
- ► Option RM27 (Section 9.3.4) - Relocate the Wyong evacuation centre off the floodplain.
- ► Option RM28 (Section 9.3.4) - Resource the Wyong and Gosford SES units appropriately so that they can perform a flood rescue function in Flood Precincts *Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road* and *Ourimbah Creek Floodplain Upstream of Pacific Motorway* at short notice (NSW SES).
- ► Option RM29 (Section 9.3.4.3) – Create a SES FIC for the existing Lees Bridge gauge.
- ► Option RM30 (Section 9.3.4.4) – Assist key floodplain exposures to create Emergency Response Plans.
- ► Option RM31 (Section 9.3.4.4) – Assist flood affected residents to create Emergency Response Plans.

9.3.5. Community Flood Education (Option RM32)

DESCRIPTION

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

> *'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension…Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.'* (Reference 28).

Based on reviews of recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to the community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not only consisting of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- Involve a range of learning styles including experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and

flooding; and

- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

DISCUSSION

Table 20 provides a list of methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 20: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S 10.7 (formerly 149) certificate notifications	Section 10.7 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has opportunity to provide more detailed information about the land's flood affectation under S10.7 (5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. shelter-in-place). Proactive and regular issuance is desirable.
Council website	Council already provides an 'emergency information' portal on its website. An additional flood management portal would be of value to describe the floodplain management process and include Flood Studies and Floodplain Risk Management Studies, a history of flooding in the Ourimbah Creek catchment, procedures for how to obtain flood information, answers to frequently asked questions (FAQs), and advice on becoming flood prepared. The portal could also provide links to BoM warnings and NSW Office of Water gauge heights.
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. NSW SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local	Ongoing articles in the newspapers will ensure that the flood issues are

Method	Comment
newspapers	not forgotten. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.
NSW SES FloodSafe Guide	Now that a Flood Study has been prepared, and given the experiences of major floods in the recent past, once the Local Flood Plan is finalised, it would be timely to prepare a FloodSafe guide for the Ourimbah Creek catchment describing flood behaviours in historical and design floods, and listing appropriate actions. If major flood mitigation works will be implemented following this FRMS&P, it would be advisable to wait until these are done.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate and visible location at a time that people will be at home. The event would be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out. These materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. A meeting could also encourage property owners to develop self-help networks and particularly people checking on neighbours if a flood is imminent. Longer-term residents with flood experience could be used to help provide other residents with an understanding of previous floods and how to prepare for future flooding.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. Flood marker poles could be installed in frequently visited locations to show the height flood waters reached in previous historic flood events.

The actual approaches that are adopted would depend upon Council Officers, advise from the SES and discussions with local community representatives. For example historical flood depth markers are accepted in some communities but not in others. Typical approaches that might be instigated would involve:

- audit the existing SES community flood education strategy;

- develop; educational messages targeting dangerous behaviours;
- improved signage at high hazard road low-points;
- install flood totem poles with coloured bands to indicate levels reached by previous floods;
- make available additional flood hazard information at a property scale, including flood depths, hazards and emergency response classifications, with suitable explanations and guidance as to how this information can be used to inform flood emergency plans;
- undertake a pilot project involving the distribution of property level flood information in "hard copy" format to a small section of the catchment;
- develop a flood information portal on Council's web-site.

RECOMMENDATIONS
► Engage with the community to prepare an ongoing flood education program, with appropriate methods for program evaluation (NSW SES and Council).

9.4. Property Modification Measures Considered

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.

The following specific property measures have been assessed:

- House Raising (Option PM1) (Section 9.4.1);
- Voluntary Purchase (Option PM2) (Section 9.4.2);
- Land Use Zoning (Option PM3) (Section 9.4.4);
- Changes to Planning Policy (Option PM4) (Section 9.4.7).

9.4.1. House Raising (Option PM1)

DESCRIPTION
House raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce flooding particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types, or properties in high hazard areas.

DISCUSSION
The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood,

particularly in high hazard areas. Ideally floor levels should be raised to be above the level of the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

An indicative cost to raise a house is $80,000 though this can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house,
- generally only single storey houses can be raised,
- generally only timber, fibro and other non-masonry construction can be raised,
- generally only pier and non-slab on ground construction can be raised,
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

House raising as a flood mitigation option in the Ourimbah Creek catchment is likely suitable for the Flood Precincts *Downstream of Wyong Road* and *Cut Rock and Bangalow Creek Floodplains* described in Section 3.1. Both of these precincts have relatively small differences in design level between the 1% AEP and PMF events making it achievable to build floor levels above the level of the PMF and typically do not experience high flood hazard classifications (H5 and H6). Additionally, numerous homes are flooded in frequent flood events such as the 20% AEP which indicates a significant reduction in flood damages could be achieved. Additionally, house raising will help to maximise the number of properties in these Precincts which have habitable floor levels above the level of the PMF and are therefore suitable for shelter-in-place during a PMF event (see Section 9.3.3.8). Areas of the Ourimbah Creek floodplain upstream of Wyong Road are generally not suitable for house raising due to high hazard flows.

The floor level database prepared as part of this study (Section 3.4.2) did not include identification of houses that may be suitable for house raising thus suitable individual houses cannot be identified from the database. However experience in other areas has shown that generally all the houses that could be raised easily have been raised, the remaining ones are either too difficult to raise, have reached the end of their life or the owners do not wish to enter via steps. Many for example have been raised at Chittaway Point. From a B/C perspective the non brick houses that could be raised are nearing the end of their useful life, thus raising them is generally not cost effective due to their expected future short life span.

Experience has shown that many owners of houses that potentially could be raised are not interested for reasons such as:

- they do not want an elevated entry to their house;
- the house is old without modern facilities and will be re-developed in the near future;
- owners will have to live elsewhere during the construction phase (possibly 2 months);
- owners are unwilling to pay the costs not funded under the grant scheme (attached garage or fireplace);
- whilst it is possible to raise most single storey non brick houses many owners consider the inconvenience too much of a burden;

- flood insurance is now available, for a typical house at Chittaway Point there is an additional premium of approximately $4,000 to include flood insurance;
- all low lying buildings will have experienced above floor inundation over the past 30+ years and this is accepted by the owners as the consequences of living close to a creek or lake.

SUMMARY

It is recommended that a house raising feasibility assessment be undertaken for the two Flood Precincts mentioned above which would include detailed analysis of individual property construction and suitability for raising as well as community consultation with residents to gauge community and personal interest. An assessment of the feasibility of a voluntary house raising scheme as a flood risk mitigation option is detailed in the Management Plan with the reference name Option PM1.

RECOMMENDATIONS

► Option PM1 - Undertake a House Raising feasibility assessment for the area downstream of Wyong Road and within the Cut Rock Creek and Bangalow Creek floodplains.

► Appropriate planning and development controls should negate the need for future raising of properties (see Section 9.4.5).

9.4.2. Voluntary Purchase (Option PM2)

DESCRIPTION

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain.

DISCUSSION

Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place. Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program as long as a number of complying criteria are met.

Council has a voluntary purchase scheme currently proposed for 14 properties in Tall Timbers Estate, and six on Mannings Road, Lisarow, which is awaiting grant funding. If the improved flood access and link road to the Tall Timbers Estate are found to be not feasible and cannot be implemented (see Section 9.3.1.8) Council should undertake the voluntary purchase of the 14 Tall Timbers Estate properties as previously recommended in Appendix G.

As part of the current study, a review of flood risk identified an additional 12 properties that are

proposed for voluntary purchase. Properties that are considered fall into the following risk categories:

- Situated in, or are completely surrounded by high hazard areas classified as H5 or H6 (see Section 6.2) in the 1% AEP event; and are
- Situated in PMF ERP areas (see Section 6.3) defined as *Low Flood Island* or *Low Trapped Perimeter Area*; or are
- Situated in, or are completely surrounded by 1% AEP floodway (see Section 6.1).

Properties situated in these areas are subject to an unreasonable degree of risk as the structural stability of these properties could be compromised in the 1% AEP event and residents are isolated with no means of egress. Voluntary purchase is the only means of risk mitigation as no suitable risk mitigation measures were identified.

The locations of these properties are not presented in this report due to privacy issues. WMAwater have provided a Memorandum to Council which identifies these properties.

A B/C analysis to justify a voluntary purchase scheme or reduce the number of additional properties (12) proposed cannot be readily undertaken. The key reason that houses are included in a voluntary purchase scheme is the potential risk to life not the economic worth of the reduction in damages. For example, at Tall Timbers no floors are inundated in the 1% AEP event (and never have been inundated) but the houses are included due to the risk to life issues with crossing the bridge. Economic quantification of the reduction in flood risk would be required to include in a B/C analysis. This reduction in intangible damages is more appropriately assessed qualitatively and cannot be compared to tangible flood damages which are included in a conventional B/C analysis.

An assessment of the feasibility of a voluntary purchase scheme as a flood risk mitigation option is detailed in the Management Plan with the reference name Option PM2.

RECOMMENDATIONS

► Council should progress the existing voluntary purchase scheme for the six properties on Mannings Road.

► Council should review how flood risk will be mitigated for properties in Tall Timbers Estate should improvements to flood access roads be found to be feasible. If found to be not feasible and cannot be implemented Council should undertake the voluntary purchase of the 14 Tall Timbers Estate properties as previously recommended in Appendix G.

► All recommended management measures and specific management controls for Tall Timbers Estate as detailed in Appendix G should be maintained.

► Council should undertake a voluntary purchase feasibility assessment to investigate extending the scheme to include the additional 12 properties identified.

9.4.3. Flood Proofing

DESCRIPTION

Flood proofing is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery

times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and other smaller barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

DISCUSSION

Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction. As such, flood proofing can be stipulated within Council DCPs as requirements for structures below the FPL.

Temporary flood barriers such as sandbagging and floodgates can be a cheaper option for existing properties, and can be useful where there is frequent shallow flooding, although it relies on someone to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

Both Gosford and Wyong Council's DCPs promote flood proofing principles for development and structures which are below the FPL. This includes considering flood compatible material to reduce impacts during a flood event, ease clean up afterwards, and maintain structural integrity; and locating electrical fixtures and sewer services above the FPL.

Whilst it is a requirement of the Floodplain Development Manual (Reference 1) that new residential properties have their flood levels above the 1% AEP event plus a freeboard, commercial properties are not subject to such a requirement unless stipulated by Council. New commercial buildings can be required to be flood proofed to the FPL when constructed which would include consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in the DCP.

RECOMMENDATIONS

► Planning controls should allow some flexibility in the type of flood proofing adopted.

► Temporary flood gate options should be included in building design for low risk non-habitable developments.

9.4.4. Land Use Zoning (Option PM3)

DESCRIPTION

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones

are generally governed by a LEP. To make any significant changes to the provisions of a LEP, a planning proposal must be prepared. The Draft Final Ourimbah Masterplan (see Section 4.2.1) is currently investigating the potential for future rezoning in the Ourimbah town centre area.

DISCUSSION

Zoning can be a powerful tool in reducing flood damages, however, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time. Progressive zoning can be used to encourage long term change in flood resilience. The current land use zones for Ourimbah Creek catchment comply with the current NSW standards. No changes to the current land use zoning are recommended from a flood mitigation perspective.

RECOMMENDATIONS

► the Ourimbah Masterplan should carefully consider flood behaviour and affectation determined by the Flood Study and this FRMS&P.

9.4.5. Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived from a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors; and
- Potential changes due to climate change.

The FPL is used in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc.

DISCUSSION

The standard FPL for residential development as defined in the Manual is the 1% AEP event plus 500 mm freeboard. Depending on the nature of the development and the level of flood risk, individual FPLs can be adopted for a local area within a greater floodplain area. For example, in areas prone only to shallow overland flooding, application of the 500 mm freeboard can be excessive.

Selecting the appropriate FPL for a particular floodplain involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use

in flood prone areas and of implementing management measures.

The FPL can be varied depending on the use, and the vulnerability of the building / development to flooding. For example, residential development could be considered more vulnerable due to people being present, whilst commercial development could be considered less vulnerable, or it could be accepted that commercial property owners are willing to take a higher risk. Less vulnerable development could therefore be prescribed lower floor levels but may then be subject to other controls, such as flood proofing, up to the level of the FPL. For developments more vulnerable to flooding (hospitals, schools, electricity substations, seniors housing, etc.) consideration should be given to events rarer than the 1% AEP when determining their FPL or situating those developments outside the floodplain where possible.

According to the 2005 *NSW Government Floodplain Development Manual* (Reference 1) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of a FPL (Flood Planning Level) is actually provided given the following factors*:

- uncertainties in estimates of flood levels,
- differences in water level because of “local factors”,
- increases due to wave action,
- the cumulative effect of subsequent infill development on existing zoned land, and
- climate change. This largely relates to rainfall increase as future sea level rise has been relatively accurately determined by the Intergovernmental Panel for Climate Change (IPCC) and should not be included within the 0.5m freeboard. For this study area sea level rise will only affect those areas affected by the Tuggerah Lakes FPA.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). For example, in a future flood 1% AEP event blockage (due to say a car wedged in the creek) may elevate the peak level just upstream. However such an event would be considered as rarer than the 1% AEP as that type of blockage is an exception as it would not always occur in every flood.

There is no scientific reason for assuming a 0.5m allowance for freeboard. In some locations (say Windsor on the Hawkesbury River) it could be argued that a greater freeboard should be applied as the PMF is several metres above the 1% AEP, thus 0.5m represents only a relatively small increase in flood magnitude. At other locations a 0.5m increase above the 1% AEP may approach the PMF level and thus represents a very large increase in flood magnitude. Council could adopt varying freeboards across its LGA however this is likely to be confusing to manage by Council staff and it is difficult, if not impossible, to justify the criteria as to why one area should have a different freeboard to another. For simplicity a 0.5m freeboard is adopted by nearly all Councils in NSW for mainstream flooding. Some Councils adopt a smaller freeboard when the depths of inundation in urban areas, with no defined creeks or channels, are shallow (less than 0.3m).

The effect of rainfall increase and sea level rise has been investigated in the 2013 Ourimbah Creek Catchment Flood Study (Reference 2). Sea level rises of 0.4m and 0.9m in Tuggerah Lakes were investigated and the results showed that any increase is negligible upstream of

Wyong Road. This issue is discussed in the Tuggerah Lakes Floodplain Risk Management Study – Final Report, November 2014 (Reference 4) and the reader should consult that report for further details.

The flood study also investigated rainfall increases of 10%, 20% and 30% and these increased average peak 1% AEP flood levels by 0.2m, 0.4m and 0.5m respectively. However to date there is no accurate information on the expected rainfall increase that will occur in the catchment. It is outside the scope of the present study to provide a definitive statement on rainfall increase over the catchment as it would have to be a LGA wide approach. This issue therefore needs to be addressed at a Council and State Government level.

RECOMMENDATIONS

► The Floodplain Development Manual (2005) recommended FPL of the 1% AEP event plus 0.5 m freeboard is considered appropriate for areas flooded by Ourimbah Creek and its tributaries.

► Climate change (rainfall increase and sea level rise) will affect flood levels and extents in the catchment. This issue needs to be addressed at a Council and State Government level.

► A review of the Tuggerah Lakes Flood Study and the Ourimbah Creek Flood Study should be undertaken to incorporate the most up to date best practice modelling approaches and the application of AR&R 2019 methodology (refer Section 5.2.4).

9.4.6. Flood Planning Area

DESCRIPTION

The Flood Planning Area (FPA) is an area to which flood planning controls are applied. A FPA map is a required outcome of the FRMS&P.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus 500 mm freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may therefore be applied to development which is not flooded in a 1% AEP event.

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

DISCUSSION

The FPA as defined by the Floodplain Development Manual (Reference 1) (1% AEP plus 0.5 m freeboard) is suitable for areas of mainstream flooding.

RECOMMENDATIONS

► The FPA developed from the Flood Study has been reviewed and is considered consistent with the Floodplain Development Manual FPA approach. Council's current FPA map based on the Flood Study findings does not require revision.

9.4.7. Changes to Planning Policy (Option PM4)

DESCRIPTION

Appropriate planning restrictions which ensure 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;
- Ensure that new development does not increase flood risk elsewhere; and
- Develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Examination of existing risk throughout the study area indicates that managing this risk is particularly problematic due to the ineffective warning times available, lack of access routes, and frequent flooding (see Section 9.3.3). However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long term management of these areas and how this can be facilitated by planning tools. For example, high risk areas may need to be rezoned or have more stringent development controls applied to ensure areas of safe refuge onsite for shelter-in-place (Section 9.3.3.8) and flood compatible buildings.

DISCUSSION

Both Councils address development in flood risk areas in their respective DCPs, and provide matrices which apply varying degrees of restrictions to development based on the land use and flood risk. Applying stricter development controls in the hotspot areas has the potential to reduce the long term flood risk. Consideration should be given to the following options:

Wyong Council:

- For those areas classed as risk precinct 3 in the DCP, but classified Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - Properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by;
    - demonstrating that rising road and/or pedestrian access through low hazard flooding (H1 and H2) is available to a 'safe haven' at or above the level of the PMF; and
    - If a structure is to be used as the primary 'safe haven', the structure must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the PMF;
  - Issuing annual flood awareness information with the rates notices in these areas to maintain a high level of understanding of the risk, and what it means at that particular property. In particular, promoting sheltering in place and ways to minimise damages during a flood event.
  - The current DCP allows filling of the building footprint, car parking areas and driveways

within this precinct, the cumulative impact of which has the potential to change the flood behaviour.

- For those areas classed as risk precinct 4 in the DCP, but classified Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - These areas are required to undertake a performance based assessment, however at present the assessment does not list particular targets for some aspects. For example: *"is compatible with the established flood hazard of the land…",* and *"incorporates appropriate measures to manage risk to life and property from flood."*. Whilst the DCP does advise that Council staff are consulted prior to undertaking the assessment, providing specific criteria within the DCP would ensure future development is appropriate with the flood risk and is not open to interpretation. This might include:
    - Specifying that properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by providing access to a 'safe haven' at or above the level of the PMF;
    - Requiring structures used as the primary 'safe haven' be flood compatible and structurally able to withstand the forces of flooding, and providing prescriptive building design and / or material specification.

- The current precinct mapping is based directly on the outputs from previous flood modelling, and as such, single lots may contain more than one Precinct. Consideration should be given to revising the mapping to ensure lots are only allocated as one precinct (corresponding to the highest flood risk).

Gosford Council:

- For those areas classified as Low Flood Islands / Low Trapped Perimeter Areas in the ERP (see Section 6.3):
  - Properties without safe access and egress facilitate the recommended shelter-in-place strategy (see Section 9.3.3.8) by;
    - demonstrating that rising road and/or pedestrian access through low hazard flooding (H1 and H2) is available to a 'safe haven' at or above the level of the PMF; and
    - If a structure is to be used as the primary 'safe haven', the structure must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the PMF
  - Issuing annual flood awareness information with the rates notices in these areas to maintain a high level of understanding of the risk, and what it means at that particular property. In particular, promoting sheltering in place and ways to minimise damages during a flood event.

Central Coast Council Merger – Integration of Flood Controls

The recent merger of Wyong and Gosford Councils will require the integration of Councils' planning polices, including the LEPs and DCPs. Advice on how the integration of these planning policies is best achieved is outside of the scope of the current study. It is recommended that Council engage a specialist planning consultant to review the Wyong and Gosford LEP/DCP and to prepare advice for integration of these planning policies.

There are many differences between the Wyong and Gosford Council approach to managing flooding as described in each Council's planning and policy documentation. These need to be resolved into a single best practice approach. The following provides some of the differences that require resolution:

- different number of land use categories and approaches in the LEPs (clause 7.3);
- different land use matrices in the DCP. These also need to be adequately defined;
- the DCP should be updated to include the national guidance as described in the *Australian Disaster Resilience Handbook Collection: Handbook 7: Managing the Floodplain: a guide to best practice in flood risk management in Australia Handbook: https://knowledge.aidr.org.au/resources/handbook-7-managing-the-floodplain/.* In particular Council needs to update its hazards criteria in terms of the new H1 to H6 flood hazard categories;
- checking that the land use categories in the DCP are consistent with the LEP;
- avoid duplication of requirements between documents;
- simple, clear and unambiguous description of the prescriptive controls (floor levels, car parking, basement car parks, electrical and other hazardous facilities, access requirements, structural integrity, flood compatible material, impacts of proposed developments, filling in the floodplain, evacuation plans and flood warning / awareness, shelter in place in the DCP);
- review inclusion of climate change in all documentation;
- compatibility with and not in conflict with requirements of the Building Code of Australia;
- clarify the experience and skill set of any certifier;
- review approach for agricultural and recreation buildings, commercial and industrial, tourist facilities, caravan parks and critical services;
- consideration whether a requirement should be for regular reviews of evacuation plans;
- review of concessional development criteria;
- review of fencing requirements;
- inclusion of overland flow issues;
- there are a variety of floodplain environments in the Central Coast LGA (near large lakes, land subject to rapid overland flow, land subject to mainstream flooding ranging from the larger river systems such as Wyong River and Ourimbah Creek to the Hawkesbury River to minor creek systems). Consideration should be given to whether different matrices should be adopted for each distinct area;
- the DCP needs to specify the maximum allowable impact (outside the subject property) resulting from a 1% AEP flood impact assessment as 0.01m and there is to be no loss of temporary floodplain storage below the 1% AEP flood level;
- under Clause 5 of S117 (2) of the EPA Act filling is not permitted below the FPL in order to raise the land to above the FPL and so obtain approval for a rezoning;
- the DCP needs to specify that a cumulative impact assessment of future development be undertaken for any rezoning or sub-division, changes to roads and railways or other significant development on the floodplain (as determined by Council) by a private or public authority;
- review of Section 10.7 (2) and (5) certificates.

An assessment of the feasibility of changes to Council's planning policies as a flood risk mitigation option is detailed in the Management Plan with the reference name Option PM4.

RECOMMENDATIONS

► Council could consider applying more stringent, and specific, planning and development controls to the areas classified as Low Flood Islands / Low Trapped Perimeter Areas.

► Flood Mapping for the DCP should be updated based on the findings of this current study, potentially taking into consideration the ERP classifications described in Section 6.3.

► Option PM4 - Council should engage a specialist planning consultant to prepare advice/content for the conflation of Councils' LEPs and DCPs.

9.4.8. Modification to the S10.7 Certificate

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land.

Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

> ***7A Flood related development controls information***
>
> *(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.*
>
> *(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.*
>
> *(3) Words and expressions in this clause have the same meanings as in the standard instrument set out in the Standard Instrument (Local Environmental Plans) Order 2006.*

Legal reviews of the effectiveness of s.10.7 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (low, moderate or high) and also whether flooding applies generally to the area or more specifically to the land which is the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- The type of flooding;
- Whether flooding is from major rivers or local overland flooding; and

- The extent of flooding (whether widespread or relatively confined).

It should be noted that the s.10.7 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in a s.10.7 (2) Planning Certificate, there is scope within a s.10.7 (5) Planning Certificate for providing this additional type of information.

Some Councils include detailed flooding information in s.10.7 (5) Planning Certificate as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.10.7 (5) Planning Certificates could include:

- Flood levels / depths over the property;
- Percentage of property which is flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

Council currently provide property-based flooding information on Council's website which is a benefit to the community. More detailed information can be obtained from Council by way of purchase of a flood information certificate.

Under the s117 directions Council cannot impose flood related development controls above the residential flood planning level for residential development (such as precincts where Council might seek to impose controls for a PMF refuge for the sake of refuge-in-place). In these instances Council would have to apply to the Minister for exceptional circumstances.

RECOMMENDATIONS

► Council should review the information provided on the s.10.7 certificates in light of the information in the Ourimbah Creek Flood Study and this FRMS&P.

9.5. Flood Insurance

DESCRIPTION

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments.

DISCUSSION

It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance as well as how insurance companies evaluate the risk (for example an insurance company may base premiums on ground level or may choose to consider the actual floor level of the development). These issues are outside the scope of this present study and were assessed as part of the

Commission of Inquiry into the South East Queensland floods of January 2011. Flood insurance at an individual property level is encouraged for affected land owners, but is not an appropriate risk management measure as it does not reduce flood damages.

Insurance against storm surge, tidal inundation, and permanent inundation from sea level rise is not available.

RECOMMENDATIONS

► Continued access to flood insurance in flood-affected areas is, in part, dependent on the current system of flood studies and risk management planning represented by this FRMS&P. This planning must include consideration of the future risk from sea level rise and climate change.

10. ACKNOWLEDGEMENTS

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Figures

FIGURE 1
OURIMBAH CREEK STUDY AREA

Ourimbah Ck
Canada Drop Down Ck
Toobys Ck
Bumbles Ck
Ourimbah Ck
Pacific Highway
Enterprise Drive
Pacific Motorway
Dog Trap Gully
Chittaway Ck
Bangalow Ck
Cutrock Ck

N

Creeks

Flood Precincts

- Precinct 1. Ourimbah Creek Downstream of Wyong Road
- Precinct 2. Ourimbah Creek Floodplain between the Pacific Motorway and Wyong Road
- Precinct 3. Ourimbah Creek Floodplain Upstream of the Pacific Motorway
- Precinct 4. Cut Rock and Bangalow Creeks
- Ourimbah Creek Catchment

0 1 2 4 km

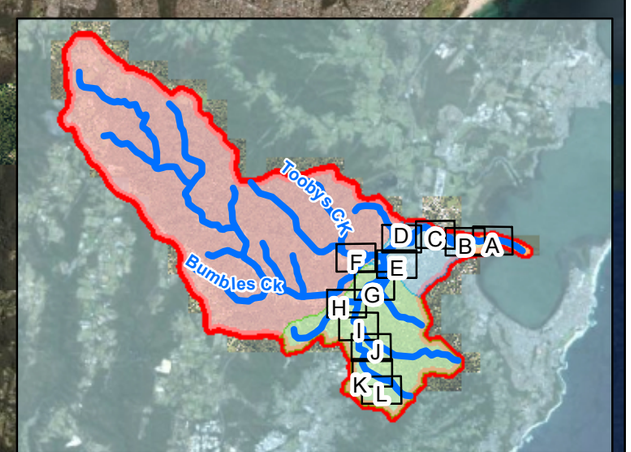

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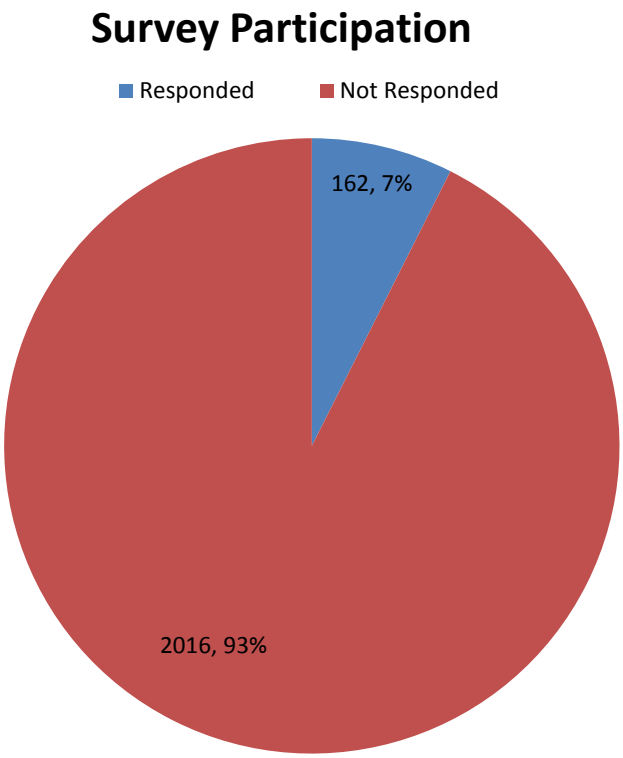
FIGURE 2a
COMMUNITY CONSULTATION RESULTS



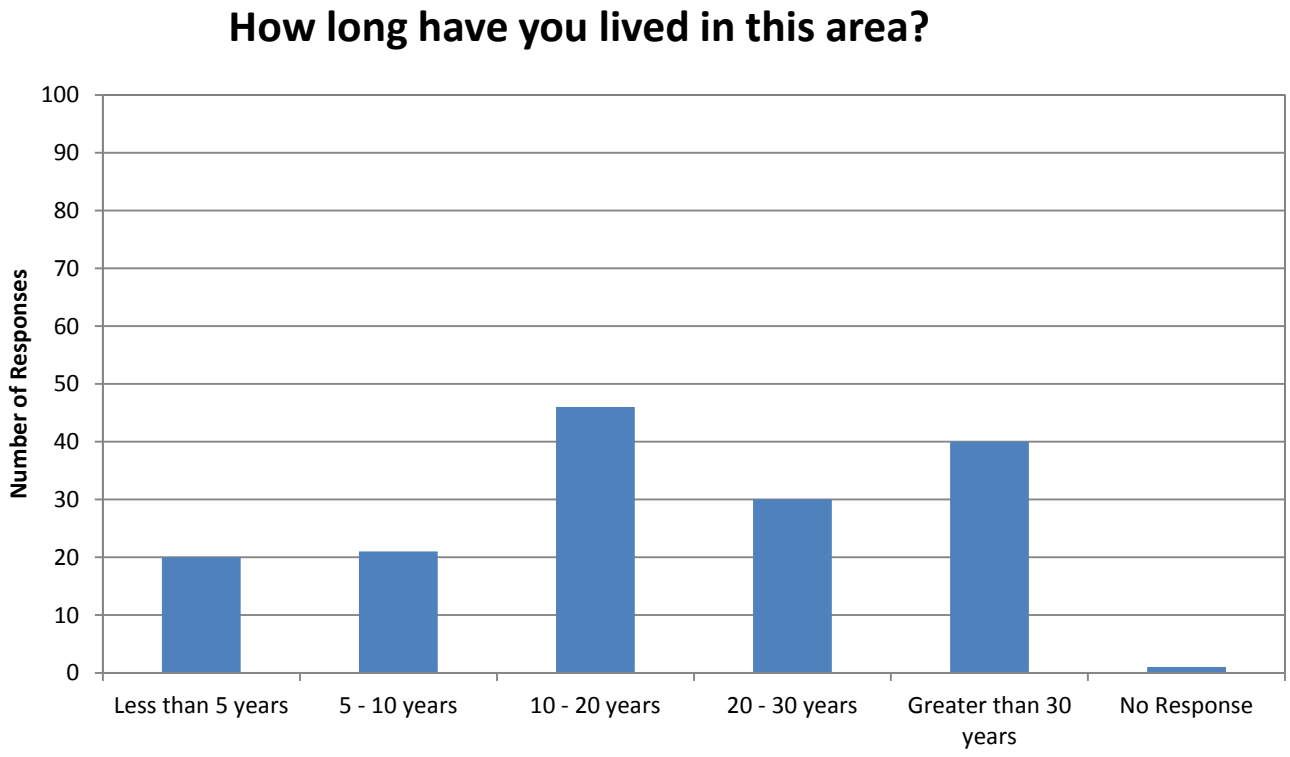


FIGURE 2b
COMMUNITY CONSULTATION RESULTS

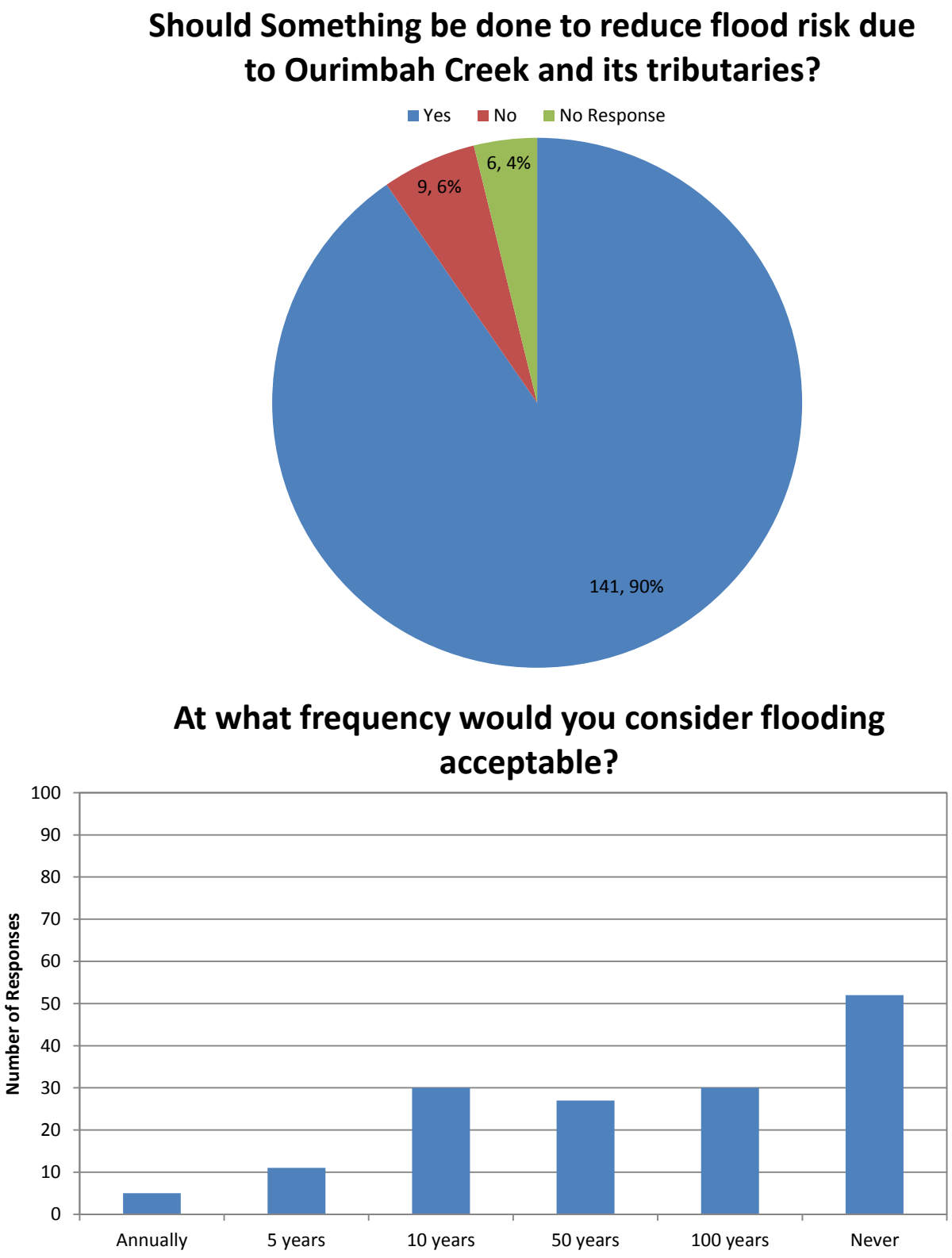
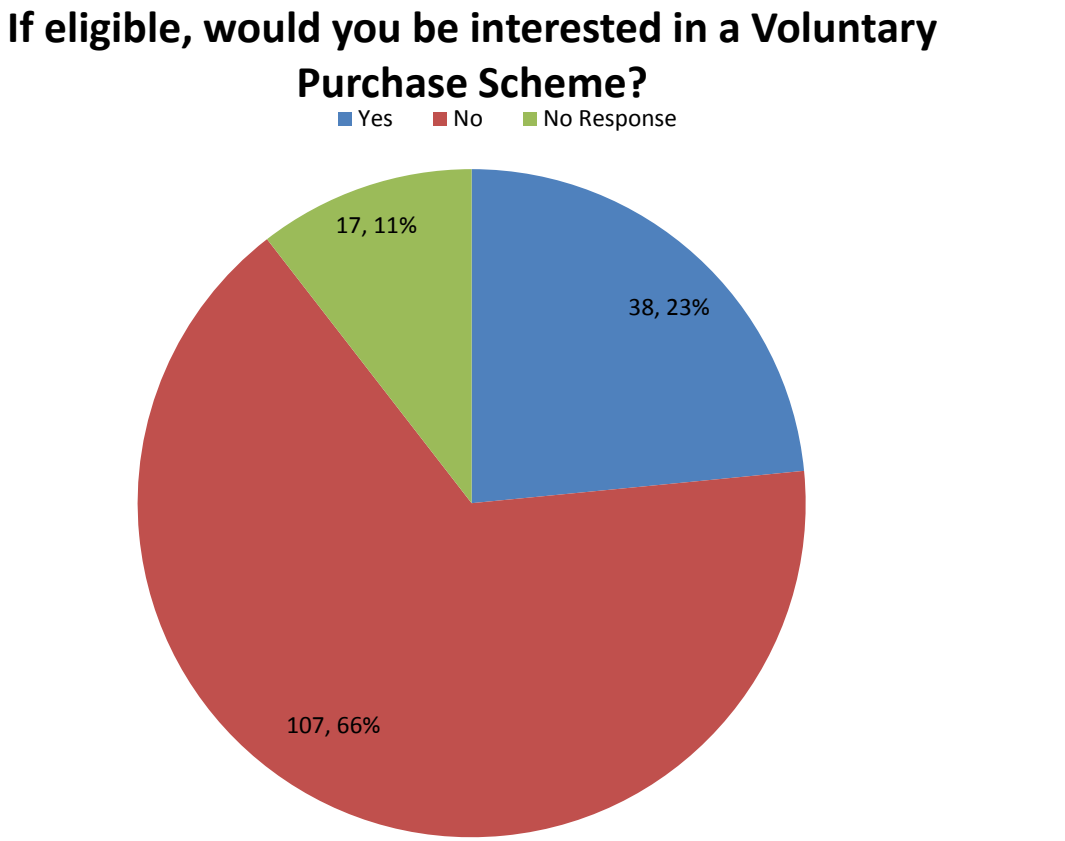


FIGURE 2c
COMMUNITY CONSULTATION RESULTS



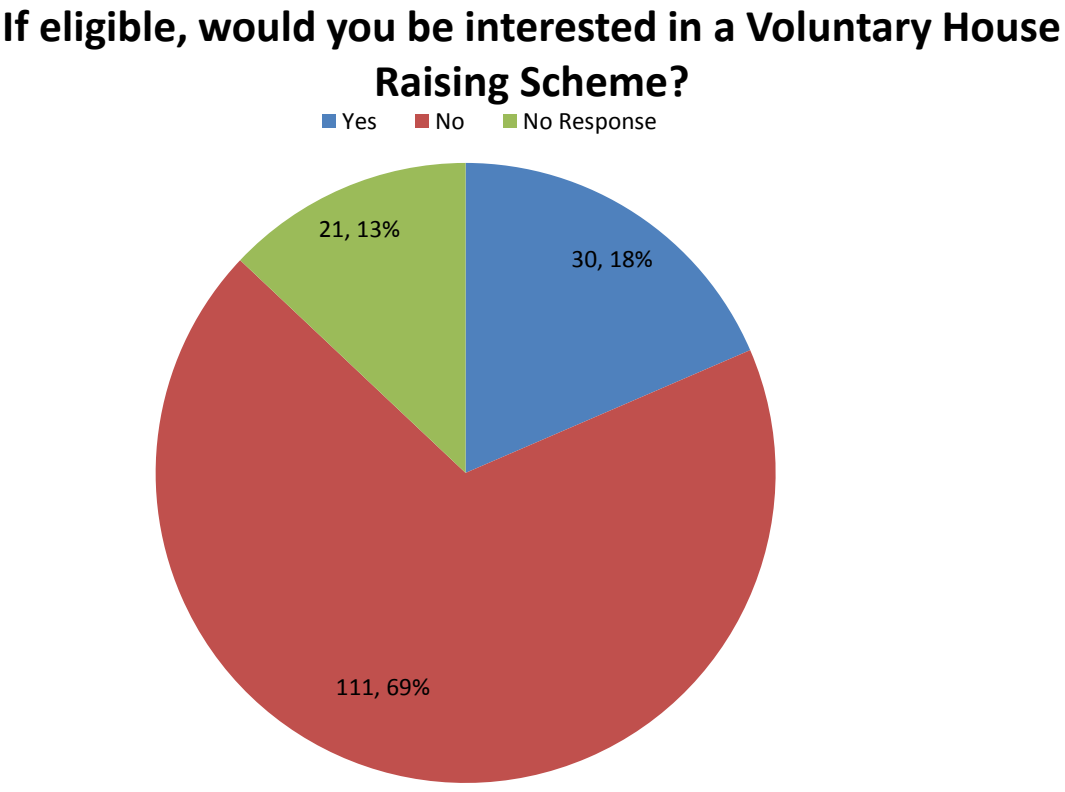
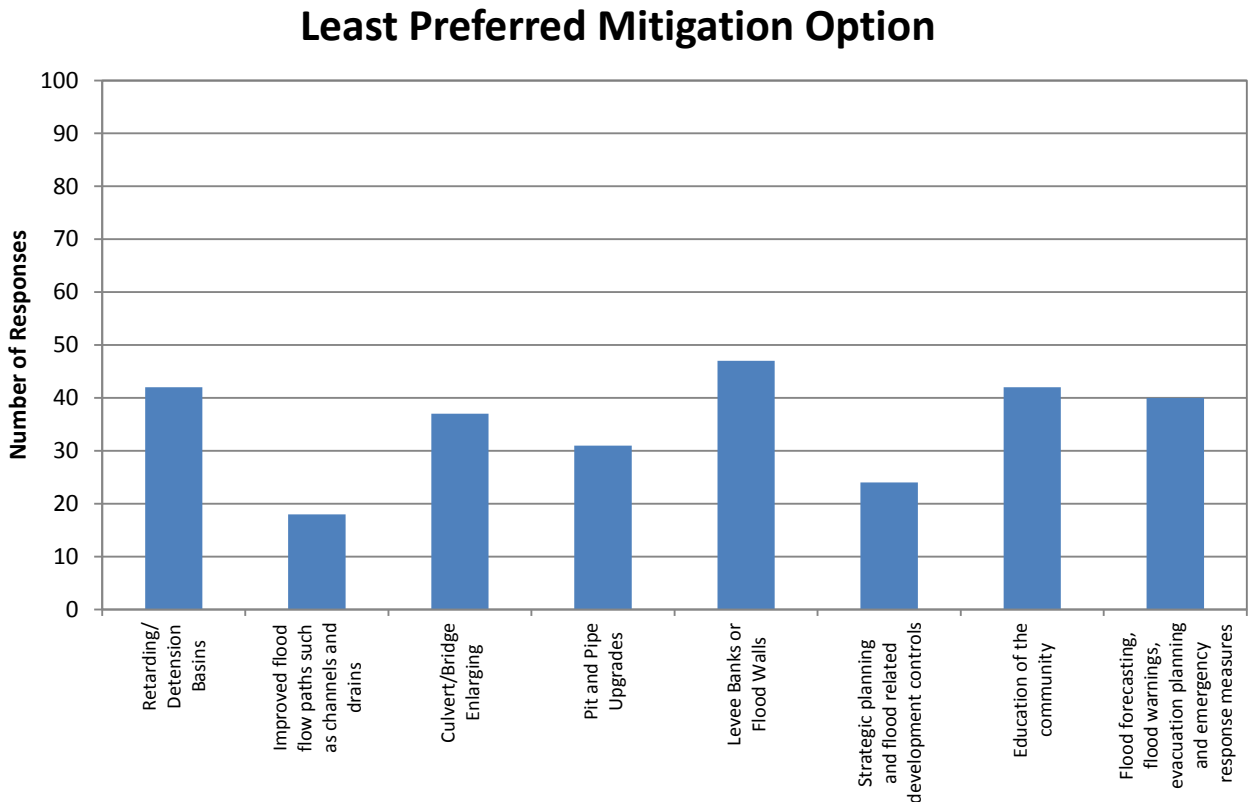


FIGURE 2d
COMMUNITY CONSULTATION RESULTS



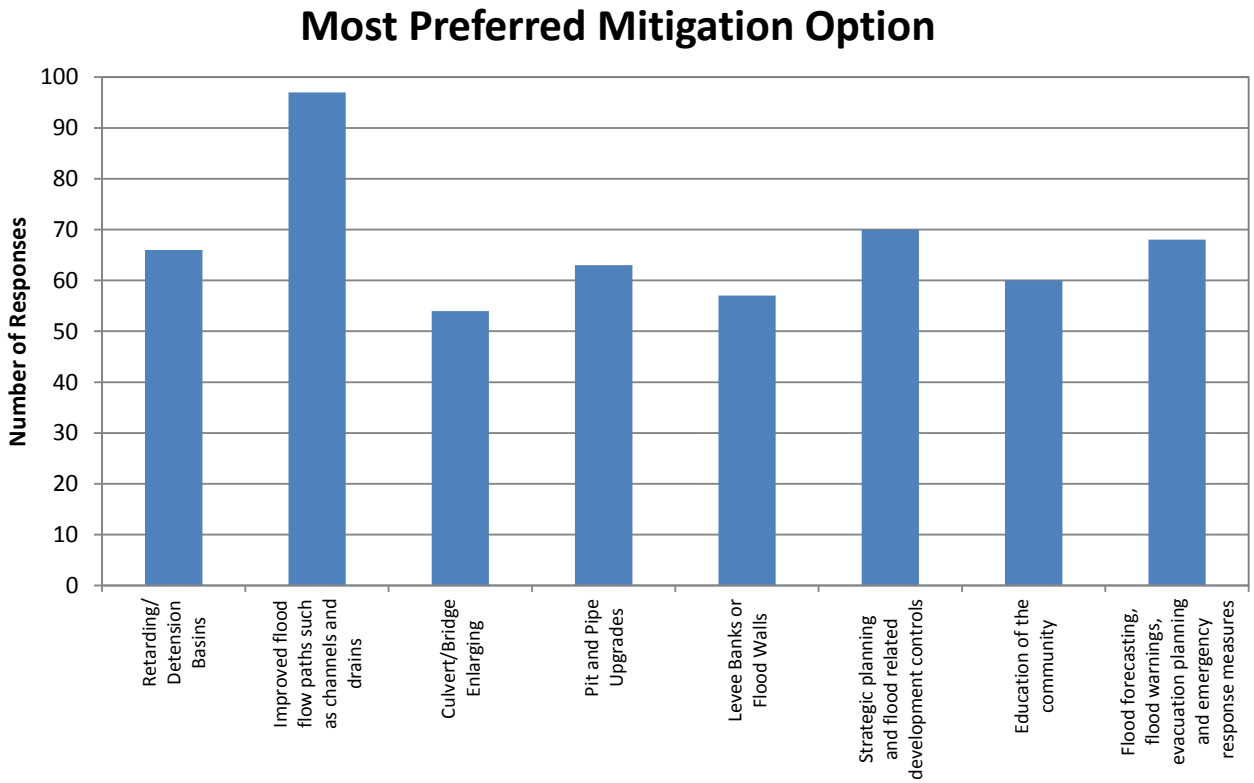


FIGURE 3

OURIMBAH COMMUNITY CONSULTATION RESPONDENT LOCATIONS

Ourimbah Ck

Toobys Ck

Canada Drop Down Ck

Bumbles Ck

Ourimbah Ck

Chittaway Ck

Dog Trap Cut

Bangalow Ck

Cutrock Ck

Bangalow Ck

Cutrock Ck

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N

Responded to Questionnaire

Ourimbah Creek Catchment

Rivers

km

0 1 2 4

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FIGURE 4
HYDRAULIC HAZARD CLASSIFICATION
1% AEP EVENT

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
AG

N

Ourimbah Creek Catchment

Hydraulic Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 1 2 4 6 km

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FIGURE 5
HYDRAULIC HAZARD CLASSIFICATION
PMF EVENT

A
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C
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K
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O
P
Q
R
S
T
U
V
W
X
Y
Z
AA
AB
AC
AD
AE
AF
AG

N

Ourimbah Creek Catchment

Hydraulic Hazard

- H1 - Generally safe for people, vehicles and buildings
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and the elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people or vehicles. Buildings require special engineering design and construction
- H6 - Not suitable for people, vehicles or buildings

0 1 2 4 6 km

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FIGURE 6

FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
5% AEP

SYDNEY NEWCASTLE FREEWAY
Ourimbah Ck
Drop Down Ck
Toobys Ck
Bumbles Ck
Dog Trap Gul
Chittaway Ck
Bangalow Ck
Cutrock Ck

N

Ourimbah Creek Catchment

FERP Classification

- Area with Overland Escape Route
- High Flood Island
- High Trapped Perimeter Area
- Indirectly Affected
- Low Flood Island
- Low Trapped Perimeter Area
- Overland Refuge Area on High Flood Island or High Trapped Perimeter Area
- Rising Road Access

0 1 2 4 km

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FIGURE 7

FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
1% AEP

Ourimbah Creek Catchment

FERP Classification

- Area with Overland Escape Route
- High Flood Island
- High Trapped Perimeter
- Indirectly Affected
- Low Flood Island
- Low Trapped Perimeter
- Overland Refuge Area on High Flood Island or High Trapped Perimeter Area
- Rising Road Access

N

0 1 2 4 km

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FIGURE 8

FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
PMF

SYDNEY NEWCASTLE FREEWAY
Ourimbah Ck
Drop Down Ck
Toobys Ck
Bumbles Ck
Ourimbah Ck
SYDNEY NEWCASTLE FREEWAY
Dog Trap Gul
Chittaway Ck
Bangalow Ck
Cutrock Ck

N

Ourimbah Creek Catchment

FERP Classification

- Area with Overland Escape Route
- High Flood Island
- High Trapped Perimeter Area
- Indirectly Affected
- Low Flood Island
- Low Trapped Perimeter Area
- Overland Refuge Area on High Flood Island or High Trapped Perimeter Area
- Rising Road Access

0 1 2 4 km

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FIGURE 9

RECOMMENDED MANAGEMENT MEASURES IN THE PLAN

FM7:Tuggerah Business Park & Railway Levees Survey and Maintenance (Sect 9.2.1.7)

RM7:Orchard Road, Link Road (Sect 9.3.1.7)

RM6:Howes Road, Link Road (Sect 9.3.1.6)

RM11:Elmo Street near Footts Road (Sect 9.3.1.11)

RM10:Burns Road Raising and Culvert Upgrades (Sect 9.3.1.10)

RM9:Burns Road Bridge (Sect 9.3.1.9)

RM5:Chittaway Road near Burns Road (Sect 9.3.1.5)

RM14:Pacific Highway at Dog Trap Gully (Sect 9.3.1.14)

RM4:The Boulevard at Univ Newcastle Ourimbah Campus (Sect 9.3.1.4)

FM5:University Lower Carpark Filling (Sect 9.2.1.5)

RM3:Coachwood Drive North of Mahogany Close (Sect 9.3.1.3)

RM8:Tall Timbers, Link Road (Sect 9.3.1.8)

RM2:Tuggerah Street and Cutrock Road near Pluim Park (Sect 9.3.1.2)

RM1:Tuggerah Street at the Pacific Highway (Sect 9.3.1.1)

RM13:Macdonalds Road near Indigo Place (Sect 9.3.1.13)

RM12:Tapley Road (Sect 9.3.1.12)

Canada Drop Down Ck

Toobys Ck

Ourimbah Ck

Dog Trap Gully

Chittaway Ck

Bangalow Ck

Cutrock Ck

N

FM/RM Floodplain Management Measure - Table 4

Creeks

Ourimbah Creek Catchment

0 1 2 4 km

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Appendix A: Glossary of Terms

Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

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

	that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse,

	and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the 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.
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.

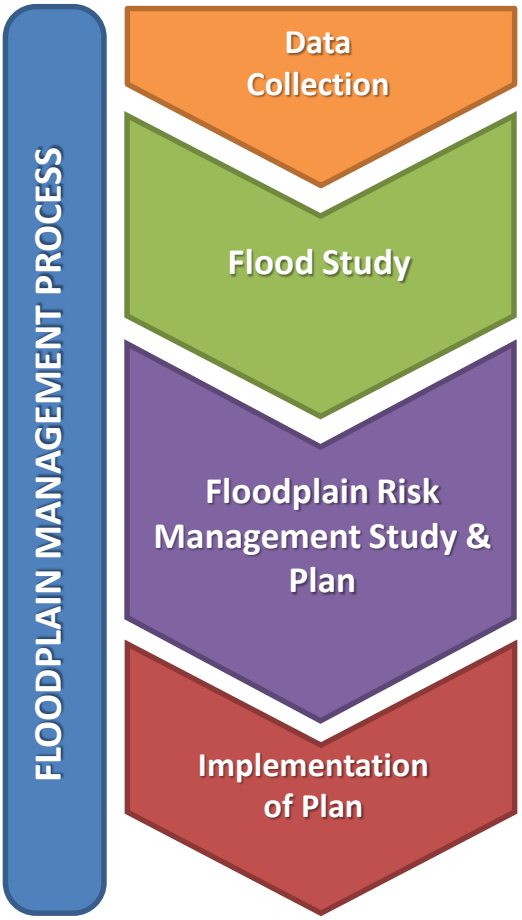
Appendix B: Community Consultation Newsletter and Questionnaire

Appendix B

Ourimbah Creek

Floodplain Risk Management Study & Plan

A Floodplain Risk Management Study and Plan is currently being prepared for Ourimbah Creek. This is the next phase of the Floodplain Risk Management Process after completion of the Ourimbah Creek Flood Study in October 2013. Wyong Shire and Gosford City Councils have appointed WMAwater specialist engineering consultants to do this Study.



The Floodplain Management Process

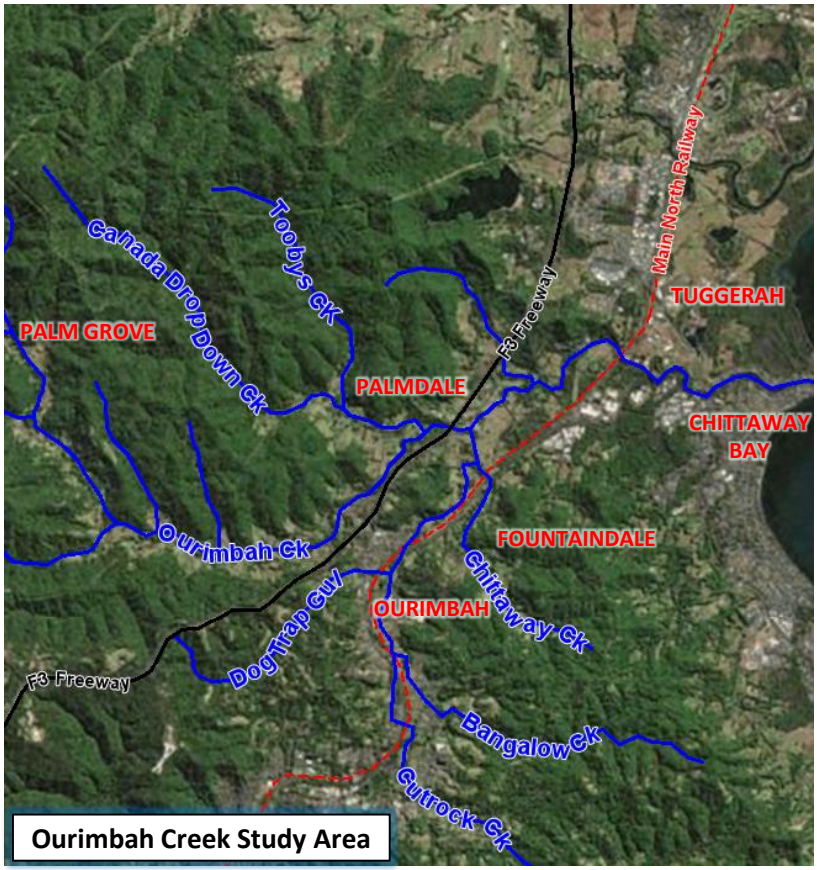
The NSW State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual land owners and occupiers, as well as reducing private and public losses resulting from flooding. Under the Policy, local government is responsible for managing flood liable land.

The Policy encourages the development of:

- Solutions to existing flood problems in developed areas
- Strategies for ensuring 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 NSW State Government's Floodplain Management Program, Wyong Shire Council and Gosford City Council.

Ourimbah Creek Study Area and Flood History



Ourimbah Creek Study Area

Flooding in the Ourimbah Creek catchment is primarily due to Ourimbah Creek and its tributaries, however elevated water levels in Tuggerah Lake can also exacerbate flooding in the lower reaches. Ourimbah Creek flows in an easterly direction through Gosford and Wyong Council areas and has a catchment area of approximately 160 km². Historic flood events in the Ourimbah Creek catchment have occurred in 1953, 1974, 1977, 1990, 1992, 2007, 2011 and 2013 with a number of these events leading to over floor flooding.

The largest events on record in the Ourimbah Creek catchment occurred in February 1992 and June 2007. The larger of these two events, the February 1992 flood, inundated hundreds of homes and businesses and caused significant damage throughout the region. The Flood Study estimated this event had an Average Recurrence Interval (ARI) between 50 and 100 years.

More recently, in June 2007 significant flooding of properties was again experienced. The Flood Study estimated this event had an ARI of approximately 20 years.

Ourimbah Creek
Floodplain Risk Management Study & Plan

An important aspect of this Study is devising various flood mitigation options that may help reduce flood risk, liability and damage. The consulting engineers have come up with various mitigation measures. However, we would like to hear your ideas on how we can help reduce flooding in your area. This is where we need your help. Please complete the attached questionnaire and return using the enclosed replay paid envelope.

Flood Risk Mitigation through computer modelling

The Flood Study aimed to understand and determine the nature and extent of flood affectation in the Ourimbah Creek catchment. As part of this work, detailed computer models were established to model flood behaviour in the catchment. One of the benefits of these models is various flood mitigation measures can be tested. This will allow us to determine what works best while ensuring that there are no negative impacts in the surrounding areas.

What mitigation works can help reduce flood risks?

Various types of flood mitigation works are used to reduce the affects of flooding. Not all mitigation measures are appropriate for all areas. For example, levees are often used to exclude flood water due to riverine or creek flooding from flood prone areas. However, these will often increase flood levels outside of the levee as well as stopping local runoff from entering the creek. Accordingly, a detailed investigation of all proposed flood mitigation works must be done using the Flood Study Models. Some examples include:

Levees

Levees are used to exclude flood water from flood prone areas. Levees are often constructed from earth embankments such as those protecting the Tuggerah Business Park area from Ourimbah Creek flooding.


Example earth bank levee

Culverts and bridges

Culverts and bridges allow water to flow under roads, train tracks or similar obstructions. The use of bridges and culverts helps reduce upstream flood levels until the capacity of the structure is exceeded. In some instances it may be beneficial to increase the conveyance capacity of existing culverts to decrease upstream water levels, however the downstream impacts of such works must also be taken into account.

Drains and channels

Drains and channels assist in the removal of floodwaters by increasing the rate at which flow is removed from a flood affected area. These structures are often situated in existing flow paths and are generally either earthen or concrete lined.

Voluntary Purchase

Voluntary Purchase (VP) involves the acquisition of flood affected properties situated in high hazard areas, and demolition of the residence to remove it from the floodplain. The floodplain is then reserved for a more appropriate land use. The New South Wales State Government recognises VP as an effective floodplain risk management measure for existing properties in areas with highly hazardous flood conditions.

Voluntary House Raising

Voluntary House Raising (VHR) has been widely used throughout NSW to significantly reduce flooding of habitable floors particularly in lower hazard flood areas. VHR is recognised as an effective floodplain risk management measure for properties that often experience flood damage.


High Hazard Flooding

Ourimbah Creek
Floodplain Risk Management Study & Plan

Community involvement in this Study is important. The Ourimbah Floodplain Management Committee includes members from Councils, Office of Environment and Heritage, and the State Emergency Services who will oversee this Study. A questionnaire is included with this newsletter so your views and ideas can be included in this Study.

How can I have my say?

A questionnaire is enclosed with this newsletter. Please complete and return to the FREEPOST address in the envelope provided.

Please make sure all surveys are returned before 10th December 2015 or they may not be counted.

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

Feedback from the community will be analysed and considered in this Floodplain Risk Management Study.

The hydraulic models constructed in the Flood Study will be used to assess the impacts of the potential mitigation options raised by the community in more detail and determine if these mitigation ideas are viable. Modelling will also ensure there are no negative impacts in the surrounding areas.

The newsletter/questionnaire provides an opportunity for the community to assist WMAwater engineers in determining potential mitigation works or other management options. If you have any questions about the study or would like more information please contact Council or WMAwater using the contact details below.

Contacts

Robert Baker
Flooding & Drainage Planning Engineer
robert.baker@gosford.nsw.gov.au

Gosford City Council
P.O. Box 21, Gosford NSW, 2250

Tel: 02 4304 7087

Phil Foster
Engineer Hydrology
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Wyong Shire Council
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Tel: 02 4350 5745

Zac Richards
Project Engineer
Ourimbah@wmawater.com.au

WMAwater
Level 2, 160 Clarence Street
Sydney, NSW 2000

Tel: 02 9299 2855

Ourimbah Creek
Floodplain Risk Management Study & Plan

Wyong Shire Council

Please complete this questionnaire and return to the FREEPOST address in the envelope provided. Please make sure all surveys are returned before 10th December 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:

Telephone:

Email:

2. How long have you lived in this area?

☐ Years ☐ Months

3. Can we contact you directly for more information?

☐ Yes ☐ No

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

4. Do you think something should be done to reduce flood risk due to Ourimbah Creek and its tributaries (i.e. Bangalow Creek, Cut Rock Creek, Chittaway Creek, Canada Drop Down Creek, Dog Trap Gully etc.)?

☐ Yes ☐ No ☐ Don't Know

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

Please name nearest street and cross street and other useful information to identify the location of the flood risk. If you are not flood affected by Ourimbah Creek please consider that you may be flood affected by one of its many tributaries including; Bangalow Creek, Cut Rock Creek, Chittaway Creek, Canada Drop Down Creek, Dog Trap Gully etc.

6. At what frequency would you consider flooding "acceptable"?

☐ Annually ☐ 5 years ☐ 10 years ☐ 50 years ☐ 100 years ☐ Never

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

☐ Yes ☐ No

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

☐ Yes ☐ No

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

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

☐ Yes ☐ No

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

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

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

Other (please specify any other options you think are suitable):
Please use as many details as possible to describe how flood risk may be reduced.

Appendix C: New Intercity Fleet Maintenance Facility – Community Notification May/June 2016

Appendix C

NSW GOVERNMENT Transport for NSW

NSW MAKING IT HAPPEN

New Intercity Fleet Maintenance Facility

MAY/JUNE 2016

COMMUNITY NOTIFICATION – REF OVERVIEW

Artist's impression of maintenance facility from the new access at Orchard Road

About the project

New Intercity Fleet

The NSW Government is delivering a New Intercity Fleet to replace the trains carrying customers from Sydney to the Central Coast, Newcastle, the Blue Mountains and the Illawarra.

This next-generation fleet of trains will give long distance customers a more comfortable travelling experience. Other customers will also benefit from this significant investment. The new trains will stop at many busy Sydney interchanges such as Central and Strathfield as well as enabling a number of improvements to future train operations.

A number of enabling infrastructure projects will be required across the wider rail network as part of the New Intercity Fleet program. Details of this work is in development and will be done under separate planning assessments.

The new trains will come into service progressively, with the first trains anticipated to be delivered in 2019 and the rest of the fleet being delivered through to 2024.

The trains will be safe, comfortable and accessible, providing an appealing environment for customers during longer journeys.

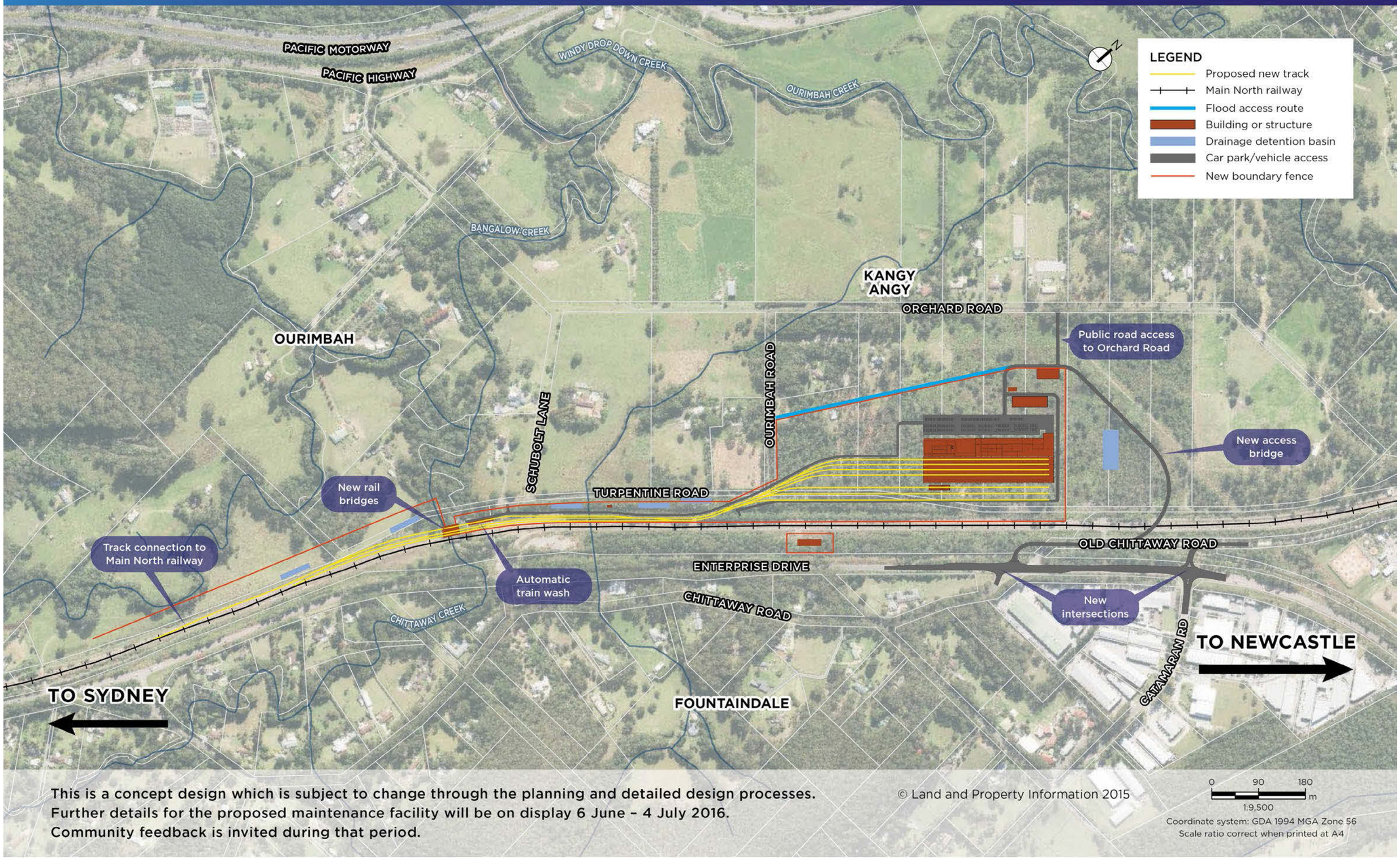
Maintenance facility

A new purpose-built train maintenance facility will be built at Kangy Angy to service and maintain the new fleet of trains, subject to planning approval. The location provides easy access, from the Northern Line.

This brochure outlines the current planning for the new facility and provides details about the proposed site and the Review of Environmental Factors (REF). It also shows how you can have your say during the public display of the Review of Environmental Factors.

For more information call **1800 684 490**
email **projects@transport.nsw.gov.au** or visit **transport.nsw.gov.au/projects**

PROPOSED MAINTENANCE FACILITY



This is a concept design which is subject to change through the planning and detailed design processes.
Further details for the proposed maintenance facility will be on display 6 June – 4 July 2016.
Community feedback is invited during that period.

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1:9,500
Coordinate system: GDA 1994 MGA Zone 56
Scale ratio correct when printed at A4

NSW GOVERNMENT Transport for NSW

How was the site chosen?

Transport for NSW considered a number of locations alongside existing railway lines across the network for their suitability, as well as existing maintenance facilities.

The Central Coast was identified as the ideal location as the new trains will regularly operate on the Main Northern Line.

Kangy Angy was identified as the preferred site based on operational, environmental, land ownership and construction considerations, including the requirement to have the facility in operation for the introduction of the new fleet.

More information about the process undertaken by Transport for NSW to select the Kangy Angy site will be detailed in the Review of Environmental Factors.

About the proposal

Details of the proposed maintenance facility site are provided in the map opposite.

The purpose built facility will provide a high standard of maintenance for the new state-of-the-art intercity train fleet. Designed to accommodate trains of up to 205 metres in length, the maintenance building will hold four trains, with the ability to expand to five in the future, if required.

New jobs will be created during the construction phase of the project. Flow-on economic benefits are expected for the local community during the operation of the facility. Work force apprenticeships and strategies on how to support local small to medium enterprises and social not-for-profit enterprises will be put in place.

The maintenance facility will include:

- a maintenance building including a stores area for carrying out general maintenance and to hold the necessary spare parts to maintain the new trains
- offices and amenities to house maintenance and office staff, including staff parking areas
- a wheel lathe building to maintain the train wheel sets
- train decanting and cleaning facilities
- an automated train wash building to wash trains
- a yard area with tracks to allow for the efficient movement of trains within the site for maintenance activities
- power supply equipment for the facility.

Associated project elements to support the new maintenance facility include:

- construction of three track bridge structures to facilitate train entry/exit into the facility from the existing main line
- new bridge over the railway to provide access to the facility. The bridge will connect Enterprise Drive to Orchard Road and offer an alternative access for local residents in times of flood
- upgrade to Enterprise Drive and Catamaran Road intersection and revised access to Chittaway Road from Enterprise Drive
- installation of high voltage power, stormwater detention, sewer, water and fire services infrastructure.

Construction

Construction of the maintenance facility is due to start in early 2017 and is planned to be completed in late 2019. Construction would consist of the following stages:

- project enabling work including utility diversions, building new access roads, bridge and general roadwork
- main construction work.

Review of Environmental Factors

A Review of Environmental Factors (REF) is an environmental assessment that is required to obtain project approval under Part 5 of the NSW *Environmental Planning and Assessment Act 1979*.

A REF examines the significance of likely environmental impacts of a proposal. It identifies the measures required to mitigate any adverse impacts to the community or environment during the construction and operation phases of a project.

A REF which includes project information, concept plans and specialist impact assessment studies will be on display for public comment from 6 June 2016 for four weeks.

Specialist impact assessment studies carried out for the project include:

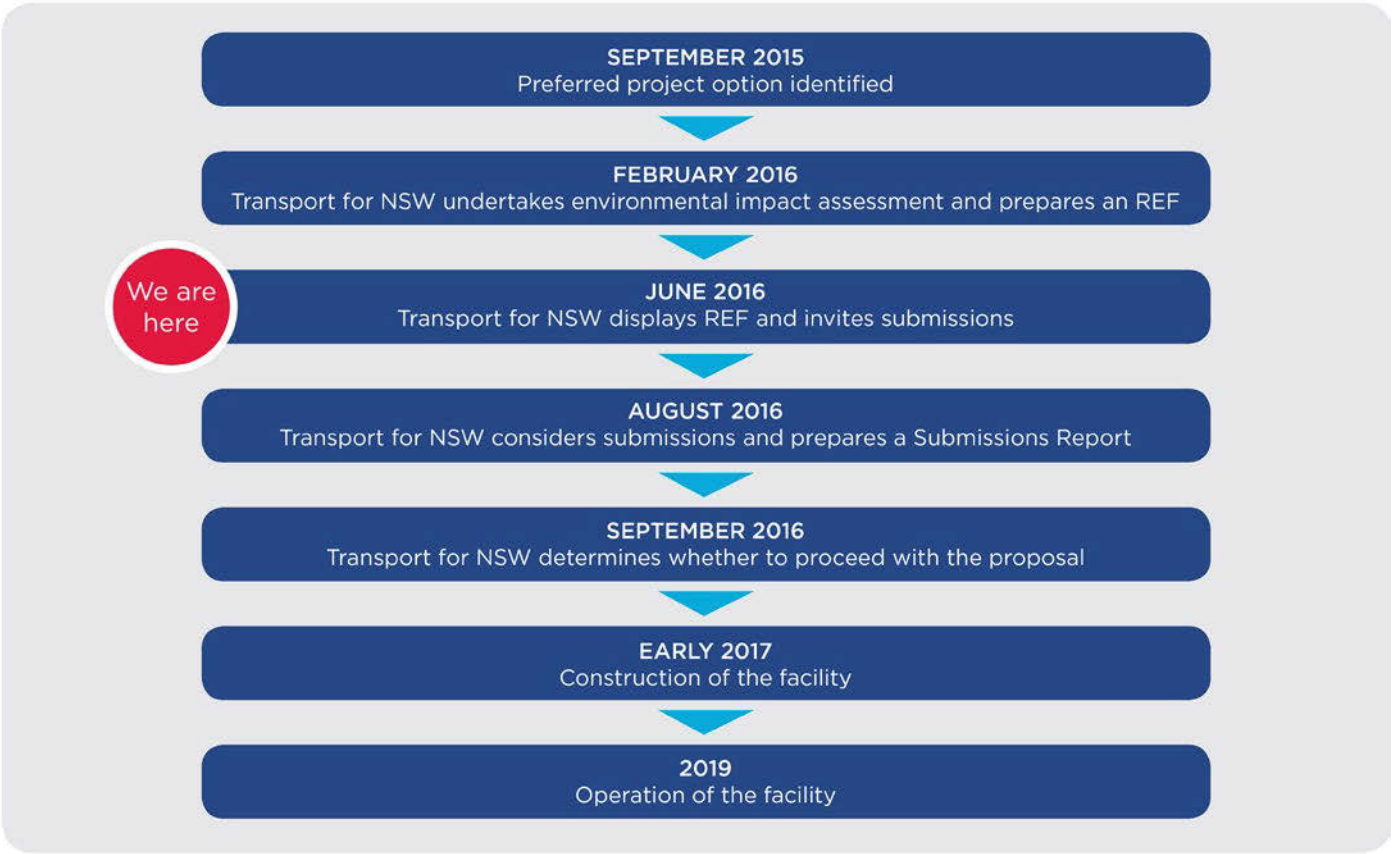
- biodiversity
- noise and vibration
- visual and landscape character
- Aboriginal heritage
- non-Aboriginal heritage
- traffic and transport
- water quality, hydrology and drainage
- air quality
- social
- groundwater.

The key potential impacts identified in the REF and proposed high level mitigation include:

Subject	Proposed key potential impact	Proposed key mitigation
Biodiversity	Loss of existing vegetation, some of which has been identified as threatened species and endangered ecological communities	Preparation of a vegetation management plan for the construction phase and the development of a biodiversity offset plan
Noise and vibration	Noise impacts during both construction and operation of the project	Preparation of noise and vibration management plans for construction and operation phases
Landscape and visual character	Changes to the rural-residential nature of the existing environment	Retaining existing vegetation where possible and undertaking revegetation with native species for visual screening
Traffic and transport	Increase in light and heavy vehicle use on local roads during construction	Preparation of a construction traffic management plan
Hydrology, flooding and groundwater	Potential for impact to both local flood levels and the facility by the 1:100 year flood event.	Preparation of a detailed flood impact assessment and design of the project to be out of the 1:100 year flood zone.
Aboriginal heritage	Impact currently undiscovered Aboriginal artefacts within the site	Preparation of an Aboriginal Cultural Heritage Assessment Report including further Aboriginal community consultation and archaeological test excavations

Specific mitigation plans outlining detailed mitigation measures will be prepared during the detailed design phase of the project.

The planning process



Have your say

As design and planning progresses, this is our first opportunity to provide more details to the community about the project. We want to continue to work with the community to understand local issues and identify appropriate mitigation measures.

The Review of Environmental Factors (REF) and concept design for the proposed maintenance facility will be on public display between **6 June to 4 July 2016**.

You can view the REF and project information at the following locations:

Wyong City Council Civic Centre
16 Hely Street, Wyong
Opening Hours: 8:30am to 5.00pm Monday to Friday

Tuggerah Library and Council Services
50 Wyong Road, Tuggerah
Opening Hours: 9:00am to 5:30pm Monday to Friday
9.00am to 3.00pm Saturday

Transport for NSW
Level 5, Tower A, Zenith Centre,
821 Pacific Highway, Chatswood
Opening Hours: 8:30am to 5.00pm Monday to Friday

Department of Premier and Cabinet Office
Level 3, 131 Donnison Street, Gosford
Opening Hours: 9.00am to 5.00pm Monday to Friday

Or visit the project website
www.transport.nsw.gov.au/projects

Community information sessions

Transport for NSW will be holding two community information sessions during the public display period. These sessions will provide an opportunity for interested members of the community to find out more about the project and the REF. Members of the project team will be available to answer your questions.

The details of these sessions are listed below:

Saturday 18 June
Drop in any time between **10am to 1pm**
Central Coast Steiner School
45 Catamaran Road, Fountaindale NSW

Thursday 23 June
Drop in any time between **4pm to 7pm**
Central Coast Steiner School
45 Catamaran Road, Fountaindale NSW

Formal submissions

Feedback on the project can be given by filling in a form at the community information sessions or by:

- emailing **projects@transport.nsw.gov.au**
- visiting **haveyoursay.nsw.gov.au**
- writing to **New Intercity Fleet Maintenance Facility**
  Principal Manager Environmental Impact Assessment
  Transport for NSW
  Locked Bag 6501
  St Leonards NSW 2065

All submissions must be in writing and received by 5pm on Monday 4 July 2016.

Next Steps

Following the close of the public display period, Transport for NSW will consider all submissions received from the community and respond to this feedback.

A Submissions Report will be prepared by Transport for NSW and made publically available. The project team will write to those who made a submission to advise them when the report is available.

Subject to planning approval, preliminary construction work on utilities and road access including the new bridge is expected to begin in early 2017.

The project team is committed to keeping the local community updated on the progress of planning and construction of the new maintenance facility.

Contact us

For more information:
email **projects@transport.nsw.gov.au**
call **1800 684 490**
or visit **transport.nsw.gov.au/projects**

This document contains important information about public transport projects in your area. If you require the services of an interpreter, please contact the Translating and Interpreting Service on **131 450** and ask them to call Transport Projects on **(02) 9200 0200**. The interpreter will then assist you with translation.

Appendix D: Flood Mitigation Options – Impact Mapping

Appendix D

FIGURE D1
PEAK FLOOD LEVEL IMPACT
OPTION FM3
MILLS STREET INDUSTRIAL PRECINCT LEVEE
1% AEP EVENT

N

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 0.1 0.2 0.4 0.6 km

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FIGURE D2
PEAK FLOOD LEVEL IMPACT
OPTION FM4
UNIVERSITY OF NEWCASTLE OURIMBAH CAMPUS
LOWER CARPARK LEVEE
1% AEP EVENT

N

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 25 50 100 150 200 m

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FIGURE D3
PEAK FLOOD LEVEL IMPACT
OPTION FM6
CANNTREE ROAD LEVEE
0.5% AEP EVENT

N

Canntree Rd Levee

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 100 200 400 600 m

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FIGURE D4
PEAK FLOOD LEVEL IMPACT
OPTION FM8
BAILEYS ROAD DIVERSION CHANNEL
1% AEP EVENT

N

Baileys Rd Diversion Channel

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 0.25 0.5 1 1.5 km

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FIGURE D5
PEAK FLOOD LEVEL IMPACT
OPTION FM9
INCREASING LEES BRIDGE CONVEYANCE CAPACITY
0.5% AEP EVENT

N

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 100 200 400 600 m

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FIGURE D6
PEAK FLOOD LEVEL IMPACT
OPTION FM13
CUT ROCK CREEK BASIN
1% AEP EVENT

N

Cut Rock Creek Basin

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 0.25 0.5 1 1.5 km

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FIGURE D7
OPTION FM14
COMBINED OPTION FM13 AND FM8
TUGGERAH ST AND CUTROCK RD NEAR PLUIM PARK
1% AEP EVENT

N

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

0 100 200 400 m

A B C D E F G

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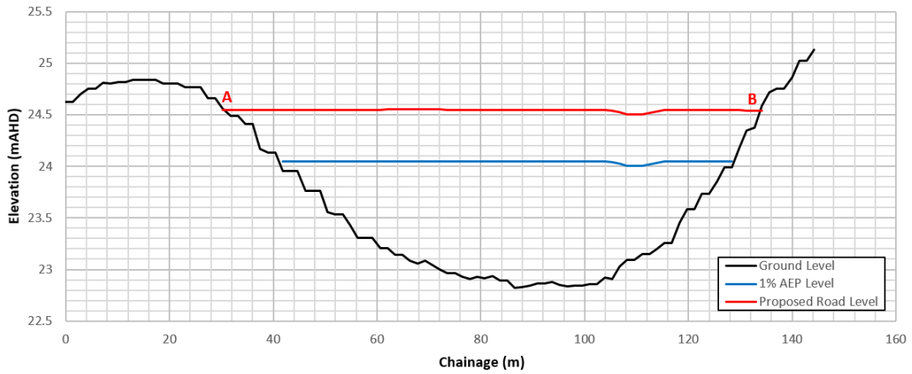
Appendix E: Flood Mitigation Options – Concept Designs

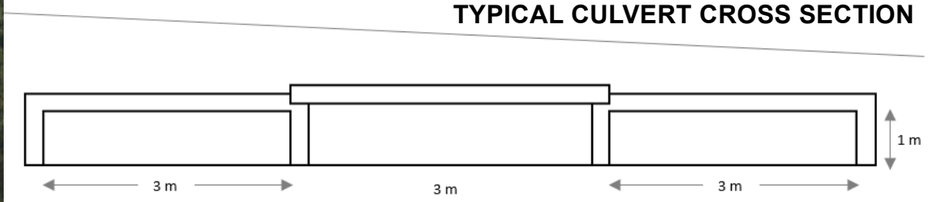
Appendix E

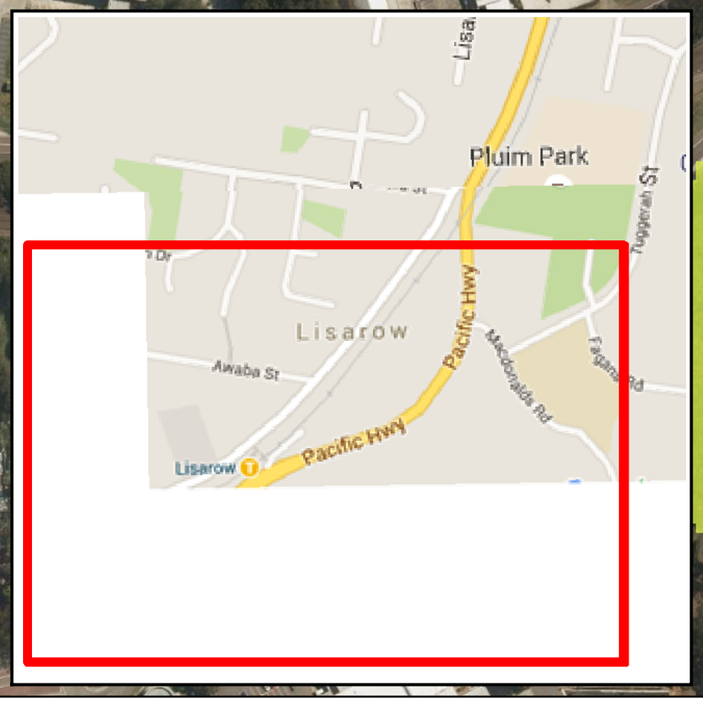
FIGURE E1
OPTION RM1
IMPROVEMENTS TO FLOOD ACCESS ROAD
TUGGERAH ST AT PACIFIC HIGHWAY

MACDONALDS RD ROAD RAISING



TYPICAL CULVERT CROSS SECTION





A

B

Updated Culverts
Road Raised

Change in Flood Level (m)

< -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.02
No Impact
0.02 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
> 0.3
No Longer Flooded
Newly Flooded

N

0 25 50 100 150 200 m

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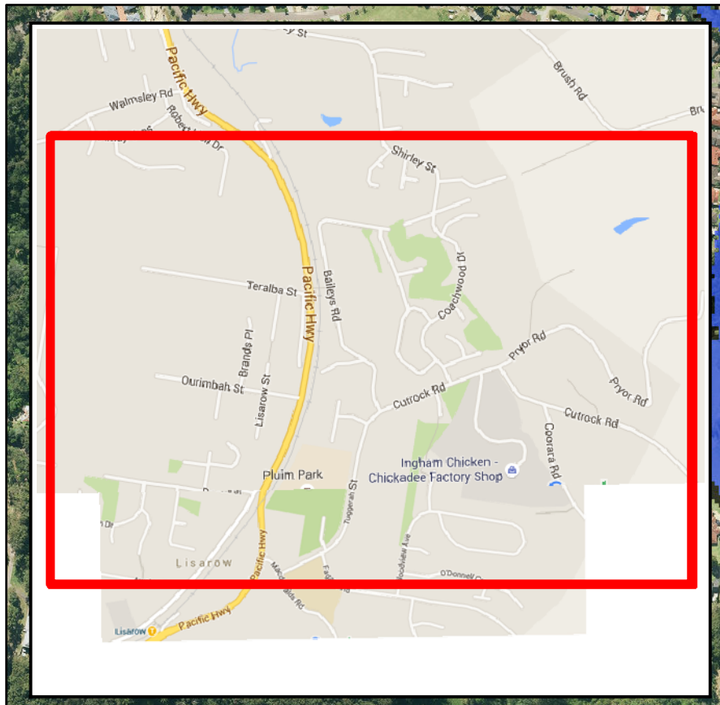
FIGURE E2
OPTION FM14
IMPROVEMENTS TO FLOOD ACCESS ROAD



Road Raised
Levee
Channel

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N

0 50 100 200 300 400 m

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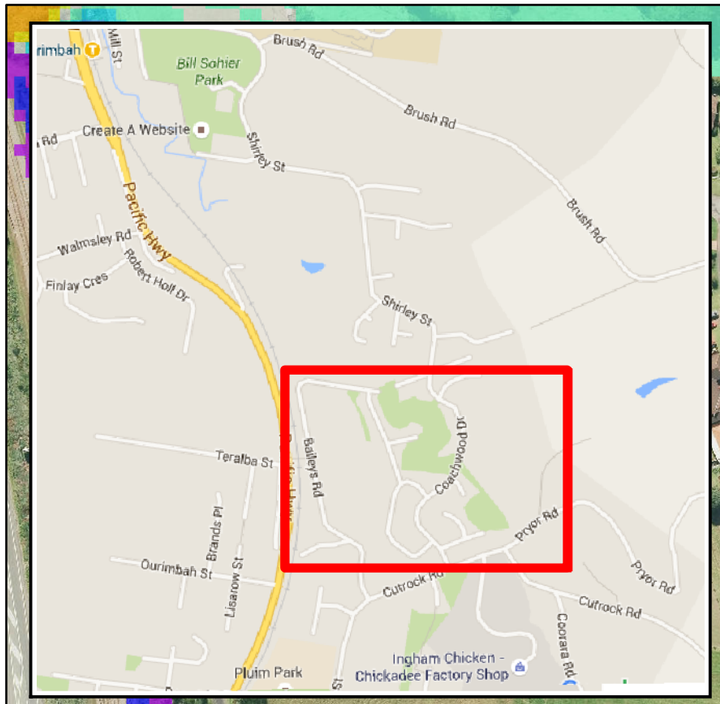
FIGURE E3
OPTION RM3
IMPROVEMENTS TO FLOOD ACCESS ROAD
COACHWOOD DR NORTH OF MAHOHANY CL



Updated Culverts
Road Raised

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N

0 50 100 200 300 400 m

TYPICAL CULVERT CROSS SECTION

COACHWOOD DR ROAD RAISING

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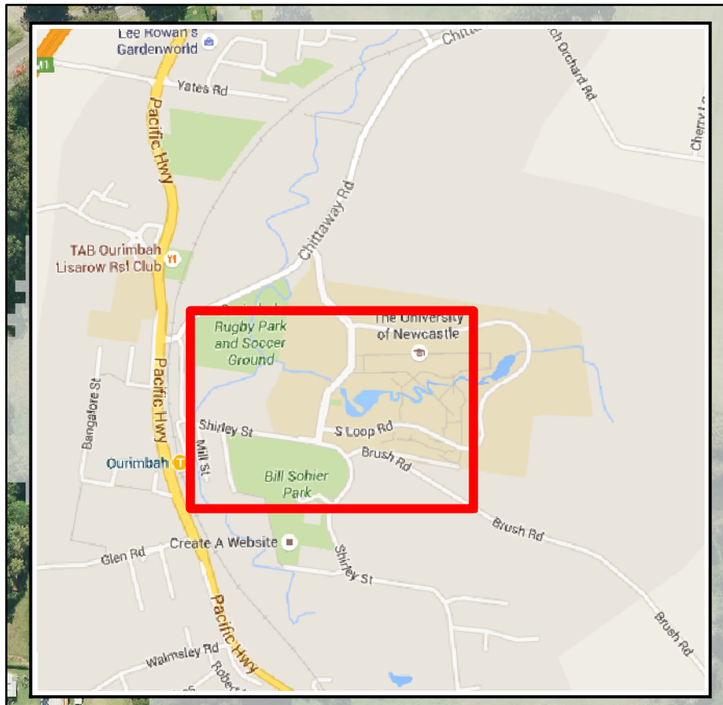
FIGURE E4
OPTION RM4
IMPROVEMENTS TO FLOOD ACCESS ROAD
THE BOULEVARDE AND UNIVERSITY OF NEWCASTLE
OURIMBAH CAMPUS



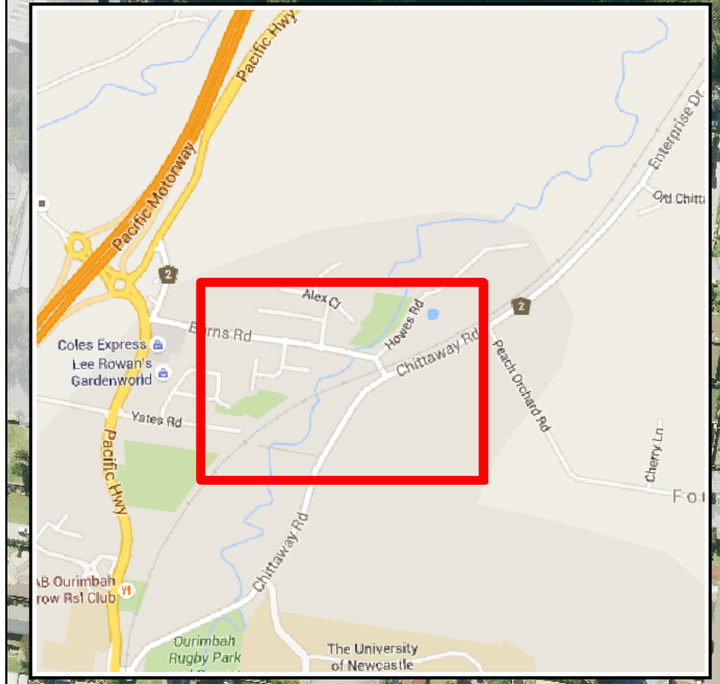
C - TYPICAL CULVERT CROSS SECTION

B - TYPICAL CULVERT CROSS SECTION

THE BOULEVARDE ROAD RAISING

J:\Jobs\115046\Arc\ArcMaps\Draft_Revision_Figures\Appendix_E\FigureE4_Option_RM4_The_Boulevard_Flood_Access_Concept_Design.mxd

FIGURE E5
OPTION RM5
IMPROVEMENTS TO FLOOD ACCESS ROAD
CHITTAWAY RD NEAR BURNS RD



Road Raised

Change in Flood Level (m)

- < -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- No Impact
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- > 0.3
- No Longer Flooded
- Newly Flooded

N

0 50 100 200 300 400 m

CHITTAWAY RD ROAD RAISING

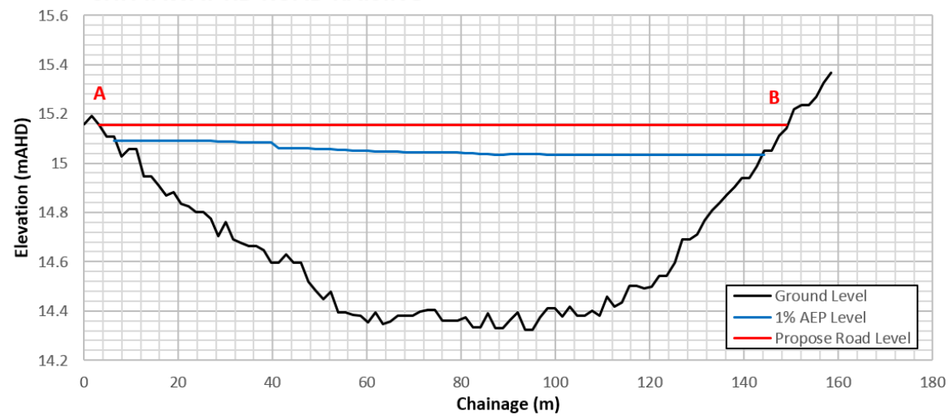


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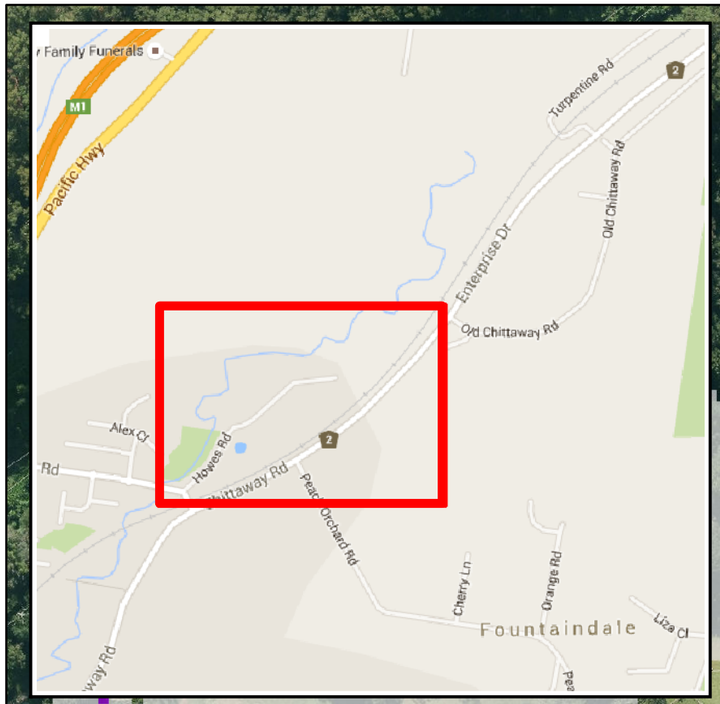
FIGURE E6

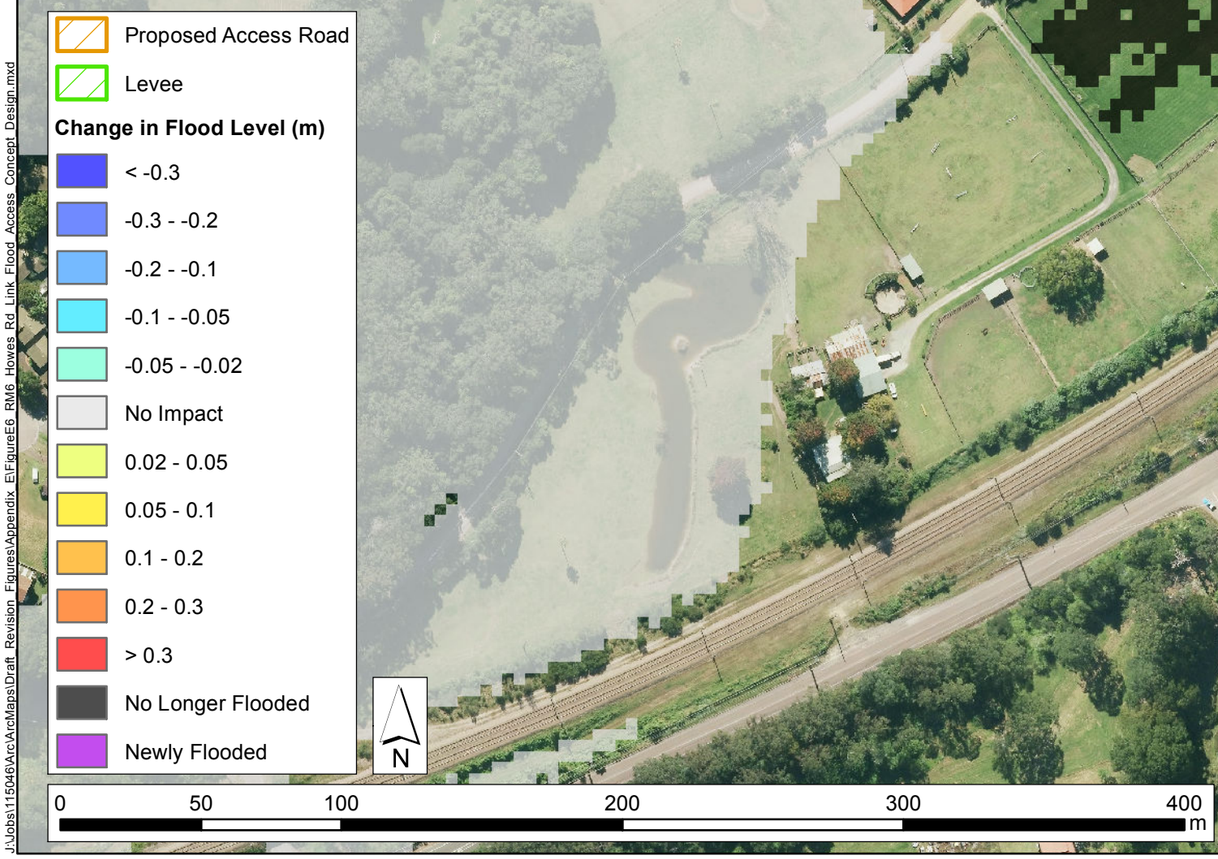
OPTION RM6

IMPROVEMENTS TO FLOOD ACCESS ROAD

ENTERPRISE DR NEAR OLD CHITTAWAY RD

HOWES ROAD LINK





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Appendix F: Consultation Letters

Appendix F

Roads and Maritime Services
205 New England Highway
Hexham NSW 2322

Letter16062015_Ourimbah_FRMSP_RMS_Information_Request.docx

16 June 2016

Attention: Craig Walker

Dear Craig,

Re: Ourimbah Creek Catchment – Floodplain Risk Management Study and Plan

WMAwater are currently undertaking a Floodplain Risk Management Study and Plan (FRMSP) for the Ourimbah Creek catchment on behalf of Wyong and Gosford Councils (Council). The aim of this study is to identify and ameliorate flood risk. There are three main issues that RMS may be able to provide advice on. These are:

1. **Early Warning Notification of Road Closures -** The potential for utilising RMS Variable Messaging System (VMS) or addition of new signage on the Pacific Highway at Ourimbah to provide early notification of road closures on Burns Road, Chittaway Road and Shirley Street due to flooding.

2. **Macdonalds Street Upgrade -** Is information available relating to the new design alignment and level of the Macdonalds Street exit with the proposed upgrade of Pacific Highway HW10, Ourimbah Street to Parsons Road, Lisarow?

3. **RMS Stream Gauges –** Council have noted that RMS have installed stream gauges on Cut Rock and Bangalow Creeks to record base flow for the above mentioned upgrade of the Pacific Highway. Can these gauges be left in situ for use by Council for automatic road closures?

Further details for the above listed questions are provided below.

Early Warning Notification of Road Closures

Three roads that are frequently flooded have been identified as posing a significant risk to motorists during flood. These roads are:

- Burns Road;
- Chittaway Road; and
- Shirley Street.

WMAwater Pty Ltd (Formerly Webb McKeown and Associates) **ABN 14 600 315 053**

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Level 2, 160 Clarence St, SYDNEY NSW 2000
Phone: 02 9299 2855 Fax: 02 9262 6208
Email: enquiry@wmawater.com.au
Website: wmawater.com.au

The location of these roads are presented in Image 1 and are numbered accordingly. The NSW SES make numerous rescues every year on these roads, and in particular, on Burns Road.

Image 1: Frequently Flooded Roads

As part of this FRMSP, WMAwater are undertaking a feasibility assessment to determine the viability of utilising RMS VMS to notify motorists of road closures on these roads due to flooding. It is hoped that motorist will then make informed decisions and select a different route, thus avoiding these roads during periods of high flow. Currently, these roads are closed during flood, however motorists have been frequently ignoring warning signs and road closures and attempting to pass flooded roads.

It is envisaged that a stream gauge on Cut Rock Creek could be used to send automatic notification using telemetry to RMS once a set threshold has been exceeded. RMS could then apply a warning to motorists using the VMS.

In preliminary discussions with RMS it was noted that there could be various issues with using VMS, particularly relating to warning priority. WMAwater are seeking advice on whether this system could work and what issues there are to be overcome.

Additionally, if use of the VMS is not recommended, would RMS allow Council to install their own warning signs that could be automatically triggered when required?

Macdonalds Street Upgrade

RMS are currently undertaking the Upgrade of Pacific Highway HW10, Ourimbah Street to Parsons Road, Lisarow. A study undertaken by JACOBS (October 2014) indicates that the Macdonalds Street exit is to be upgraded (see Image 2).

The current road alignment between the Highway and Cut Rock Creek is frequently flooded. Is there any new information available about the alignment of this road, particularly related to the road crest level and the flood affectation of this exit?

Image 2: Macdonalds Street Exit Upgrade

Figure 1-2b | Overview of the road design

RMS Stream Gauges

Council have noted that RMS have installed stream gauges on Cut Rock and Bangalow Creeks to record base flow for the above mentioned upgrade of the Pacific Highway. Can these gauges be left in situ for use by Council for automatic road closures as per the methods outlined in the 'Early Warning Notification of Road Closures' section?

If any information related to the location of and data collected by these gauges could be provided that would be helpful.

Yours Sincerely,
WMAwater

Zac Richards
Associate

New Intercity Fleet Maintenance Facility
Principal Manager Environment Impact Assessment
Transport for NSW
Locked Bag 6501
St Leonards NSW 20165

17 June 2016

Attention: Principal Manager Environment Impact Assessment

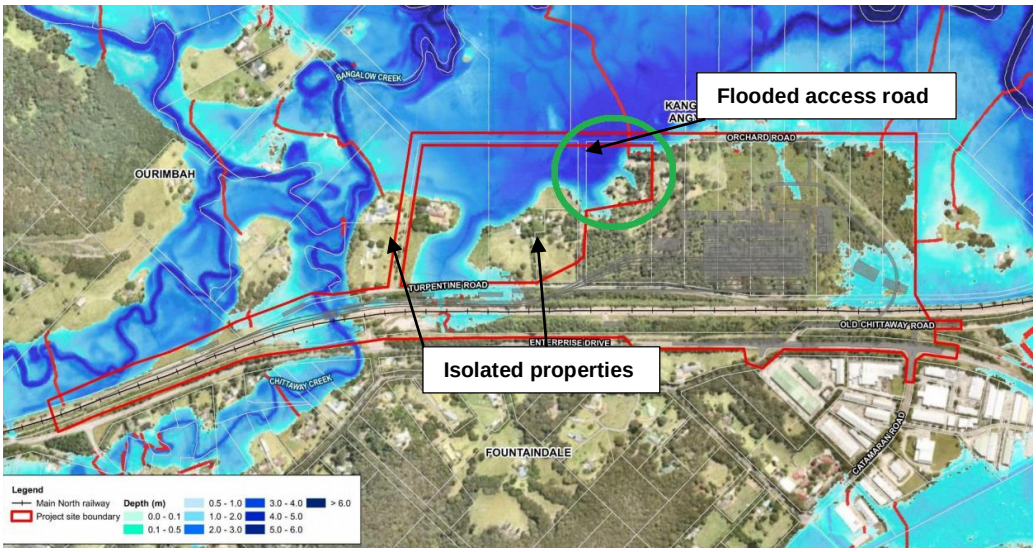
Re: New Intercity Fleet Maintenance Facility – Flooding Considerations

WMAwater are currently undertaking a Floodplain Risk Management Study and Plan (FRMSP) for the Ourimbah Creek catchment on behalf of Wyong and Gosford Councils (Council). The aim of this study is to identify and ameliorate flood risk.

WMAwater have reviewed the New Intercity Fleet Maintenance Facility (the Facility) Report and would like to provide the following feedback:

1. The proposed 'New access bridge' that connects Enterprise Drive and Orchard Road is beneficial from a flood risk mitigation perspective as it provides flood free access for events up to and including the 1% AEP to properties on Orchard Road.

2. Even with construction of the 'New access bridge', properties on Turpentine and Ourimbah Roads will still be isolated during flood as the intersection of Orchard and Ourimbah Roads is flooded by in excess of 2 m during the 0.2EY event (see image below).



WMAwater Pty Ltd (Formerly Webb McKeown and Associates) **ABN 14 600 315 053**

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Level 2, 160 Clarence St, SYDNEY NSW 2000
Phone: 02 9299 2855 Fax: 02 9262 6208
Email: enquiry@wmawater.com.au
Website: wmawater.com.au

WMAwater request that consideration is given to road raising or providing alternative access routes for properties on Turpentine and Ourimbah Roads as part of the proposed Facility. Significant benefit could be achieved in terms of flood risk mitigation for properties on these roads if improved flood access is provided.

Yours Sincerely,
WMAwater

Zac Richards
Associate

Contact Details:
Email: richards@wmawater.com.au
Phone: 9299 2855

Roads and Maritime Services
Services Central Coast Office
Locked Bag 2030
Hexham NSW 2322

20 June 2016

Attention: Craig Leckie

Dear Craig,

Re: Ourimbah Creek Catchment – Floodplain Risk Management Study and Plan

WMAwater are currently undertaking a Floodplain Risk Management Study and Plan (FRMSP) for the Ourimbah Creek catchment on behalf of Wyong and Gosford Councils (Council). The aim of this study is to identify and ameliorate flood risk.

One of the main sources of flood risk in the Ourimbah Catchment is flooded roads. Numerous roads throughout the Catchment are frequently flooded by high hazard flows. As part of this FRMS&P, WMAwater have identified roads which are of key concern. The existing Macdonalds Road exit is one of these roads.

The Pacific Highway Upgrade – Ourimbah Street to Parsons Road, Lisarow, Draft REF submission report (October 2015) indicates that the existing Pacific Highway exit at Macdonalds Road is to be replaced by an exit directly onto Tuggerah Street. WMAwater have examined flood affectation of the proposed exit based on the above mentioned report and make the following comments:

- The exit is flooded in the 0.5EY event and potentially more frequent events not modelled.
- In the 0.2EY flood the exit experiences depths > 0.5 m and velocities of ~1 m/s. Based on new guidelines *(Managing the floodplain: a guide to best practice in flood risk management in Australia, Australian Government, 2013)* the flood hazard at this exit is classed as H3 which means that it is unsafe for all vehicles.
- In the 1% AEP flood the exit experiences depths > 1.8 m and velocities >1.5 m/s, placing flooding of the proposed exit in the H5 flood hazard classification. This poses an extreme risk to motorists.

In light of the above, it is noted that motorists using the proposed Pacific Highway Tuggerah Street exit at times of flood are subject to high levels of risk. Due to the frequency at which this exit is flooded, risk to life is particularly high.

WMAwater Pty Ltd (Formerly Webb McKeown and Associates) **ABN 14 600 315 053**

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WMAwater recommend that the proposed Tuggerah Street exit be examined as part of the detailed design for Pacific Highway upgrade between Ourimbah Street and Parsons Road. Providing flood free access for the 1% AEP event at this location will significantly reduce flood risk within the catchment.

Yours Sincerely,
WMAwater

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Appendix G: Copy of WMAwater – Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2, December 2014 (Reference 10) and Summary from Bangalow Creek & Cut Rock Creek Floodplain Management Plan (Reference 11)

Appendix G

Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2

wma water

DECEMBER 2014

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Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2

DECEMBER 2014

Project **Review of Bangalow Creek and Cut Rock Creek Floodplain Management Plan – Area G2**	Project Number **111076**
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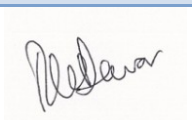
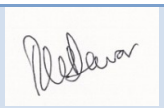
Authors Richard Dewar	**Prepared by** 
Date 11 December 2014	**Verified by** 

Revision	Description	Date
1	Final Draft	April 2014
2	Final	11 December 2014

REVIEW OF BANGALOW CREEK AND CUT ROCK CREEK FLOODPLAIN MANAGEMENT PLAN – AREA G2

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FOREWORD

The NSW State Government's Flood 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 subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

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

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management Study***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***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.

This report provides a review and update of Stage 3 of the above; namely Area G2 – Pluim Park/Tall Timbers estate/Mannings Road of the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan as an interim measure until a more detailed assessment of the catchment can be undertaken in a Floodplain Risk Management Study.

The Ourimbah Creek catchment, of which Cut Rock Creek is a tributary, was recently reviewed by Wyong Shire and Gosford City Councils following receipt of a government grant to undertake a Flood Study. However it may be in excess of 12 months before a Floodplain Risk Management Study & Plan for this area is reviewed as part of the floodplain risk management program process as detailed above.

This report provides the basis for the interim management of flood prone lands within Area G2 of the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan based upon existing flood information as of the date of this review. No additional investigation of surrounding land included within the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan was undertaken as part of this review.

EXECUTIVE SUMMARY

Gosford City Council is continually reviewing previously completed floodplain management plans within its LGA. The present study is a desktop review of the 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan (Area G2 – Pluim Park/Tall Timbers estate/Mannings Road) and was undertaken due to the inability for residents of the Tall Timber estate to ingress or egress the estate during frequent storm events experienced on several occasions in 2011, 2012 and 2013.

The outcome is reported as an addendum to the current Floodplain Management Plan and is viewed as an interim measure to ascertain whether any short term measures could be implemented to reduce the risk to life. In the long term, it is Council's intention to review the 1997 Floodplain Management Study and Plan as resources become available.

The study area is located immediately upstream of the Pacific Highway at Lisarow and includes Pluim Park, the 14 houses within the Tall Timbers estate and the 6 houses on Mannings Road.

The work included a review of all flood related information and the issuing of a newsletter and questionnaire. This was followed by a public workshop held on 30th January 2012 and subsequent investigation and review of the outcomes of both the questionnaire and workshop. An additional public workshop was convened on 17th June 2013 to discuss the contents of the Draft Addendum.

The main outcomes of this review are:

1. The access road from Tuggerah Street to Tall Timbers estate is privately owned. The road level is not considered to be in accordance with current best practice in floodplain management due to its vulnerability to be cut in minor frequent storm events (potentially several times a year). Construction of an upgraded bridge or high level footbridge on privately owned land to improve access and funded by Council does not conform with Council's responsibilities. The responsibility for upgrading the road should rest with the private owners of the access road. Raising of the access road would provide benefit in minor frequent storm events only and may place people at greater risk in another part of the floodplain.

2. The proposed access via the railway maintenance track during rare flood events was not formalized at the time of development of the site and the area has since been fenced off to the public. Council has approached Railcorp regarding permission for Council to construct an elevated pedestrian/cycleway alongside the railway line on Railcorp land to provide flood free pedestrian access from the estate.

   A pedestrian footbridge over the railway line near Ourimbah Street Lisarow has also been considered however Railcorp have safety concerns.

3. All past works on Pluim Park have been approved and any addition of topsoil has been undertaken in a manner that complies with Council's conditions of development consent. All development assessments for Pluim Park ensure works do not exacerbate flooding. Council is

liaising with the Central Coast Football Club to incorporate works to reduce the volume of topsoil reported as washing off the site during frequent storm events.

4. Council does not undertake creek maintenance on privately owned land where there is no easement in place. Council would only consider such works if a life threatening or similar situation arose. Dredging or clearing within the easement will reduce flood levels and the frequency of overtopping of the private access road but the benefit will be very minor unless the capacity of the waterway opening under the access road is significantly increased.

5. Council will clear debris or fallen trees which are causing a blockage in main drainage infrastructure or on local roads. Residents wanting debris removed from their property are responsible for the organisation and payment for the works either through Council's household pick up service or a private company. If an area is declared a Natural Disaster area, government funding could be made available for clean up through the appointed Recovery Committee.

6. Council has an annual program for road inspection, maintenance and upgrading. Any road works necessary are prioritised within the limits of the funds available. Council does not maintain privately owned access roads e.g. the access road to Tall Timbers estate.

7. As an outcome of the 1997 Floodplain Management Plan, the house at 7 Mannings Road was raised as part of a development application for an extension to the existing dwelling. No other houses have been raised in the study area but would be considered on their merits if an application was made. There are no houses within the Tall Timbers estate with habitable floors below the 1% AEP flood level.

8. All houses in this area have on-site sewer management (OSSM) systems which are generally difficult to access for maintenance purposes, are situated close to a permanent water body and are easily affected by floods. As this estate is situated in an area of the floodplain, these types of systems would not be approved under current regulations.

   Council is currently preparing a Master Plan which will identify several priority 'investigation areas' which are not currently sewered but identified as requiring sewer service primarily due to OSSM problems. Should Tuggerah Street be identified as a priority area, the cost of connection would need to be borne by the residents at a rate negotiated with Council.

9. Gosford City Council, in conjunction with NSW SES, is in the process of preparing additional flood intelligence for the Gosford City Local Flood Plan for Tall Timbers Estate. The NSW SES will undertake a flood safety awareness program for the residents. Gosford City Council has installed a flood warning system. The construction of a safe refuge in the estate for flood events larger than the 1% AEP (sometimes referred to as vertical evacuation or shelter in place) would ensure that residents remain dry in events larger than the 1% AEP. However this measure does not eliminate the risk to life for the entire community.

10. Voluntary purchase of all houses in Tall Timbers estate is unlikely to receive funding from state or federal government authorities because the house floors are only inundated in events larger than the 1% AEP, consequently this option will have a very low benefit cost ratio.

11. Development controls will ensure that any future development are constructed in accordance with best practice but will not reduce the risk to life of the road access.

12. Gosford City and Wyong Shire Councils commissioned a new Flood Study of the Ourimbah Creek catchment, which includes the Cut Rock Creek catchment. The new flood study incorporates more technologically advanced computer modeling (use of a 2 dimensional hydraulic model) than used in the previous study together with the use of detailed up to date ground survey (ALS). The 2013 Ourimbah Creek Flood Study supersedes the 1994 Bangalow Creek and Cut Rock Creek Flood Study. A review of the Bangalow Creek and Cut Rock Creek Floodplain Management Study and Plan will be undertaken based on the updated flood modeling information as funding becomes available.

A glossary of flood related terms is provided in Appendix A.

1. INTRODUCTION

1.1. Background

The Bangalow Creek and Cut Rock Creek Floodplain Management Plan was completed in March 1997 (by Webb McKeown & Associates – now trading as WMAwater) and followed on from completion of the Management Study in 1996 and the Flood Study in 1994.

Gosford City Council's Floodplain Risk Management Committee Meeting of 22nd September 2011 recommended that a desktop review of the Cut Rock Creek Floodplain Management Plan (Area G2 – Tall Timbers estate) be undertaken as a matter of urgency due to the inability to access the estate during frequent storm events, with the outcomes to be reported as an addendum to the current Floodplain Management Plan.

Council adopted the recommendation and WMAwater was engaged in December 2011 to undertake the review. Figure 1 (taken from Google Maps) indicates the study area and Photo 1 shows the vehicular entrance to Tall Timbers estate from Tuggerah Street.

Figure 1: Study Area (courtesy Google maps)

The development in the area consists of 14 houses in the Tall Timbers estate, 6 on Mannings Road and the soccer club house and associated facilities on Pluim Park. All the houses in the Tall Timbers estate have similar floor levels at approximately 22.9 m AHD (lowest floor level).

Photo 1: Tall Timbers estate access road taken from Tuggerah Street (courtesy Google maps)

1.2. History of Flooding

1.2.1. 1994 Cut Rock Creek Flood Study

A comprehensive description of previous flooding is provided in the 1994 Bangalow Creek and Cut Rock Creek Flood Study and a summary is as follows:

- Approximately 20 floods have been qualitatively recorded in the Cut Rock Creek catchment since 1974. The largest of these were January 1978, October 1985, February 1990 and February 1992 which reached approximately 22.5 m AHD at Tall Timbers estate,
- The design flood levels (m AHD) taken from the 1994 Flood Study at the access road are:
    - 1% AEP = 23.0
    - 2% AEP = 22.8
    - 10% AEP = 22.4 and
    - Extreme Flood (approximation of the PMF) = 24.1.

A selection of historical flood photographs is provided below.

Photo 2: Debris under Tall Timbers estate access road

Photo 3: Flood downstream of Pacific Highway (2012)

Photo 4: Tall Timbers estate access road (alignment in red) in flood viewed from Mannings Road (1991)

1.2.2. Updated Flood Modelling (2013)

The crest level of the access road to the estate is 20.6 m AHD. According to residents the access road is inundated on average once every 1 or 2 years. In 2011 to 2012 it was inundated 3 times and impassable and in 2013 it was inundated 7 times. The duration of overtopping varies from 2 to more than 6 hours.

As a joint project between Gosford City and Wyong Shire Councils, a comprehensive Ourimbah Creek Catchment Flood Study Review, of which Cut Rock Creek is a tributary, was completed whilst preparing this document. Results from the modelling indicate a slight reduction in design flood levels to those given in the 1994 Flood Study. This is due partly to channel works constructed downstream since the 1994 Flood Study and improved modelling technology and survey detail available today. The results in Table 1 are taken from the 2013 Flood Study.

	AEP and Level in m AHD			
Location	**10%**	**2%**	**1%**	**PMF**
Tuggerah Street	23.67	23.86	23.81	24.59
Tall Timbers estate (access bridge)	21.93	22.29	22.47	23.81
Main North Railway (upstream)	21.78	22.18	22.38	23.69

Table 1: Design Flood Levels from the 2013 Ourimbah Creek Flood Study

1.2.3. Additional Flood Related Information

In the past gauges (termed Maximum Height Recorders or MHRs) recorded the peak level of floods along the creek system. There is an automatic water level recorder upstream of Tall Timbers estate in Tuggerah Street and records can be obtained from Manly Hydraulic Laboratory (MHL). In addition, there was a proposal as part of this investigation to install additional automatic water level recorders in the area with the potential to link them to some form of warning system. A water level recorder with real time data relay to MHL has now been installed at the private access bridge and SMS messages can be issued to residents advising

them that the bridge is about to be submerged.

Many residents have questioned why there has been so much flooding and overtopping of the Tall Timbers access road in the last few years. Some have thought it may have been due to the boulders placed downstream, increased sedimentation or some other man made or natural cause. The flooding may be due to increased rainfall as indicated by the annual rainfall graph (Figure 2) at Mt Elliot (located approximately 3 kms to the south east of Lisarow) which indicates significantly more rain from 2008 than in the period prior. However it should be noted that flooding occurs as a result of intense rain over a short period of time and annual rainfall statistics cannot reflect this.

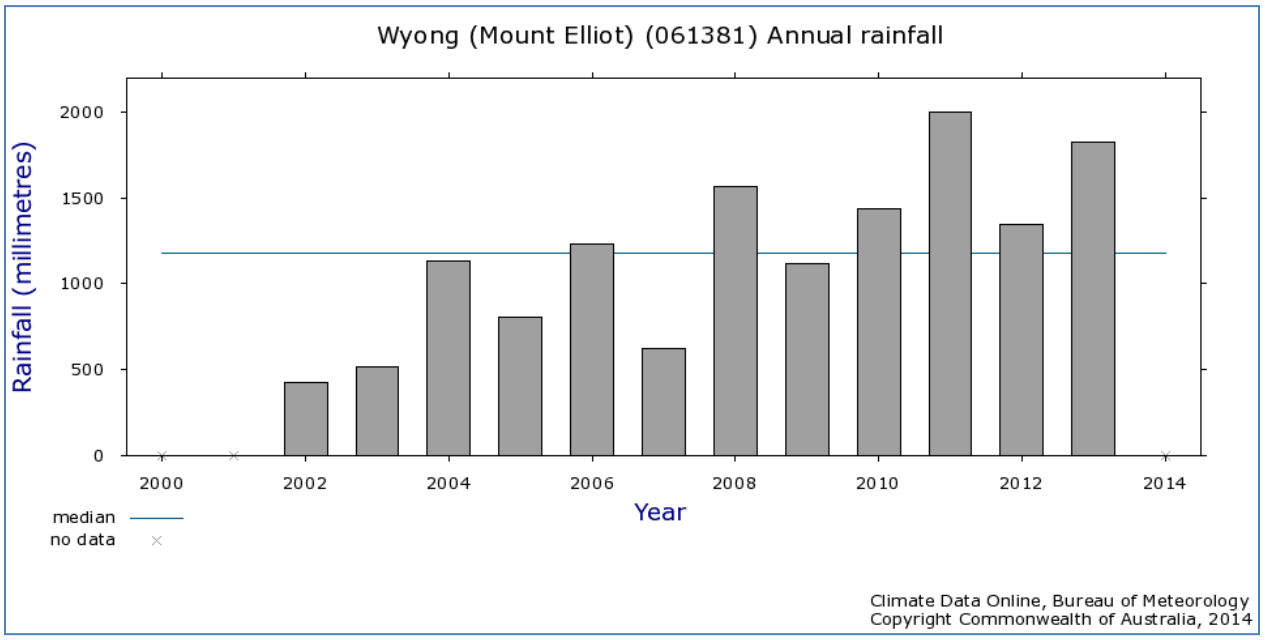

Figure 2: Mt Elliot Annual Rainfall

1.3. Scope of Work

The scope of work for WMAwater to undertake this review encompassed the following stages:

- review of all flood related information;
- prepare and mail out a newsletter and questionnaire (copy of this is provided in Appendix B**)** to all residents on Mannings Road and in the Tall Timbers estate (approximately 20); analyse results of the questionnaire (copy of this is provided in Appendix B);
- prepare and attend public workshops (held on 30th January 2012 at the Ourimbah-Lisarow RSL club and 17 June 2013 at Gosford City Council Administration Office);
- review all comments from the public, address issues, liaise with Council;
- review 1997 Bangalow Creek and Cut Rock Creek Floodplain Management Plan (Area G2) and prepare this report.

However, as investigations were undertaken to address issues raised by both the residents and Council officers, the scope of work was increased.

1.4. Public Workshops

1.4.1. January 2012

A PowerPoint presentation was provided by WMAwater at the public workshop. The purpose of the public workshop was to ensure that the residents were aware of:

- Who is responsible for what aspects of the estate e.g. ownership of the access bridge and who is responsible for the creek maintenance?
- The history surrounding the development;
- Historical flood events and flood extents;
- The current 1997 Floodplain Management Plan and works undertaken in accordance with that plan;
- Emergency management issues in relation to the current NSW Floodplain Development Manual;
- Potential flood events in relation to projected climate change;
- Potential management measures, namely:
    - Property modification;
    - Flood modification;
    - Emergency Response.

The desired outcomes from undertaking the workshop were to:

- Reduce misunderstandings regarding who is responsible for maintenance on and around the estate;
- Reduce misunderstandings regarding the intent of works that have been undertaken as recommended in the 1997 Floodplain Management Plan;
- Ensure residents were aware of the specific safety issues;
- Obtain information on what the residents may find acceptable as management measures.

1.4.2. Additional Workshop in June 2013

An additional public workshop was held on 17th June 2013 in the Council Committee Room. The purpose of this workshop was to present the Draft Addendum to the residents to bring them up to date and ensure that they understood, and generally were in agreement with, the outcomes from Council's investigations. These investigations have been undertaken by Council staff in response to issues raised at the previous January 2012 public meeting. A newsletter was issued to residents (a copy of this is provided in Appendix B**)**. A PowerPoint presentation was provided by WMAwater at the workshop and a copy of the Draft Addendum issued to the participants.

A number of additional issues were raised at this workshop which have been addressed both with the individual and / or incorporated into this document.

2. ASSESSMENT OF FLOODPLAIN MANAGEMENT ISSUES

The key issues and proposed outcomes following the public workshops and subsequent reviews by Council are summarised in the sections below.

2.1. Access to estate Frequently Cut by Floodwaters

The frequency and risk to life associated with flooding of the privately owned access road is the main issue of concern to the residents of the Tall Timbers estate. It is understood that the proposed subdivision development was approved in 1986. A plan of the proposed development (Figure 3) indicates a low level access road from Tuggerah Street with emergency access via the "railway maintenance track" in rare flood events.

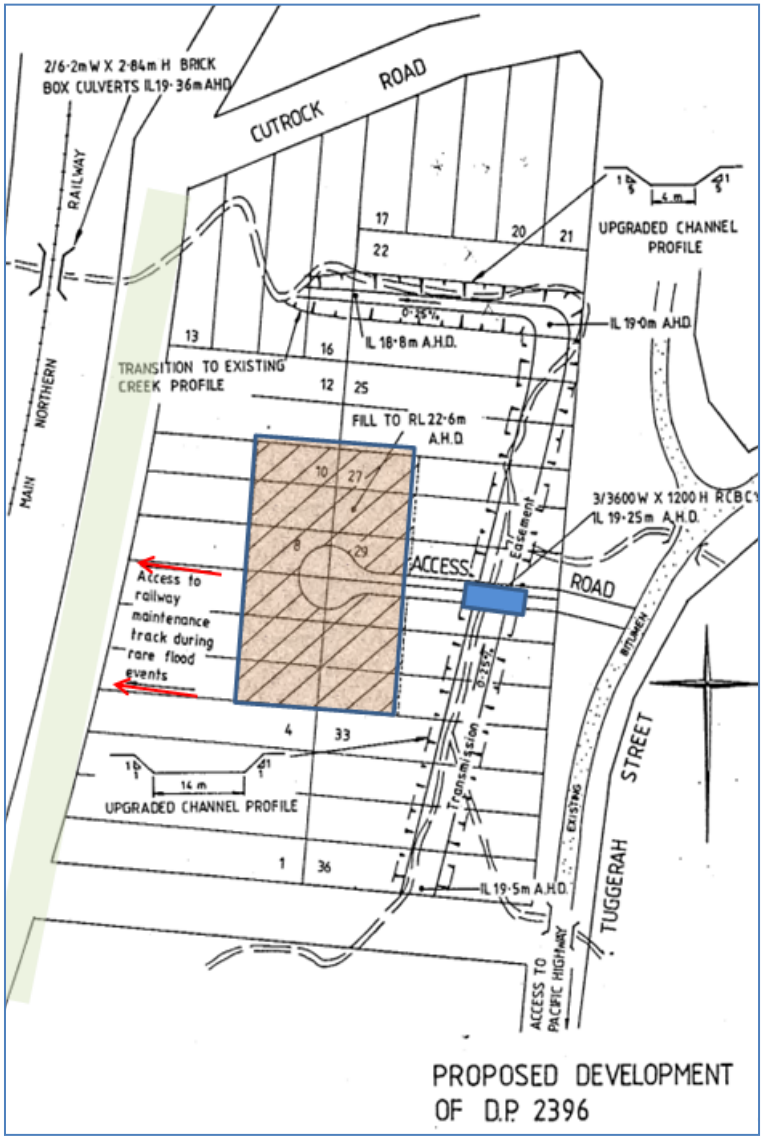

Figure 3: Development Plan circa 1986

For the 1980's design of the access bridge, the developer's hydraulic consultant estimated it would overtop in a storm event greater than the 20 year ARI (5% AEP) i.e. greater than approximately 20.6m AHD. This was deemed acceptable at that time. The modelling undertaken for the 1994 Flood Study of Cut Rock Creek indicated that the flood height for a 20

year ARI (5% AEP) was 22.6m AHD – a difference of approximately 2.0m AHD. The level of the deck of the access bridge is 20.6m AHD and is estimated to be overtopped in less than a 1 year ARI event (based on the 1994 Flood Study of Cut Rock Creek).

Figure 4 provides a typical cross section from west to east through the estate. ***Please note*** that the flood and ground levels are taken from the 2013 Ourimbah Creek Catchment Flood Study.

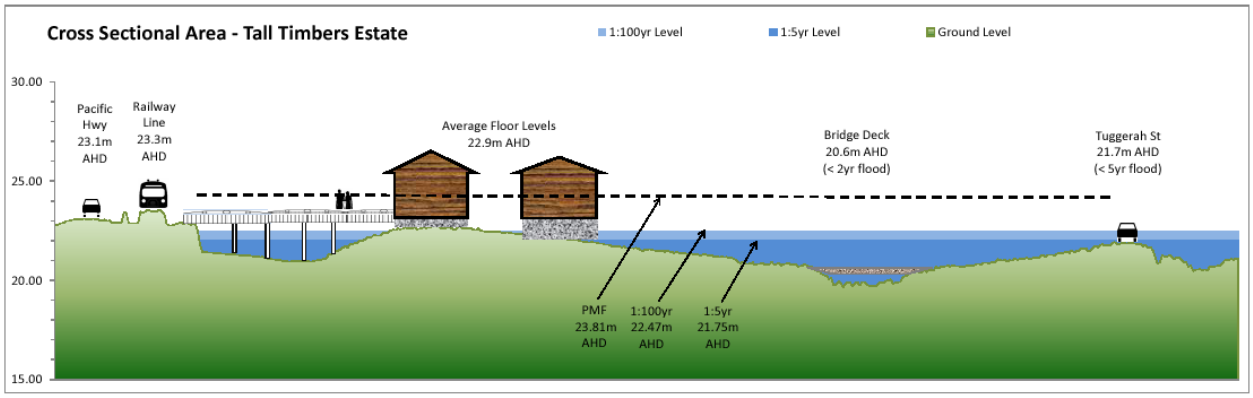

Figure 4: Cross Section of Tall Timbers estate showing flood heights

The outcome is:

a. The present level of access to Tall Timbers estate could be improved however, raising the access road would provide limited improvement in access as Tuggerah Street becomes impassable in approximately the 5 year ARI (20% AEP) flood event.

2.1.1. Raise Height of Private Access Road

The present frequency of overtopping of the access road (the only formal access to and from the estate) during floods is not in accordance with current best practice in floodplain management. The access road off Tuggerah Street is privately owned (this has been verified by searching of land titles) and therefore the responsibility of the owners of the estate to maintain, upgrade and replace when required.

The estimated cost to raise this road to equal the height of the adjoining public road i.e. Tuggerah Street is approximately $1M. Annual costs of approximately $25,000 would also be required to manage the overall life of the asset.

If Council were to consider taking ownership of the access road then it would set a precedent for all other privately owned access roads throughout its local government area. Council would also be required to purchase the land or acquire an easement over which the access road resides.

The cost to raise the section of the access road land within Council's road reserve to the level of Tuggerah Street is in the order of $40,000.

The outcomes are:

a. Should Council agree to take ownership of the access road it would set a precedent for other privately owned infrastructure and would need to procure an easement over the access road to ensure access for any future ongoing maintenance work.
b. Raising the access road would require a large number of culverts, or possibly a bridge structure, as well as raising the roadway adjoining either end of the structure. It is estimated that the cost to undertake this work is in the vicinity of $1M and $25,000 per annum to maintain the life of the asset.

2.1.2. Construct Pedestrian Bridge to Tuggerah Street

An alternative is to construct a pedestrian bridge capable of withstanding flood flows and potential frequent inundation. The cost for such a structure is estimated to be $840,000, however this would still only link to Tuggerah Street which is inundated in approximately the 5 year ARI (20% AEP) event

The outcome is:

a. Constructing an elevated pedestrian bridge would cost approximately $840,000.

2.1.3. Provide Pedestrian Access over Railway

The viability of the emergency access route indicated on the circa 1986 development plan (Figure 3) is unclear given that there is low lying land between the estate and the railway. No original approval from the relevant rail authority for use of their land for emergency access has been found. Regardless, this route is not available today as the railway is fenced to prevent access due to a fatality that occurred several years ago (it is understood that this is the reason why the overhead rail pedestrian footbridge near Teralba Street was constructed).

As a result there is no legal way of crossing the track. Construction of a pedestrian over bridge would cost in the order of $1.35M and the Rail Authority is reluctant to install more structures which will introduce an additional hazard to trains. It should be noted that an elevated path would also be required from the estate to any over bridge.

The residents of Tall Timbers estate are concerned that, with any new access to the estate from the west (railway side), there is the potential for increased loss of privacy or even higher risk of theft or similar. These concerns could be addressed with a gated access and/or additional street lighting.

The outcomes are:

a. There is no legitimate access across the railway.
b. Construction of a pedestrian over bridge would cost of the order of $1.35M.

2.1.4. Provide Emergency Access Route

NSW SES has indicated that if early evacuation is not possible or not undertaken, then the rescue of anyone trapped in Tall Timbers estate in an emergency during a flood could be

complex and resource intensive. The estate is surrounded by overhead power lines and densely forested on three sides with inadequate space for a helicopter evacuation. Also, the local roads would be inundated at the same time or very shortly after the access road, making evacuation by vehicle too dangerous.

Preliminary discussions have been held with Railcorp who has indicated that Council may be permitted to construct an elevated pedestrian/cycleway on railway owned land. Railcorp is also seeking permission to construct a bridge over Cut Rock Creek – from the western end of Mannings Road upstream of the present rail bridge - to gain vehicular access to their land for maintenance purposes. Railcorp indicated that they would erect another fence between the railway tracks and any proposed elevated pedestrian / cycleway.

A copy of the Concept Plan showing the proposed location and construction stages of the pedestrian / cycleway is shown as Figure 5. The total estimated cost of the elevated pathway is approximately $3.74M. The elevated pedestrian / cycleway should be capable of providing flood free access in a 100 year ARI (1% AEP) event to comply with current best practice for floodplain risk management. However, it will not provide safe access in a PMF event.

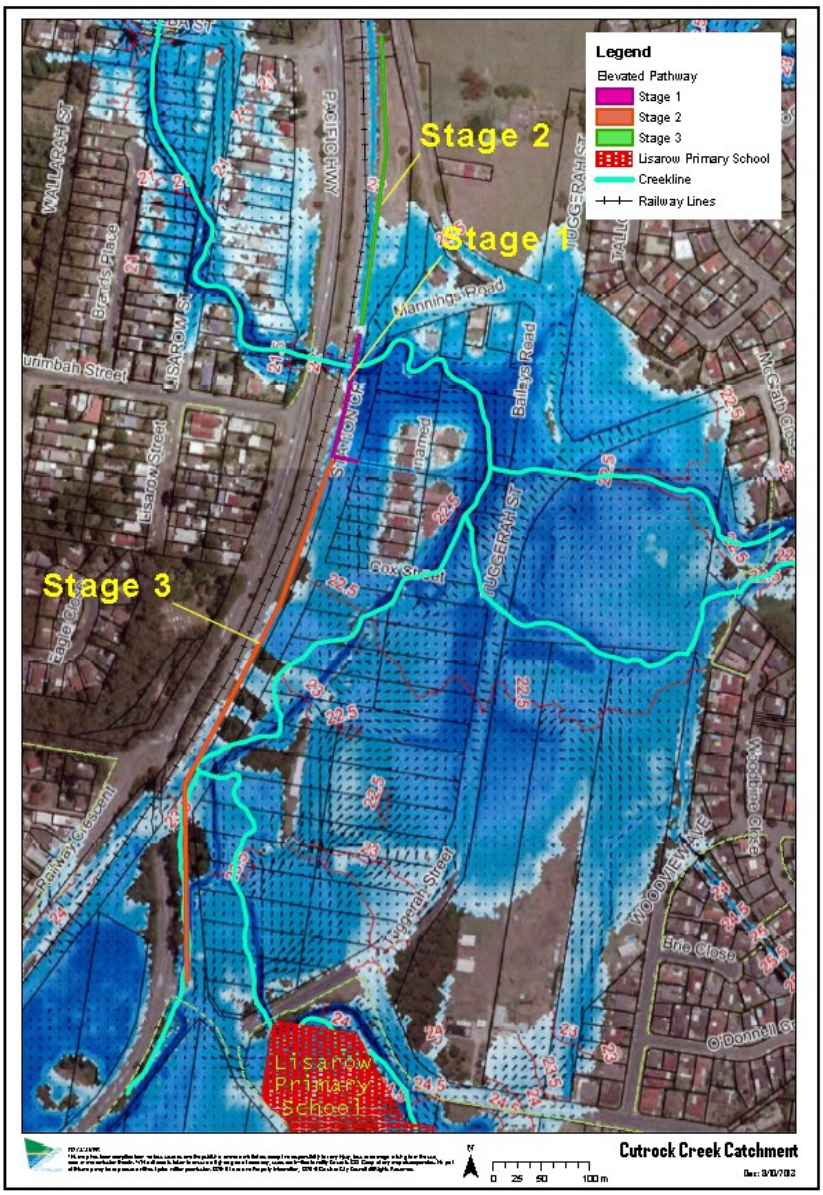

Figure 5: Proposed Pedestrian Emergency Access Route

It should be noted that this proposal is preliminary only and construction estimates could change. Further development of this proposal will depend on community acceptance, Council adoption of the concept design and Council's ability to attract funding towards each stage of the project. Prior to a detailed design being prepared, further negotiations will need to be undertaken with Railcorp, Wyong Council, Office of Environment and Heritage and also Roads and Maritime Services. Similar privacy and security risks as described in Section 2.1.3 are also relevant for this measure.

The proposal indicates that the pathway could be constructed in three stages with preliminary costs for each stage estimated as follows:

Stage 1: **Construction of an elevated pedestrian / cycleway providing access from Tall Timbers estate right-of-footway to the western end of Mannings Road.**
This would improve access and reduce the risk to life of residents on the estate. However, preliminary estimates indicate that Mannings Road is inundated in a 10 year ARI (10% AEP) storm event. Thus Stage 1 would only provide limited improvement however it would give residents flood free pedestrian access during the smaller more frequent storm events and additional time to evacuate to safety during larger events. The estimated cost of Stage 1 is $988,000.

Stage 2: Construction of elevated pedestrian / cycleway providing access from Mannings Road to railway pedestrian overbridge opposite Teralba Street.
As funding permits, the elevated pedestrian / cycleway (Figure 5 and Photo 5) could be further extended from Mannings Road to improve access to the railway pedestrian overbridge opposite Teralba Street. This would not only provide a safer pedestrian evacuation route to higher ground but would also improve the linkage between the various communities within both Wyong and Gosford Council areas. The estimated additional cost for this section is $594,000.

Stage 3: **Construction of elevated pedestrian / cycleway providing access from Tall Timbers estate right-of-footway to Macdonalds Road.**
The elevated pedestrian / cycleway could then be extended from the right-of-footway to link with Macdonalds Road. The access would provide a quicker, safer route to the local public school, Pluim Park gates and the Pacific Highway cycleway as well as to an area beyond the 100 year ARI (1% AEP) flood extent. This stage may require extensive bridging over the drainage paths at a cost of $2,158,000.

Photo 5: Example of an elevated pedestrian / cycleway

The outcomes are:

a. Construction of an elevated pathway is the only viable option that will provide safe access for the evacuation of residents from the Tall Timbers estate in floods up to the 100 year ARI (1% AEP) event.
b. There are potentially significant environmental issues with construction of the elevated pathway and these would need to be addressed with the respective authorities.

2.2. Pluim Park

The residents expressed the following concerns regarding Pluim Park:

- **Past or future works on Pluim Park have or might raise flood levels downstream.**
  All past developments since the mid 1990's have been assessed by Council to ensure that flood levels are not affected (this condition is the same for all potential developments on the floodplain). All future works at Pluim Park will be similarly assessed and thus it is concluded that this opinion is not supported by the available information.

- **Large amounts of top soil have been placed on the field which have reduced temporary floodplain storage (raising flood levels) and much of this has washed off and contributes to siltation at the culverts beneath the Tall Timbers estate access road.**
  Top dressing has occurred on the fields but the quantities involved have had an insignificant affect on the temporary floodplain storage capacity. During floods any exposed soil on the fields will be lost (as it will be for many other areas on the floodplain during a flood). There is no scientific documentation that confirms that the sand present beneath the Tall Timbers estate access road is from Pluim Park. During floods (Photo 6) there is likely to be significant amounts of erosion and subsequent mobilisation of sediment and vegetative matter transported downstream. All bridges, culverts and other structures have the potential to be affected; some may experience erosion of their abutments whilst others may have silt and debris deposited. Rivers are dynamic bodies and even during non-flood times siltation may occur, but generally to a lesser extent. Erosion and sedimentation are both natural phenomena and impossible to control, however both Pluim Park and Council will take steps to minimise this as far as is possible (for example reducing river velocities through appropriate vegetation planting, fencing and/or low walls).

Photo 6: Small flood across Pluim Park in 2011

- **There are future proposals for Pluim Park that will affect flooding downstream**.
  There are no submitted Development Applications for works within Pluim Park that will impact on flooding downstream. All development applications will be assessed (as in the past) to ensure that affectation on flooding downstream does not occur.

- **Works on Pluim Park have in the past not been approved or undertaken without consent**.
  All works having a possible impact on flooding have conformed to the required conditions according to Council records.

The outcomes are:

a. No past works on Pluim Park have had a significant impact on flood levels and none will be approved unless it can be demonstrated that no significant adverse impact will arise.
b. Erosion and sedimentation issues arising from developments on Pluim Park will be monitored and addressed if required.

2.3. Creek Maintenance

Cut Rock Creek is regularly inspected in accordance with Council's Area Maintenance Program and, where applicable, specific Plans of Management. This process allows routine maintenance actions to be prioritised on a network Council wide risk basis. Where the potential impacts are significant and life threatening, Council may carry out the removal of light vegetation and sediment deposits however, in general, these actions do not warrant regular maintenance intervention.

Council does not undertake creek maintenance on privately owned land where there is no easement in place. Council would only consider such works if a life threatening or similar situation arose. However, clearing has previously been undertaken by Council under the railway and highway bridge downstream of Tall Timbers estate due to complaints from residents regarding the deposition of rail ballast. Generally Council will only remove large trees, or similar, that have the potential to block culverts/bridges but do not remove light vegetation or remove deposited sediment.

Any resident undertaking works within the creek must be aware of environmental legislation requiring approval for such works from the Department of Primary Industries. Any resident undertaking illegal works without approval may be prosecuted. Council is also required to obtain similar approvals prior to undertaking any works within the creek.

If an area is declared a Natural Disaster area, government funding could be made available for clean up through the appointed Recovery Committee. Should residents wish to remove debris themselves (with approval), it is their responsibility to organise and pay for the work and the disposal of waste.

2.3.1. Works within the Creek

Residents have suggested that the creek be dredged or widened to increase the hydraulic capacity. These works would only have a limited benefit as the private access road provides the main constraint. In addition, dredging to below the invert of the culverts under the Pacific Highway would provide little benefit. Regardless, the dredging or widening of a creek is generally not supported in NSW on environmental and/or sustainability grounds if undertaken purely for flood mitigation purposes.

An approximate cost to undertake the creek dredging works for the full length of the easement as envisaged in Figure 3 is $122,000. These works will reduce flood levels and the frequency of overtopping of the private access road but the benefit will be very minor (less than 0.1m) unless the capacity of the waterway opening under the access road is significantly increased and bank and bed control works undertaken to stabilise and maintain the channel.

2.3.2. Upstream Bank and Bed Control Works

The worst area for bank erosion and sediment deposition has been occurring upstream of the access road causing the creek to become significantly narrower through 41A and 53 Tuggerah Street properties and the sediment deposited downstream reducing the capacity of the access bridge culverts. The portion of the creek downstream of the access road appears to have maintained its shape since it was formed by the developer.

At the 17th June 2013 workshop, residents requested that the portion of the creek upstream of the access road, and within the easement owned by Council, be rock lined with bed control to stabilise the banks and improve access for sediment removal.

An approximate cost to undertake the rock work for this portion of the easement as per the sketch in Figure 6 and Figure 7 is $567,000. These works will reduce flood levels and the frequency of overtopping of the private access road but the benefit will be very minor (less than 0.1m) unless the capacity of the waterway opening under the road is significantly increased.

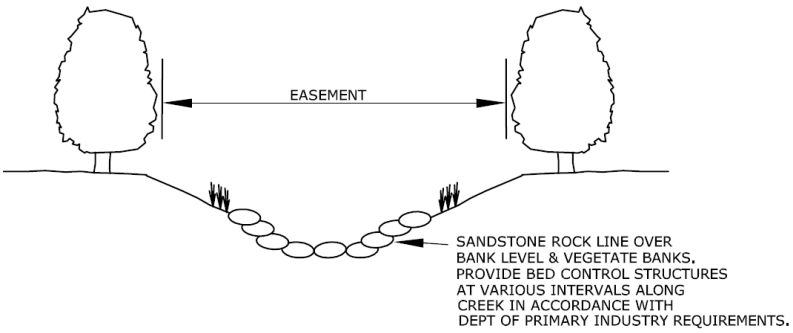

Figure 6: Proposed rock lining and bed control

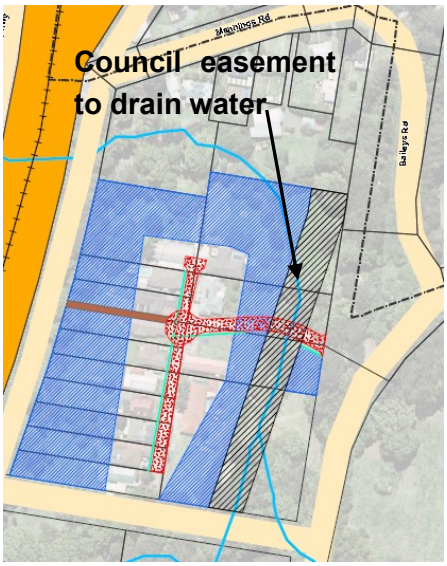

Figure 7: Site proposed for rocklining and bed control

2.3.3. Bank Erosion adjacent to Pluim Park

There is bank erosion and a large log and debris jam on land immediately upstream of 41 Tuggerah Street. The jam is causing flood water to flow around the debris and erode the soft sediment bank. Residents requested that this area be rock lined to stop the banks from eroding and the debris jam be removed.

A site meeting was held with the Catchment Management Authority (CMA) on 6th August 2013 and their verdict was that nothing should be removed (refer Appendix C). The land above the eroded bank is heavily vegetated with trees whose roots should hold the banks in place for some time to come, and the debris jam is acting as a collection point for other debris and sediment being transported from upstream.

The CMA advised that this is a natural process and undertaking any structural works would be unsatisfactory. The bank would continue to erode around the new rock work. Also, the debris jam was detaining floodwaters as well as slowing the migration of sediment from upstream of the estate. The CMA recommended that the erosion site and debris jam be regularly monitored over the next few years to see if the situation deteriorated however some of the smaller debris could be removed in conjunction with the CMA if desired.

The outcomes are:

a. Council will continue with its present level of involvement in creek management and monitor the situation with the assistance from the affected property owners.
b. Council will liaise with the owners of Pluim Park to construct measures to reduce erosion of topsoil.

2.4. Maintenance of Roads within Tall Timbers estate

Council has a regular road inspection, maintenance and upgrade program in place for public roadways throughout the Local Government Area. This program does not cover privately owned access roads e.g. the access road to Tall Timbers estate. The maintenance and upgrade of private access roads is the responsibility of the property owner/s.

The outcome is:

a. The maintenance and upgrade of private access roads is the responsibility of the property owner/s.

2.5. Boulders Placed in the Creek Downstream of the Pacific Highway

Channel works have been undertaken by Gosford City Council for the area between the Pacific Highway and Teralba Street (boundary with Wyong LGA). These works involved widening and clearing the channel of dense vegetation, purchase of a house, removal of private foot bridges across the creek, re-alignment and rock lining of the main channel, and revegetation. As a result of these works flood levels downstream of the Pacific Highway were reduced.

However it was acknowledged in the design of the works that these channel improvements would also lower flood levels upstream of the Pacific Highway. Whilst this is of benefit to residents of Tall Timbers estate, it meant that there is less temporary floodplain storage

upstream of the Pacific Highway and thus the peak flow would be increased to properties downstream of the Pacific Highway. This meant that flood levels immediately upstream of Teralba Street, and also within Wyong Shire, would be increased and so would adversely affect those residents.

Such an increase in level is not in accordance with Council's development control standards and for this reason boulders were included in the design to be placed immediately downstream of the Pacific Highway. The boulders would cause an obstruction to the flow of water during floods immediately downstream of the culverts and would raise flood levels back to near the pre-works levels in Tall Timbers estate. By using this design there would be no increase in flood level within Wyong LGA and also to properties located immediately upstream of Teralba Street.

Hydraulic modelling undertaken as part of the 2013 Ourimbah Creek Flood Study has indicated that, by removing the boulders and widening the channel (as discussed in Section 2.3.2) the flood levels would decrease upstream at Tall Timbers estate by 0.06m to 0.1m during the 1% AEP and by 0.07 to 0.15m during the 20% AEP.

The outcome is:

a. The boulders provide a satisfactory approach for maintaining the pre-works flood levels and flows both upstream and downstream of the Pacific Highway culverts.

2.6. Sewerage Leaching & Connection to Main Sewer Management System

Area G2 is not located within Council's defined sewer service area, nor have properties within the area contributed toward provision of or connection to Council's sewer reticulation system. Residents have complained of effluent overflows, smells and associated problems.

Approval for development of the land involved the applicant providing private individual On Site Sewerage Management (OSSM) systems. In 2009, Gosford City Council Waste Services staff undertook an audit of properties in Mannings Road and Tuggerah Street which encompassed the Tall Timbers estate. The audit revealed that due to the constraints of the sites, none of the properties would be able to comply with either the '*Environment and Health Protection Guidelines for On-site Sewage Management for Single Households'*, or the '*Australian Standard 1547:2012 On-site domestic wastewater management*'.

Council has identified this and another five un-serviced areas within the LGA for investigation for the provision of sewer under the Master Plan. Investigations may not be undertaken for several years as the Master Plan is proposed to address future service requirements to the year 2050.

It should be noted that Pluim Park was connected to Council's sewer reticulation system via a privately owned and operated pump and rising main at their expense.

An indicative cost to connect the houses to a sewer reticulation system is in the order of $800,000 to $1 million or $35,000 to $50,000 per household. The costs of connection would need to be negotiated between Council and the residents.

The outcome is:

a. Council will continue to investigate the potential for connection of the houses to Council's sewer reticulation system.

2.7. House Raising

As an outcome of the 1997 Management Plan, when 7 Mannings Road applied to undertake additions to the house, the floor level was raised to above the 100 year ARI (1% AEP) flood level. No other houses have applied to be raised but would be considered on their merits if an application was made and if grant funding could be obtained from State or Federal funds.

Slab on ground houses can be raised (as undertaken in Fairfield) but the cost is significantly higher than the estimated cost for raising a house on piers (say $60,000). However technically it can be undertaken. The main issues with raising houses are:

- only part of the cost is covered by grant funding (attached garages and pergolas are excluded);
- residents may resent having to climb steps;
- the house may be considered aesthetically less attractive;
- as this is voluntary residents may not agree to raising;
- raising may crack tiles or cause some other damage;
- residents may consider that it may be more economical to construct a new house at a higher level and thus would prefer the money for this purpose (this approach is not supported by the grant authorities);
- house raising will eliminate above floor damages (to the nominated flood level) but will not necessarily eliminate the risk to life as residents may still attempt to enter floodwaters to collect children from school, reach high ground or similar.

The outcomes are

a. Council will continue to assist with applications for house raising.
b. Increasing the density of development on Tall Timbers estate is not recommended.

2.8. Flood Emergency Management

2.8.1. SES and FloodSafe Education Programs

Gosford City Council has been working with NSW SES to include additional flood information for the Gosford City Local Flood Plan in regards to the Tall Timbers estate. NSW SES will also undertake a FloodSafe education program for all community members in Area G2 including the Lisarow Public School and Pluim Park.

According to the *Flood Emergency Response Planning Classification of Communities* guideline issued by the then Department of Environment and Climate Change in 2007, Tall Timbers estate is classified as a Low Flood Island. This means the area is isolated by floodwaters and will be completely covered in a flood event greater than the 100 year ARI (1% AEP).

The NSW SES provides FloodSafe kits and conduct flood awareness programs to make residents aware of the risk. In the event of an emergency during storms and/or floods, the NSW SES is available to assist if requested to do so by a resident or by other emergency services. The NSW SES also issue Evacuation Warnings and Orders if and when deemed necessary if "risk to life" is too great for residents to remain in situ and if there is sufficient warning time to evacuate residents from this area. Depending on the event, especially if it is flash flooding, there may not be sufficient warning time to consider early evacuation. If self-evacuation of the community is chosen to be achievable (which is obviously preferred) then it should be in a manner which is consistent with the NSW SES's principles for evacuation.

A flood warning system is not practical on a catchment wide basis but possibly an SMS flood warning message may provide some pre-warning for Area G2. This system has now been installed relatively economically but requires ongoing maintenance and continued flood awareness. The cost for this gauge was $9,250 with an annual cost of $2,500.

NSW SES does not have its own aircraft or pilots. However, from time to time, NSW SES work with these resources which are provided by other agencies or contractors and decisions relating to their use depends on a variety of factors including, but not limited to, weather and availability which can only be determined at the time of the incident. Decisions on flying and landing must be made by the pilot and the agency at the time of the emergency.

However in summary, none of the above measures would be an acceptable mitigation measure. The measures would reduce the risk but not eliminate the risk to life and is only a stop-gap measure until a more permanent measure is found.

The outcome is:

a. All available flood emergency awareness measures should be introduced however, they are only a stop-gap measure until a more permanent solution is found.

2.8.2. Vertical Evacuation or "Shelter in Place"

For some existing urban areas located in the floodplain there is no realistic opportunity to reduce flood levels, provide flood free access or purchase the land and buildings. The term vertical evacuation or "shelter in place" has been introduced to describe where persons relocate to higher levels of a building, usually on-site, and above the reach of flood waters. In some areas this is seen as the only means of providing a safe refuge. This requires the house to be constructed to a structural integrity much greater than for a normal house.

'Shelter in place' and 'vertical evacuation' are not equivalent to evacuation and therefore should not be considered as a primary means of dealing with the risk. The fact that people become trapped in their homes means that they have failed to evacuate safely from the flood affected area and therefore are considered 'trapped'. People who are trapped are still exposed to indirect flood risks relating to;

- their behaviour (drowning if they change their mind and attempt to leave after entrapment);
- their mobility (not being able to reach the highest part of the building);

- their personal safety (fire and accident); and
- their health (pre-existing condition or sudden onset e.g. heart attack).

Generally the SES do not support vertical evacuation as a means of approving a new development. However as a retro-fit solution for an existing problem, such as at Tall Timbers estate, the construction of such a structure (possibly as an addition to an existing building) would ensure that there is a secure flood free refuge for residents isolated in the estate during a flood greater than the 100 year ARI (1% AEP). However, vertical evacuation does not address the main concern which is frequent inundation of the private access road and consequent potential risk to life of crossing floodwaters.

The outcomes are:

a. Vertical evacuation could provide a safe refuge during a flood greater than the 100 year ARI (1% AEP).
b. Vertical evacuation does not address the risk of residents trapped in their homes and therefore exposed to potentially life threatening hazards during an emergency.
c. Vertical evacuation does not address the main concern of flood free access.

2.9. Voluntary Purchase

The homes at Tall Timbers estate are surrounded by floodwaters with vehicular access cut in frequent minor storm events. Even if the vehicular access is improved with a higher level crossing of the private road there is still no safe flood free access due to the relatively low level of Tuggerah Street. As these homes are all brick it would probably be more cost effective to rebuild the houses than raise them, but access would still be an issue.

As there are no viable means of improving the vehicle access, is voluntary purchase an appropriate measure for the existing 14 homes in the estate? This measure would cost approximately $5.6 million and up to $8 million if the 6 houses in Mannings Road are included. However it is difficult to justify this measure as the building floors in Tall Timbers estate are all above the 100 year ARI (1% AEP) flood level and thus the frequency of above floor damages is less than many other homes in NSW.

Furthermore, as the scheme is voluntary, it is likely that not all owners will wish to be purchased. Voluntary purchase schemes have been in place for many years (e.g. Maitland) with little success. Therefore a voluntary purchase scheme should be viewed in the long term.

Generally, houses are only placed in a voluntary purchase scheme when there is a significant risk to life and frequent above floor inundation. Whilst there is a significant risk to life if access is attempted during a flood, in events smaller than the 100 year ARI (1% AEP) event there is no risk if the resident stays in the house. If a house is placed in a scheme this may disadvantage the owner if a private sale is attempted, as disclosure of the scheme to a prospective purchaser may be required or even a note placed on the Section 149 certificate.

There are 14 houses on the Tall Timbers estate and 6 houses in Mannings Road serviced by privately owned individual on-site sewerage management systems which do not comply with current regulations (refer Section 2.6). If these properties are not connected to Council's sewer reticulation system in future they may need to be purchased.

The outcomes are:

a. Voluntary purchase is costly and may not be acceptable to all residents.
b. Houses should be connected to the sewer reticulation system to comply with current regulations and address ongoing health risks or potentially face voluntary purchase.
c. Voluntary purchase would eliminate the risk to life of the residents dwelling in the 14 houses on the Tall Timbers estate.

2.10. Household Flood Insurance

Household insurance has changed in the last 5 years and in particular since the January 2011 Brisbane River floods. As a consequence the majority (if not all) insurance companies offer flood insurance. Some companies require flood insurance to be taken out whilst others allow owners to opt out. A comparison of quotes can be obtained online and this suggests that flood insurance can add up to an additional $5,000 to the normal non flood household premium. However the rates vary markedly amongst the insurance companies and between houses in Tall Timbers estate although all have their floors at the same AHD level and thus similar likelihood of inundation.

For the majority of home owners with a mortgage, household insurance is compulsory, thus it is likely that for many owners their household insurance premium will have risen in the order of two or three times (even though there has been no above floor inundation of houses in the Tall Timbers estate). This situation is not unique to this area and there are many other examples in urban and rural areas of NSW.

Due to the flood hazard in this area, insurance companies in the future may not be able to provide affordable insurance or may choose to not provide any insurance.

The outcomes are:

a. Flood insurance for houses is now available from many companies.
b. Premiums may increase if flood insurance is included.
c. Flood insurance may be compulsory for homes with a mortgage.
d. Flood insurance does not address the main concern of flood free access.

2.11. Mitigation Dams

Residents have asked if retarding basins could be constructed in the upper catchment to temporarily store flood waters and so reduce flood levels at Tall Timbers estate. This suggestion is not feasible for a number of reasons, the main one being that the catchment area above Tall Timbers estate is over 6 km^2 and a small dam would not provide any significant benefit. There is no suitable space for such a large structure and the cost would be of the order of $15 million. In addition there would be significant environmental issues (loss of vegetation / habitat) to resolve. Construction of several small basins is not viable due to the lack of available sites.

A retarding basin was recently completed in Chamberlain Road to retard frequent minor flows from new development upstream of Pluim Park and Tall Timbers estate.

The outcome is:

a. Flood mitigation dams or basins upstream are not possible.

2.12. Development Controls for Mannings Road & Tuggerah Street

Increasing the density of development in Tuggerah Street and Mannings Road is not recommended. Development controls will ensure that there are limitations to expansion of this area in future. However controls will not reduce the existing risk of damage to existing properties and to life during a flood event. Increasing the density in this area will also potentially increase the health risks associated with the on-site sewer management systems, and the number of people put at risk placing a greater demand for the SES to rescue residents during a flood event.

The outcomes are:

a. No further intensification of development in Mannings Road and Tuggerah Street.
b. Increased flood related development controls will not reduce damages to existing development, health issues related to the OSSMS or risk to life.

2.13. Do Nothing

The do nothing option will mean that residents will continue to be faced with a significant risk to life during times of flood and in time will have their floors inundated when a large flood occurs.

With the potential for future changes in climatic conditions, there is also the potential for more frequent inundation of the 20 privately owned individual on-site sewerage management systems as well as the continuation of effluent leaching from those systems into the creek. This would increase the risk to both the health of the residents and the surrounding environment.

3. SUMMARY OF MANAGEMENT MEASURES CONSIDERED

The measures were separated into short, medium and long term. It should be noted that these measures will be reviewed in any future Floodplain Risk Management Study and Plan when resources and funding becomes available.

POSSIBLE MEASURE	COST	RESPONSIBILITY	BENEFIT	TIMEFRAME
2.1.1 *Raise Private Access Road to connect to Tuggerah Street*				
Raise private access road to the level of Tuggerah Street	$1.07m + $25,000 per annum ongoing maintenance and replacement cost	Residents	Provide flood free vehicular access up to < 20% AEP.	Long term
2.1.2 *Raise Private Access Road to connect to Tuggerah Street*				
Construct pedestrian bridge adjacent to access road	$840,000	Residents	Provide flood free pedestrian access up to < 20%+ AEP.	Long term
2.1.3 *Pedestrian Access over Railway*				
Construct pedestrian bridge over railway immediately adjacent to estate	$1.35m	Rail Authority / Local Govt	Provide flood free access to Pacific Highway.	Long term
2.1.4 *Emergency Pedestrian Access Route*				
Stage 1 **Tall Timbers estate to Mannings Road - would significantly improve access and lessen the risk to life for the residents of Tall Timbers estate in a 1% AEP event.**	$988,000	Rail Authority / Local Govt	Provide pedestrian access to Mannings Road up to 1% AEP	Long term
Stage 2 **- Mannings Road to pedestrian overbridge opposite Teralba Street.**	$594,000	Rail Authority / Local Govt	Provide pedestrian access up to 1% AEP.	Long term
Stage 3 **Tall Timbers to Macdonalds Road - would provide quicker, safer route to the Lisarow Public school, Pluim Park and Pacific Highway in the 1% AEP event.**	$2.16m	Rail Authority / Local Govt	Provide pedestrian access up to 1% AEP.	Long term
2.2 Pluim Park				
Minimise sedimentation transfer from Pluim Park through vegetation growth and/or additional low wall and fencing	$20,000	Central Coast Football	Reduce incidence of sedimentation of creek	Short term
2.3 Creek Maintenance				
2.3.1 Remove sediment build-up from easement	$122,000 + $50,000 per annum	Local Govt	Marginally lower flood levels	Short term
2.3.2 Widen channel and stabilise banks for 200 lineal metres of easement	$566,600	Local Govt	Reduce bank erosion and slumping and marginally lower flood levels	Long Term
2.3.3 Monitor log jam, slumping and sediment migration adjacent to Pluim Park		Local Govt / benefiting residents & owners	No impact on flood levels	Short Term
2.4 Maintenance of Private Roads				
Council does not maintain private roads		Residents		n/a

POSSIBLE MEASURE	COST	RESPONSIBILITY	BENEFIT	TIMEFRAME
2.5 Boulders Downstream of Highway				
Council to maintain present approach		Local Govt		n/a
2.6 *Sewer Management System*				
Extend sewer system to 14 properties in Tuggerah Street and 6 properties in Mannings Road	$35,000- $50,000 per property	Residents / Local Govt	Ensure properties comply with current sewage standards and eliminate health risk	Long term
2.7 *House Raising*				
Raise house floor levels to above the PMF flood level. *NB All floor levels are above the 1% AEP flood level according to the 2013 Ourimbah Creek Study*	$60,000 for non brick and $100,000 for brick	Local & State Govt grant & residents	Will reduce flood damages but not the risk to life with access	As required by residents
2.8 Emergency Management				
2.8.1 Provides all available emergency management measures	$9,250 + $2,500 ongoing annual maintenance cost	SES / local Govt	Automatic flood warning system for SES and residents	Short term
2.8.2 Provide structure suitable for vertical evacuation	Will depend on type of structure	Residents	Reduce risk to life in a greater than 1% AEP event	Long term
2.9 Voluntary Purchase				
14 properties in Tall Timbers estate and 6 in Mannings Road	$5.6m - $8m	Local & State Govt	Will eliminate the flood hazard, risk to life and health and environmental issues	Long term
2.12 Development Controls				
Introduce development controls to reduce damages and risk to life in the modification of existing houses	Paid for by owner	Local Govt to implement	Reduces damages for new development and risk to life	n/a
2.13 Do Nothing				
Residents continue to face a significant flood risk – risk to life and damage to property			None	n/a

4. RANKING OF MANAGEMENT MEASURES

4.1. Management Measures Scoring Matrix

The management measures being considered were assessed using the matrix shown in Table 2 which is based on the guidelines in Appendix 10 of the NSW Government Floodplain Development Manual 2005.

This scoring system looks at social, environmental and economic issues. It should be noted that all measures will be reviewed in any future Floodplain Risk Management Study and Plan when resources and funding becomes available.

It should also be noted that, with solely a benefit / cost analysis all the Benefit / Cost ratios for works and voluntary purchase are less than 1 i.e. very little tangible economic benefit compared to the high cost for the various measures.

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50mm increase	<50mm increase	neutral	<50mm decrease	50 to 100mm decrease	>100mm decrease
No. of Properties Benefiting	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issue	moderate issue	minor issue	neutral	moderately straight forward	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 & Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impact on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political / Admin Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Services & Infrastructure	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

Table 2: Management Measures Matrix Scoring System

4.2. Management Measures Assessment

The results of scoring each measure according to the values in Table 2 is shown in Table 3.

Report Ref	Option	Impact on Flood Behaviour	Properties Benefiting	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental & Ecological Benefits	Impact on SES	Political / Admin Issues	Risk to Life	TOTAL
2.1.1	Raise height of private access road	-1	3	2	3	0	-2	0	-1	-2	-2	0
2.1.2	Construct pedestrian bridge to Tuggerah Street	-1	3	2	3	0	-2	0	-1	-2	-2	0
2.1.3	Provide pedestrian access over railway line	0	3	-2	2	-1	-3	0	2	-3	3	1
2.1.4	Provide emergency pedestrian access above the 1% AEP	-1	3	1	0	-1	2	0	3	-1	3	9
2.2	Sediment controls at Pluim Park	1	0	2	3	0	2	1	0	3	0	12
2.3.1	Creek dredging	0	0	2	3	-2	2	1	0	2	1	9
2.3.2	Bank and bed control	0	0	2	3	-2	1	1	1	-1	1	6
2.3.3	Bank erosion adjacent to Pluim Park & log jam	0	0	0	2	0	0	1	0	-1	0	2
2.4	Maintenance of roads on Tall Timbers estate	0	3	2	3	0	-2	0	-1	-3	0	2
2.6	Connect 20 properties to the sewer reticulation system	0	3	-3	0	-3	-3	3	0	-3	3	-3
2.7	House Raising	0	0	-2	0	0	0	0	0	1	0	-1
2.8.1	Flood warning and preparedness	0	3	3	3	-1	3	0	3	2	3	19
2.8.2	Shelter in place	0	1	-1	2	0	0	0	1	1	2	6
2.9	Voluntary purchase	0	3	-2	0	0	2	3	3	-2	3	10
2.11	Mitigation dams	0	0	-2	1	0	-2	0	0	-3	0	-6
2.12	Development controls	0	3	3	1	0	2	1	1	3	0	14

Table 3: Management Measures Assessment

5. DETAILED COSTING OF MANAGEMENT MEASURES CONSIDERED

5.1. Raise Private Access Road

POSSIBLE MEASURE	Item	Cost
Raise private access road to the level of Tuggerah Street Construction - Concrete beam and decking on concrete piers 5.0m wide carriageway (*similar construction to Mills Creek bridge*) Decking and piers required to be able to withstand flood flows with additional forces from floating debris. Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*)	Design Geotechnical Foundations Piers and abutments Deck Guard Rail Pavement **Total**	20,000 20,000 400,000 120,000 400,000 70,000 40,000 **1,007,000**

5.2. Construct Pedestrian Bridge

POSSIBLE MEASURE	Item	Cost
Construct Pedestrian Bridge adjacent to private access road Pedestrian Bridge to be construction to the same level as Tuggerah Street. Construction - Concrete pier foundations, 3.0m wide concrete decking with galvanised steel handrails Decking and piers required to be able to withstand flood flows with additional forces from floating debris. Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*)	Design Geotechnical Foundations Piers and abutments Deck **Total**	20,000 20,000 200,000 50,000 550,000 **840,000**

5.3. Construct pedestrian bridge over railway

POSSIBLE MEASURE	Item	Cost
Pedestrian Bridge to be constructed over Great Northern Railway Construction - Concrete beam and decking on concrete piers 3.0m wide with galvanised steel handrails from estate to overhead bridge Decking and piers required to be able to withstand flood flows with additional forces from floating debris Estimate of cost provided by Rail Authority for construction of a bridge over the railway line Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*) **NB Although cost provided, rail authority is reluctant to install additional bridges over lines due to increasing potential hazards for trains**	Deck Railway Overbridge **Total**	550,000 800,000 **1,350,000**

5.4. Emergency Access Route

POSSIBLE MEASURE	Item	Cost
<u>Stage 1</u> Tall Timbers estate to Mannings Road - would significantly improve and lessen the risk to life for the residents of Tall Timbers estate.		
Concrete slab on ground 3.0m wide (53m @ $266/lm)	Design	20,000
Elevated boardwalk 3.0m wide for entire length (149m @ $1,800/lm)	Geotechnical	40,000
Elevated boardwalk supporting structure 1-2m high (55m @ $1,800)	Boardwalk	268,200
Elevated boardwalk supporting structure 2-3m high (74m @ $2,100)	Bridge and Abutments	355,000
Bridge spanning over Cut Rock Creek (17m span)	Slab on ground	14,098
Construction - Concrete pier foundations, concrete decking with galvanised steel handrails 3.0m wide	Supporting Structure	290,550
Decking and piers required to be able to withstand flood flows with additional forces from floating debris.		
Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*)		
(There has been no indication from Rail Authority that permission to use their land will be approved, therefore it cannot be used as an assumption)	**Total**	**987,848**

POSSIBLE MEASURE	Item	Cost
<u>Stage 2</u> - Mannings Road to pedestrian over bridge opposite Teralba Street – would connect residents to assistance outside the floodplain		
Clearing and disposal of vegetation	Design	20,000
Elevated boardwalk 3.0m wide for 134m @ $1,800/lm	Clearing	20,000
Elevated boardwalk supporting structure (134m @ $1,800)	Geotechnical	20,000
Concrete slab on ground 3.0m wide for (193m @ $266/lm)	Boardwalk	241,200
Construction - Concrete pier foundations, concrete decking with galvanised steel handrails	Supporting Structure	241,200
Decking and piers required to be able to withstand flood conditions with floating debris.	Slab on ground	51,338
Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*)		
(There has been no indication from Rail Authority that permission to use their land will be approved, therefore it cannot be used as an assumption)	**Total**	**593,738**

POSSIBLE MEASURE	Item	Cost
<u>Stage 3</u> Tall Timbers estate to Macdonalds Road - would provide quicker, safer route to the school, Pluim Park and Pacific Highway in a 1% AEP event.		
Elevated boardwalk 3.0m wide for entire length (520m @ $1,800/lm)	Design	40,000
Elevated boardwalk supporting structure (520m @ $2,100)	Geotechnical	40,000
Construction - Concrete pier foundations, concrete decking with galvanised steel handrails	Clearing	50,000
Decking and piers required to be able to withstand flood conditions with floating debris.	Boardwalk	936,000
Estimate provided without geotechnical information or structural design. Costs may escalate due to suspected poor foundations. (*Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations*)	Supporting Structure	1,092,000
(Unclear whether this option is possible due to ecologically endangered vegetation)	**Total**	**2,158,000**

5.5. Creek Maintenance - Sediment Removal

POSSIBLE MEASURE	Item	Cost
Remove sediment build-up from easement.		
Removal of sediment and weed growth	Govt Application	
	Erosion & sediment control	25,000
	Dredge & disposal	77,000
	Site restoration	20,000
(Ongoing maintenance costs of approximately $50,000 per annum)	**Total**	**122,000**

5.6. Upstream Bank and Bed Control Works

POSSIBLE MEASURE	Item	Cost
Widen channel and stabilize banks in Council easement.	Govt Application	
Widen and rock line 200 lineal metres of creek channel		
Construction - Increase depth and width of creek and line with rip-rap rock base and toe of batter	Geotechnical	20,000
	Erosion & sediment control & Dewatering	31,600
	Excavation and disposal	172,000
	Rip-rap and	53,000
Excavation and disposal costs may vary up or down due to not being any geotechnical information. Rail line crossing at Cut Rock Creek required extensive footings to reach good foundations,	Supply & lay batter	270,000
	Site restoration	20,000
	Total	**566,600**

6. RECOMMENDED MANAGEMENT MEASURES

The following are a list of the recommended measures based on the risk and socio-economic results. They have also been further assessed for short, medium and long term timeframes.
It should be noted that all measures will be reviewed in any future Floodplain Risk Management Study and Plan when resources and funding becomes available.

It should also be noted that the estimated costs may rise due to having geotechnical or structural details when undertaking the estimates.

RECOMMENDED MEASURE	COST	RESPONSIBILITY	BENEFIT	TOTAL SCORE IN MATRIX	TIMEFRAME
2.9 Voluntary Purchase					
14 properties in Tall Timbers estate and 6 in Mannings Road	$5.6million to $8 million	Local and State Govt	Will eliminate the sewerage and flood risks	10	Long term
2.1.3 *Emergency Pedestrian Access Route*					
Stage 1 **Tall Timbers to Mannings Road**	$988,000	Local Govt	Provide up to 20% AEP pedestrian access	9	Medium term
Stage 2 **- Mannings Road to pedestrian overbridge opposite Teralba Street.**	$594,000	Local Govt	Provide up to 1% AEP pedestrian access	9	Medium term
Stage 3 **Tall Timbers to McDonalds Road**	$2,158,000	Local Govt	Provide up to 1% AEP pedestrian access.	9	Long term
2.2 Pluim Park					
Minimise sedimentation from Pluim Park	$20,000	Central Coast Football	Reduce sedimentation	12	Short term
2.3 Creek Maintenance					
2.3.1 Remove sediment build-up from easement	$50,000 per annum	Local Govt	Marginally lower flood levels	9	Short term
2.3.3 Monitor log jam, slumping and sediment migration	$2,500 per annum	Local Govt / benefiting residents	No impact on flood levels	2	Short Term
2.8 Emergency Management					
2.8.1 Provide emergency management measures and install automatic flood warning system	$9,250 + $2,500 per annum	SES / Local Govt	Residents prepared for floods	19	Short term
2.12 Development Controls					
2.12 Controls to restrict type of development on existing houses	Paid for by owner	Local Govt	Reduces damages and risk to life during floods	14	Short term

7. SPECIFIC DEVELOPMENT CONTROLS

7.1. For Tall Timbers estate and Mannings Road

- no further subdivision permitted;
- no further intensification of development which results in additional load on OSSMS or increase in the number of bedrooms;
- no filling of the floodplain beyond the building envelope;
- double storey houses are permitted if the 2nd floor to be used for "shelter in place";
- alterations and additions permitted on a one off basis within the set building envelop and shall not exceed 20% of the current building value. A building valuation report is to be submitted with the development application confirming compliance with this criterion. **This condition applies to Tall Timbers estate properties only;**
- alterations and additions are encouraged to provide "shelter in place" and which are able to withstand the forces of water and debris loading in flood events up to the PMF;
- any alterations or additions to take into account flooding issues (i.e. electrical boxes and air conditioners etc. above the Flood Planning Level and all construction below the Flood Planning Level to consist of flood proof building materials);
- the Flood Planning Level be maintained at the 1% AEP (100 year ARI) flood level plus a 0.5m freeboard;
- renovations, landscaping, swimming pools, minor extensions to buildings, fences and other home improvements must not impede the passage of flood flows so as to adversely affect adjoining properties.

7.2. For Pluim Park

- development controls for future development of Pluim Park must be in accordance with the guidelines in Appendix C of the Bangalow Creek and Cut Rock Creek Floodplain Management Plan (1997).

7.3. General

- all new buildings, development or filling on the floodplain must be in strict accordance with Council's Guidelines outlined in the Development Strategies – Local (refer to Bangalow Creek & Cut Rock Creek Floodplain Management Plan 1997 for details).

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of (old) 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 Flood Planning 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)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the 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 streaFPLow, 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

Cut Rock Creek Catchment – Area G2
Pluim Park/Tall Timbers Estate/Mannings Road
Review of Floodplain Risk Management Plan

— Community Information Newsletter January 2012

Introduction

Under the NSW Government's Flood Prone Land Policy, management of flood prone land is primarily the responsibility of councils.

Gosford City Council has appointed WMAwater (formerly Webb McKeown & Associates) to carry out a Review of the 1997 Bangalow and Cut Rock Creek Floodplain Risk Management Plan for **Area G2: Pluim Park/Tall Timbers Estate/Mannings Road**.

The Floodplain Risk Management Plan provides a basis for sound floodplain management planning for the area, which recognises the demands for development and change, the need for good urban and environmental outcomes, and the social and economic benefits of reducing flood damage.

FIGURE 1: Study Area

The Bangalow and Cut Rock Creek Floodplain Risk Management Plan, completed in 1997, was the first to be funded under the NSW Government's Floodplain Management Program within the catchment. This study determined design flood levels (i.e. the 100 year and other average recurrence interval events) and flows throughout the catchment and recommended measures to manage the flood problem.

The Study Area

Cut Rock Creek has a catchment area of approximately 10 km² and is a major tributary of Bangalow Creek which enters Ourimbah Creek and eventually Tuggerah Lakes.

The Study area comprises the floodplain from Pluim Park downstream to the Sydney-Newcastle railway line and includes the two residential areas of Tall Timbers Estate and along Mannings Road.

The main flooding issue from the Tall Timbers Estate is the inundation of the privately owned vehicle access bridge from Tuggerah Street. However other issues include:

- The impact of upstream development on water quantity and quality,
- The placement of a series of rocks in the channel immediately downstream of the highway,
- Erosion of the channel,
- Frequent nuisance flooding,
- Maintenance of the channel (removal of vegetative and other debris),

PHOTOGRAPH 1: View to Tall Timbers Estate from Tuggerah Street

Floodplain Management Program

The first step in the process (Diagram 1) is data collection and the preparation of the Flood Study (completed in 1994).

DIAGRAM 1: The Floodplain Risk Management Process

The second step is the preparation of a Floodplain Risk Management Study (FRMS) that identifies a range of floodplain management measures to address the problems and areas of concern (completed in 1997).

The third stage involves preparation of a Plan that documents how the proposed measures identified in the FRMS are to be implemented in terms of resources and timing (completed in 1997). The final stage of the process is the allocation of funds and undertaking of the works (as occurred downstream of the highway).

The Floodplain Risk Management Plan

The objectives of the Floodplain Risk Management Plan are to:

- manage flooding as an integral part of the planning and development process;
- systematically identify and address flooding problems;
- prepare a schedule of strategies to manage the existing flood problem and reduce future flood damage;
- implement a unified approach;
- ensure sustainable development principles are achieved;
- maintain and enhance the capacity and quality of the drainage system; and
- gain community participation in the decision making process.

Why is this Review being Undertaken?

This Review is being undertaken as part of the above NSW Government Floodplain Management Program to ensure that the past recommended management measures are still appropriate or new measures should now be considered.

PHOTOGRAPH 2: Houses along Mannings Road

The Community Consultation Program

Community involvement is important at all stages of the Floodplain Risk Management Process. Residents' local knowledge of the catchment and personal experiences of previous flooding provide an invaluable source of data to define the nature and extent of flooding.

It is important to get community input and feedback to ensure proposed measures meet the needs and expectations of the local community. The importance of community involvement is recognised through the implementation of a community consultation program that is an integral part of each stage of the Floodplain Risk Management Process.

How Do I Get Involved?

Community input into the Review of the Floodplain Risk Management Plan for this area is essential and a Public Meeting will be held at: Ourimbah-Lisarow RSL Club on Monday 30 January 2012. RSVP Sue Stanford before Monday 23 January for catering purposes.

Please return the attached Questionnaire in the Reply Paid envelope. To seek clarification on any issue, please contact us.

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or

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Email: **dewar@wmawater.com.au**

COMMUNITY QUESTIONNAIRE

Cut Rock Creek Catchment – Area G2
Pluim Park/Tall Timbers Estate/Mannings Road
Review of Floodplain Risk Management Plan

INTRODUCTION

Gosford City Council is carrying out a Review of the Floodplain Risk Management Plan for **Area G2: Pluim Park / Tall Timbers Estate / Mannings Road** within the Cut Rock Creek catchment near Lisarow.

Your local knowledge and personal experiences of flooding in the area will help us in this Review. The extent of the Study Area is shown on the enclosed map.

1

The purpose of this Review is to re-look at the floodplain management measures adopted in the March 1997 study to enable Council to better plan and manage the potential flood risk. We may contact you to discuss some of the information that you provide.

Name: _____

Address: _____

Email: _____ Daytime Phone no: _____

2

How long have you lived or worked in this area?

_____ Years _____ Months

3

Are you aware of flooding from Cut Rock Creek upstream of the railway line? (Please tick one)

☐ Aware ☐ Some Knowledge ☐ Not Aware

4

Has your house floor level ever been inundated by flooding in the past? ☐ Yes (give details) ☐ No

_____

_____

_____

COMMUNITY QUESTIONNAIRE

Cut Rock Creek Catchment – Area G2
Pluim Park/Tall Timbers Estate/Mannings Road
Review of Floodplain Risk Management Plan

5

If your property has been affected by flooding in the past, what damage occurred?

6

If your property has been affected by flooding, how often has this occurred? (Please tick one)

☐ 1 – 10 times ☐ 11 – 20 times ☐ More than 20 times

7

What measures do you think could be taken to manage these flooding problems?

8

Are there any other issues that have occurred as a result of flooding that you consider should be addressed e.g. access to property?

9

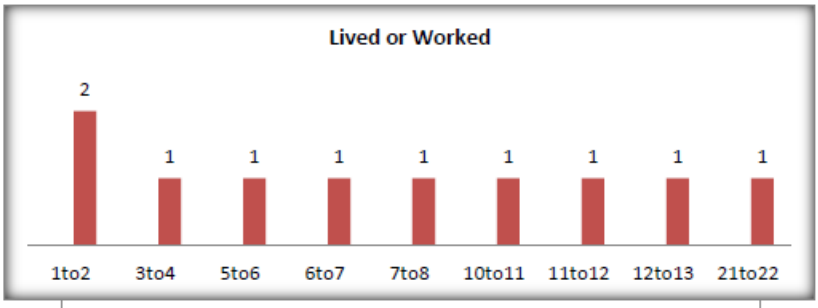
Thank you for your assistance in completing this questionnaire. Your help is greatly appreciated.

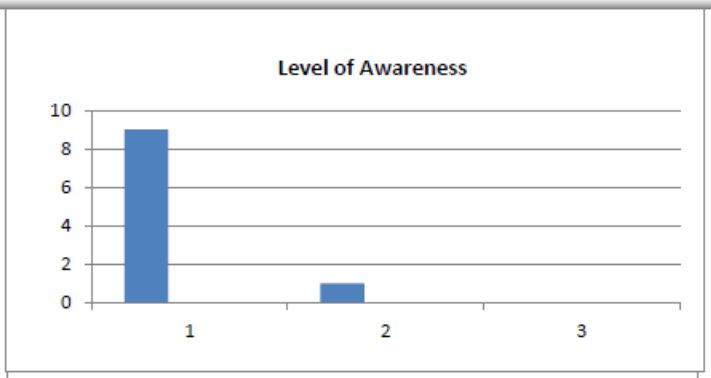
COMMUNITY QUESTIONNAIRE

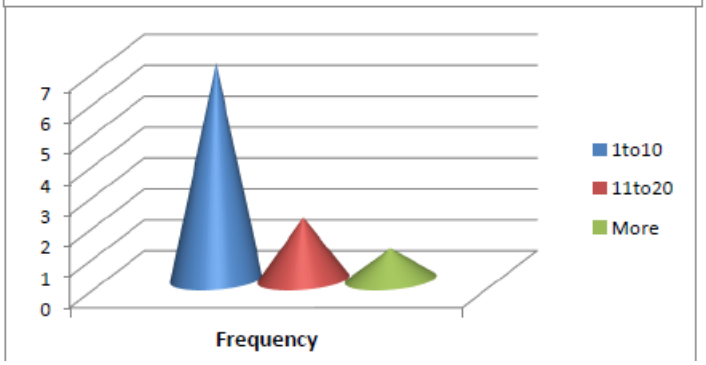
Cut Rock Creek Catchment – Area G2
Pluim Park/Tall Timbers Estate/Mannings Road
Review of Floodplain Risk Management Plan

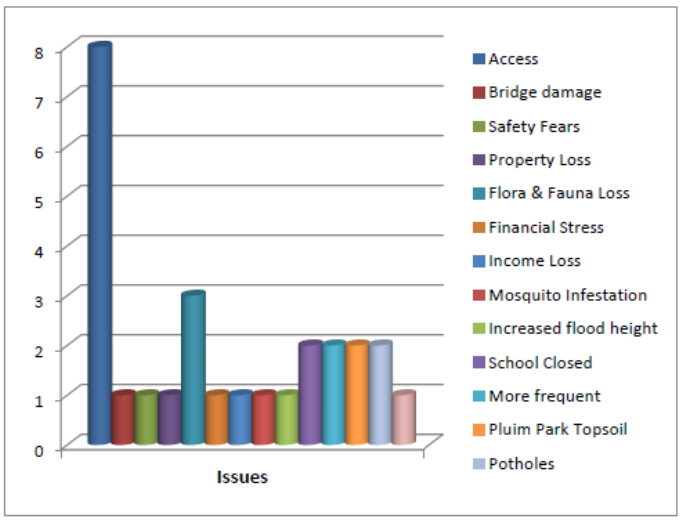
Study Area

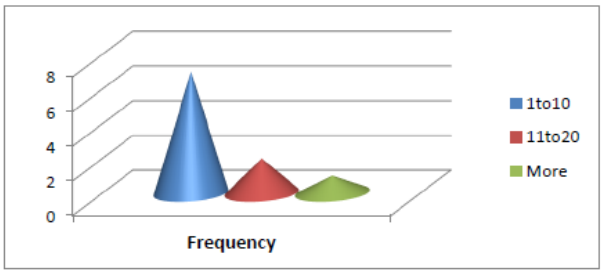
Breakdown of all responses to the questionnaire received from residents











Cut Rock Creek Catchment – Area G2
Pluim Park/Tall Timbers Estate/Mannings Road
Review of Floodplain Risk Management Plan
— Community Information Newsletter May 2013

Introduction

Due to concerns raised by residents regarding access issues during small frequent rainfall events, Gosford City Council appointed WMAwater (formerly Webb McKeown & Associates) in December 2011 to carry out a Review of the 1997 Bangalow and Cut Rock Creek Floodplain Management Plan for **Area G2: Pluim Park/Tall Timbers Estate/Mannings Road**.

The Floodplain Risk Management Plan provides a basis for sound floodplain management planning for the area, which recognises the demands for development and change, the need for good urban and environmental outcomes and the social and economic benefits of reducing flood damage.

FIGURE 1: Study Area

The main flooding issues raised by residents' from the Tall Timbers Estate via a questionnaire and at a meeting held at Ourimbah-Lisarow RSL Club on Monday 30 January 2012 were:

The inundation of the privately owned vehicle access bridge from Tuggerah Street;

Risk to life of children trying to cross access bridge;

Potholes in private access road;

The impact of upstream development on water quantity and quality;

The placement of a series of rocks in the channel, immediately downstream of the highway;

Erosion of the channel;

Frequent nuisance flooding;

Maintenance of the channel (removal of vegetative and other debris);

Odour from sewer systems.

The Review Area

Area G2 comprises the floodplain from Pluim Park downstream to the Sydney-Newcastle railway line and includes the two residential areas of Tall Timbers Estate and Mannings Road.

PHOTOGRAPH 1: View to Tall Timbers Estate from Tuggerah Street

Floodplain Management Process

The following is the process that Council follows in the preparation of a Floodplain Risk Management Plan for each estuary.

The first step in the process, the Flood Study, was completed in 1994.

DIAGRAM 1: The Floodplain Risk Management Process

The second step is the preparation of a Floodplain Risk Management Study (FRMS) that identifies a range of floodplain management measures to address the problems and areas of concern. This was completed in 1997.

The third stage involves the preparation of a Floodplain Risk Management Plan that documents how the proposed measures identified in the FRMS are to be implemented in terms of resources and timing. This was also completed in 1997.

Why this Review is being Undertaken?

This Review is being undertaken to ensure that the past recommended management measures are still appropriate or if new measures should now be considered.

Draft Addendum for Area G2 of the Bangalow Creek and Cut Rock Creek Floodplain Management Plan (1997)

A Draft Addendum is now ready for comment. It is important to gain community input and feedback to ensure all options have been considered and the management measures meet the needs and expectations of the local community.

The Draft Addendum lists recommended management measures that attempts to address issues raised and prioritises them as high, medium or low. Some high priority recommendations have already been implemented. For example, State Emergency Service has visited residents to discuss safety during floods and council is currently investigating the installation of a flood warning system. Vegetation has been cleared from amongst the boulders downstream of the Pacific Highway and contractors had been scheduled to remove sedimentation in the vicinity of the private access bridge area.

Gosford City Council would now like to invite you to attend a workshop to view the outcomes of extensive investigations into the issues raised and discuss the management measures appearing in the Draft Addendum.

PHOTOGRAPH 2: Houses along Mannings Road

How Do I Get Involved?

Community input into the Review of the Floodplain Risk Management Plan for this area is essential and you are invited to attend a workshop at: Gosford City Council Chambers on Monday 17June 2013 commencing at 7pm.

Please RSVP before Friday 7 June 2013 if you will be attending.
Sally Smith on 4325 8385

Appendix C

Catchment Management Authority
Hunter–Central Rivers

Cut-Rock Creek in the vicinity of Tuggerah Street Lisarow is a laterally unconfined alluvial stream with the capacity for vertical and lateral adjustment within its floodplain. Due to non-cohesive bank sediments (fine – medium sands), banks are highly sensitive to erosion; an intact riparian buffer of approximately 5 -10 m on both banks is largely responsible for bank stability at the site. Although a significant portion of the riparian vegetation comprises exotic species such as privet (*Ligustrum spp.*) and camphor laurel (*Cinnamomum camphora*) there are many local native species present. In sand-bed streams, riparian vegetation plays a critical role in the creation of pools and riffles, provision of structural habitat and food resources for aquatic biodiversity.

Several large camphor laurel trees on both banks of Cut-Rock Creek have fallen into the channel creating a partial blockage (debris dam) directing floodwaters to the stream banks and causing localised erosion. It is likely that some of the trees have fallen into the channel due to previous basal scour and undercutting. Flood debris, primarily comprising small branches and other vegetative matter is accumulating behind the fallen trees, further reducing channel capacity in flood flow and increasing localised scour and slumping.

The most significant erosion is occurring on the left bank; basal scour has resulted in a 5 m x 2 m section of bank slumping by around 0.5 m. This feature is fairly well vegetated although some of the larger shrubs are tilting towards the channel, indicative of roots shearing off as the bank slumped. The channel was also inspected for approximately 30 m upstream of the debris dam and it was noted that basal scour, undercutting and slumping had also occurred on a number of the outer (concave) banks.

If the debris dam experiences a net increase in woody debris, greater volumes of flood flow will be directed against the left bank resulting in additional bank erosion. However, due to bank stability afforded by the riparian buffer and nature of the erosion processes at the site, additional scour and slumping is likely to remain localised and is not considered to pose a significant risk to infrastructure in the immediate vicinity. Needless to say, volumes of sediment released through bank erosion do have the capacity to cause a range of negative impacts downstream. These include possible reductions in channel capacity, sedimentation, and burial of in-stream habitat. However, in light of the localised nature of the bank erosion at the site and significant riparian buffer, intervention is not considered necessary at this stage. It is recommended that the site is monitored, particularly after bank-full (or greater) flood events; if significant net accumulation of debris causes further bank collapse, this may necessitate the removal of some debris in-stream and/or minor structural works. The riparian buffer should be maintained with the removal of exotic species and replacement with local natives a long-term management aim.

Daniel Keating – CAP Implementation Officer, Vegetation & Riparian

13.08.13

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SUMMARY

• PRIORITY LISTING OF RECOMMENDED FLOODPLAIN MANAGEMENT MEASURES

MEASURES	COMMENT
HIGH PRIORITY	
STRUCTURAL MEASURES:	
Channel Works near Brands Place at Lisarow (Gosford City Council)	Will prevent 23 buildings from being flooded in the 1% event. Cost $610 000 with a benefit/cost ratio of 0.4. Concern regarding land resumption costs.
Realignment and Clearing of Channel from Teralba Street to the Pacific Highway (Gosford and Wyong Councils)	Any developer of flood liable land between Teralba Street and the Pacific Highway downstream, will be required to contribute to the proposed works as described in Appendix B of the Plan. Works to be undertaken by the developer at no cost to Council.
Retarding Basin Chamberlain Rd/MacDonalds Rd (Gosford City Council)	Site to be retained for a future basin. This site was identified in DCP8 for the Lisarow area and funds are available from Section 94 Contributions.
Maintenance of Creek Channel (Gosford and Wyong Councils)	Both Councils are to maintain the existing creek system to ensure that excessive vegetation, debris and silt do not significantly reduce the hydraulic capacity. Cost $10 000 per annum per Council.
Donna Close - Channel Works to contain the 1% flood and prevent inundation of private property. (Gosford City Council)	Cost $270 000. The cost to undertake these works will be partially funded from Section 94 Contributions. These works reduce flood damages and hazard.
Pluim Park "hole" in Mound (Gosford City Council)	These works will lower flood levels by up to 0.05m in a 20% event and allow the soccer fields to be used as a flood storage area during minor events. Cost $10 000, to be undertaken by the Soccer Association.
Tall Timbers - Access during floods (Gosford City Council)	Improve access by raising the private road. Cost is $80 000 with a benefit/cost ratio of 0.5. The responsibility for funding of these works has to be determined.
Bank Protection - Tall Timbers Estate (Gosford City Council)	Prevent further erosion of the creek bank. Cost $50 000.

SUMMARY

MEASURES	COMMENT
HIGH PRIORITY	
NON-STRUCTURAL MEASURES:	
Control on Upstream Catchment Development (Gosford and Wyong Councils)	Close monitoring of proposed development is required by the two Councils. Future designs to include the use of measures to minimise increases in peak flow and water quality degradation. No cost to Council.
Amend S149 Planning Certificates (Gosford and Wyong Councils)	Update the S149 Planning Certificates to include the latest information regarding flooding.
Information/Education (Gosford and Wyong Councils)	Will ensure future damages are minimised by providing regular advice to all flood affected landowners. Cost $5000 per annum per Council.
Additional Information on Flood Hazard (Gosford City Council)	Information regarding the likely hazard in evacuating from a rural property during floods is available upon request. This should include a Flood Evacuation Plan for Lisarow Primary School.
Flood Evacuation Plan for the University Campus (Wyong Council)	To be prepared by the University to Council's satisfaction.

MEDIUM PRIORITY	
NON-STRUCTURAL MEASURES:	
Local Structural Works (preventing the ingress of floodwaters) and House Raising (Gosford and Wyong Councils)	Measure is supported by both Councils. Full (approximately $40 000) or part subsidies (say $10 000) can be obtained from State and Federal funds.
Flood Warning (Gosford and Wyong Councils)	Ready-Set-Go study supported. No cost to Councils.
Lisarow Primary School (Gosford City Council)	Relocation of the school. Cost unknown.

SUMMARY

MEASURES	COMMENT
LOW PRIORITY	
NON-STRUCTURAL MEASURES:	
Retarding Basins (Gosford and Wyong Councils)	Councils to resolve whether potential sites for retarding basins in the upper catchment should be set aside.
Collect and analyse more data to gain a better understanding of flood behaviour (Gosford and Wyong Councils)	Install and maintain additional Maximum Height Recorders. Collect and analyse data from future floods to increase understanding of flood behaviour and ensure accuracy of the design flood levels. Cost $5000 per annum per Council.
Catchment Treatment (e.g. re-afforestation or minimisation of impervious areas) (Gosford and Wyong Councils)	Will not reduce the existing flood problem but can be undertaken for minimal cost to Councils or landowners.
Flood Runner Channel connecting Cut Rock Creek to Bangalow Creek near Mannings Road (Gosford and Wyong Councils)	Alignment of proposed channel to be retained as far as possible in its existing state. Further consideration of this is required during the design of the proposed arterial road. No cost to Councils.
STRUCTURAL MEASURES:	
Re-alignment and clearing of channel from Teralba Street to the Pacific Highway (Gosford and Wyong Councils)	These works to be undertaken, as described in Appendix B of the Plan (and in High Priority Items), if not undertaken by a developer.

SUMMARY

• DEVELOPMENT STRATEGIES - LOCAL (GOSFORD AND WYONG COUNCILS)

ISSUE	RESPONSE
Council's Floodplain Management Policy	All further development must be in accordance with Council's Floodplain Management Policy. Further details are given below.
Guidelines for Approved Development within the Floodplain (Gosford City Council Policy)	Floor levels of all new buildings to be at a minimum of 0.5m above the 1% flood level and 0.3 m above the surrounding ground level. Fill levels to be 0.3m above the 1% flood level. Garage floor levels to be at or above the 1% flood level. No cost to Council.
Guidelines for Approved Development within the Floodplain (Wyong Council Policy)	Floor levels of all new buildings to be at a minimum of 0.3m above the 1% flood level. Fill levels to be to the 1% flood level. No cost to Council.
Further Subdivision of Land within the Floodplain	No further subdivision should be permitted if it will increase the number of residents living in the floodplain and therefore the risk to life.
Filling on the Floodplain (Gosford and Wyong Council Policy) (Gosford City Council only)	Subject to the following guidelines: . filling is not recommended in a Floodway, . filling will be considered in a Flood Storage/Fringe area for construction of a building pad for residential use up to 500 m^2. A cut/fill approach must be adopted and the filling must not restrict overland flow paths, and not adversely affect adjoining properties, . the importation of fill is not permitted.
Renovations or Extensions to Existing Buildings including Landscaping and Fences	Works on the floodplain will only be permitted if they can be shown to have minimal impact upon the flood flow characteristics of the area and comply with the other strategies.
Access to Properties during Floods	No development will be permitted unless the developer can assure Council that access to and from the site during floods has been adequately addressed.
Control of Future Catchment Development	To ensure the flood problem is not exacerbated. No cost to Council.
On-Site Detention	Will assist in reducing increases in peak flow following catchment development. No cost to Council for works.

• DEVELOPMENT STRATEGIES - GENERAL (GOSFORD AND WYONG COUNCILS)

ISSUE	RESPONSE
Greenhouse Effect	To be monitored.
Future roadworks or construction/maintenance of other major public works on the floodplain.	Council or any other constructing authority must ensure that the proposed works will not significantly affect flood levels or flows elsewhere.
Future Bridge Upgrade Work	Prior to the design of any bridge or creek crossing by public authorities (such as the SRA or RTA) hydraulic analysis should be undertaken to assess the impacts upon flooding. No cost to Council.
Further Development of Pluim Park	Conditional upon the guidelines provided in Appendix C of the Plan.
Water Quality	Both Councils will ensure that as far as possible any approved works in the creek or in the catchment will not adversely affect the water quality downstream.
Liaison between Gosford and Wyong Councils	Each Council should be advised (in writing and given the right of reply) of any development within the other Council area which may have an impact on flooding or water quality within its Council area.

A detailed cost estimate for the proposed works for each area, and benefit/cost ratios, are provided as Appendix D. The benefits only include the reduction in tangible damages to buildings (internal and external) and do not include tangible damages to public utilities (roads, reserves, etc.). Intangible flood damages (anxiety, flood hazard, etc.) will also be reduced, and would therefore increase the benefit/cost ratio if quantified.

The key features of the Plan are:

- *the 1 % flood is to continue as the Designated Flood Standard, and the Minimum Floor Level established as 0.5 m above the 1 % flood (Gosford City Council) and 0.3 m above the 1% flood (Wyong Council - subject to possible future amendment),*
- *definition of the 1 % flood extent and identification of properties subject to Minimum Floor Level requirements on the S149 Planning Certificates for Gosford City Council; definition of the 1% flood levels for Wyong Council,*
- *a priority listing of flood mitigation strategies has been adopted to ensure that all properties inundated above floor level in a 1 % flood are offered some form of protection,*
- *criteria for the future development of the upper catchment have been determined. These will ensure that the volume of runoff and peak flows are not increased significantly downstream and the impact on water quality and sedimentation is minimised,*
- *filling of the floodplain may be permitted subject to adherence to Council's guidelines,*

SUMMARY

- *both Councils will provide information and education to the local residents in order to ensure that flood damages in the future are minimised,*
- *further data will be collected and studies undertaken to increase our understanding of flood behaviour and improve the accuracy of the design flood levels,*
- *the practice of house raising or local structural works (preventing the ingress of floodwaters to buildings) is encouraged by both Councils. Funding for house raising can be obtained either as fully funded (say $40 000 per building) or partially funded (say $10 000 per building),*
- *both Councils will amend the S149 Planning Certificates in accordance with this study,*
- *both Councils will ensure that the creek channel is continually maintained and free from excessive silt and debris, particularly under bridges, to ensure minimal impact on flood flows,*
- *applicants or property owners will be advised to make fences and home improvements flood compatible, ensuring minimal hydraulic impact, or to move such works outside the floodplain,*
- *both Councils support any measures which will increase the amount of flood warning time available to the residents,*
- *each Council will inform the other of developments likely to change flood conditions or water quality in the other Council area.*