Central Coast Council

Wyong River Catchment Floodplain Risk Management Study & Plan

Final Report

Volume 1 of 2: Report Text & Appendices

Revision 4
January 2020

Catchment Simulation Solutions

Wyong River Catchment Floodplain Risk Management Study & Plan

REVISION / REVIEW HISTORY

Revision #	Description	Prepared by	Reviewed by
1	Draft report	D. Tetley & S. Yeo	C. Ryan
2	Final draft report	D. Tetley & S. Yeo	C. Ryan
3	Final draft for public exhibition	D. Tetley & S. Yeo	C. Ryan
4	Final report	D. Tetley	C. Ryan

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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

Central Coast Council

25 May 2020 Ordinary Council Meeting

Reference: CPA/263177 - D13908037

Author: Parissa Ghanem, Team Leader Floodplain Management and Senior Planner
Peter Sheath, Section Manager, Waterways

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***

ACKNOWLEDGEMENTS

Catchments Simulation Solutions would like to acknowledge the valuable contributions of a number of individuals who assisted with the preparation of this report. In particular, Mr Peter Sheath, Mr Phil Foster and Mr Vic Tysoe of Central Coast Council provided a substantial amount of assistance and information for the study. Allison Flaxman and Kristin Ridgely from the NSW State Emergency Service also provided valuable emergency response information and feedback throughout the course of the study.

Thanks are also extended to those community members who completed questionnaires, attended the community information sessions and provided feedback on each of the flood risk management measures considered as part of the study.

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

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Executive Summary

Overview

The Wyong River catchment is located on the Central Coast of New South Wales. The catchment is drained by a network of rivers and creeks including the Wyong River, Cedar Brush Creek, Jilliby Jilliby Creek, Porters Creek, Mardi Creek and Deep Creek that ultimately drain into Tuggerah Lake. Tuggerah Lake, in turn, discharges to the Pacific Ocean via a single outlet at The Entrance.

During periods of heavy rainfall within the catchment, there is potential for water to overtop the banks of the various watercourses and inundate the adjoining floodplain. The catchment has a long history of flooding including significant events in 1949, 1964, 1977 and 2007.

In recognition of the flooding problems confronting the Wyong River catchment, Central Coast Council commisioned Catchment Simulation Solutions to prepare a Floodplain Risk Management Study and Plan for the catchment. The primary goal of the project was to quantify the nature and extent of the existing flooding problem and evaluate options that could be potentially implemented to manage the existing, future and continuing flood risk.

This floodplain risk management study and plan updates and expands upon the *'Lower Wyong River Floodplain Risk Management Study'* and *'Lower Wyong River Floodplain Risk Management Plan'* (Paterson Consultants, 2010) that focussed on the lower (i.e., downstream) sections of the Wyong River catchment only. However, it should be noted that this study excludes the Porters Creek subcatchment as well as the Tuggerah Lake foreshore areas which were included in the *'Porters Creek Floodplain Risk Management Study'* (Cardno, 2011) and *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* (WMAwater, 2014) respectively.

The Existing Flooding Problem

The extent of the existing flooding problem was quantified using a computer flood model of the Wyong River catchment. The computer model was used to simulate a range of design floods and the outputs from the model were used to quantify the potential impact of flooding on people and property across the catchment. The outcomes of the modelling determined that:

- Only 3 properties would be exposed to above floor inundation during a 20% AEP flood
- More than 500 properties would be exposed to above floor inundation during a 1% AEP flood
- More than 1,700 properties would experience above floor inundation during the probable maximum flood (PMF).

A flood damage assessment was completed as part of the study and determined that the average annual cost of flooding would be $4.3 million if the "status quo" was maintained.

The assessment ultimately determined that the following areas are likely to experience significant property damage, risk to life and/or evacuation difficulties during floods within the Wyong River catchment:

- Yarramalong valley;
- Rural residential properties located in the vicinity of Deep Creek including Yarramalong Road, Old Maitland Road, Collies Lane, McPherson Road and Mardi Road;
- The Tuggerah Straight industrial area;
- Properties in the vicinity of South Tacoma and Tacoma; and,
- Properties adjoining the Wyong River south of Wyong (e.g., Panonia Road, McDonagh Road, Boyce Avenue).

Community Consultation

Consultation with the community has been an important component of the study. Consultation was completed throughout the study. The consultation has provided a first-hand account of the community's experiences during past floods, how the community would likely respond during future floods and has also provided an opportunity for the community to provide feedback on the flood risk management options that were being considered as part of the study.

The responses to the community questionnaire showed that:

- 77% of respondents have experienced some form of inundation or disruption as a result of flooding in the catchment. The most commonly reported flooding impact was traffic disruptions (i.e., water covering roads).
- 63% of respondents indicated they would remain at home and only 8% indicated they would evacuate to an official evacuation centre. This is despite many properties in the lower catchment area (e.g., South Tacoma) being potentially isolated for several days.
- The population has a mixed level of flood awareness. About 70% of respondents correctly identified their property as being potentially flood liable. However, around 30% of respondents that believed their property could not be flooded were actually contained within the PMF extent.

The final draft 'Wyong River Catchment Floodplain Risk Management Study & Plan' was also placed on public exhibition from 25 March 2019 until 26 April 2019. The public exhibition provided the opportunity for the community and key stakeholders to review the final draft report and provide feedback on the report content. Two community drop-in sessions were also held during the public exhibition period.

A total of eight submissions were received during the exhibition period. In general, the submissions were supportive of the options being recommended for implementation (discussed further below) and no substantial modifications to the final draft report were required to address each comment. However, some sections of the report text were updated to better illustrate the community's concerns regarding lack of maintenance of drainage channels and culverts (particularly on the northern floodplain of the lower Wyong River).

Options for Reducing the Existing Floodplain Problem

A range of flood modification, property modification and response modification measures were considered to help manage the existing flood risk. Each option was evaluated against a range of criteria to provide an appraisal of the potential feasibility of each option. This included the impact of each option on existing flood behaviour, the environment, economics and emergency response as well as the technical feasibility of each option. The outcomes of the detailed assessment of each option are presented in the following chapters:

- Flood Modification Options: Chapter 7.
- Property Modification Options: Chapter 8.
- Response Modification Options: Chapter 9.

Draft Floodplain Risk Management Plan

Based upon the outcomes of the detailed evaluation, the options outlined below are recommended for implementation as part of the draft Floodplain Risk Management Plan for the Wyong River catchment. Further detailed information on each option including costs, implementation schedules and funding opportunities is provided in Chapter 10.

High Priority Options:

- Council to seek clarification from Department of Planning and Environment as to whether 'exceptional circumstances' are required to promote safer on-site refuge above the level of the PMF in dwellings located on land within the Flood Planning Area;
- Council to consider applying for exceptional circumstances to better ensure risk to life is managed satisfactorily in those parts of the floodplain located between the Flood Planning Area and the PMF extent;
- Revision to Central Coast Council's Development Control Plan to ensure future development and redevelopment is compatible with the flood risk;
- Local flood plan updates including updates to flood intelligence cards;
- Preparation of / updates to flood emergency plans for homes, businesses and vulnerable floodplain exposures;
- Council to notify key infrastructure providers of revised flood information available as part of the current study in an effort to improve the level of service afforded by key infrastructure during floods;
- Flood warning system upgrades including improving mobile phone coverage as well as developing ways of better disseminating flood information (e.g., SMS messaging, online flood information portal); and,
- Local drainage study for northern floodplain of the lower Wyong River.
- Incorporate maintenance of drainage channels and culverts across lower Wyong River floodplain into Council maintenance program.

Medium Priority Options:

- Mardi Creek detention basin;
- Anzac Road levee;
- Various community education activities including holding community meetings, providing property level flood information and developing strategies to discourage dangerous behaviour (e.g., driving through floodwaters);
- Upgrades to evacuation route through Pioneer dairy; and,
- Incorporate removal of unnecessary floodplain vegetation as part of annual asset management program.

Low Priority Options:

- Installation of flood barriers at roadway locations that are frequently overtopped;
- Council to initiate discussions with RailCorp to confirm likelihood of railway upgrades and opportunities to include flood mitigation works as part of this;
- Look at opportunities to install helipad/elevated PMF refuge at South Tacoma;
- Council to undertake discussions with owners of properties potentially eligible for voluntary house purchase and voluntary house raising to discuss options for reducing the current flood risk;
- Open and maintain fire trials to allow access to/from upper catchment during floods; and,
- Flood insurance.

It is expected that implementation of the plan will have a capital cost of approximately $2.1 million. In addition to the capital costs, some options will incur ongoing maintenance costs. Many of the options will also require a significant investment in time from various agencies including Central Coast Council, the State Emergency Service and the Bureau of Meteorology which are not accounted for in the overall cost estimate.

If the structural options (i.e., Mardi Creek detention basin and Anzac Road Levee) are implemented in isolation it is expected that the number of properties exposed to above floor flooding during a 1% AEP flood would reduce by six and flood damages would be reduced by over $850,000 over the next 50 years. Implementation of the remaining, non-structural, options will help ensure the flood damage potential is minimised across future development and re-development areas and will also help to ensure the continuing flood risk is minimised during particularly severe floods.

1 INTRODUCTION

1.1 Background

The Wyong River catchment is located on the Central Coast of New South Wales and occupies a total area of 440 km^2. The extent of the catchment is shown in **Figure 1**. As shown in **Figure 1**, the catchment is drained by a network of rivers and creeks including the Wyong River, Cedar Brush Creek, Jilliby Jilliby Creek, Porters Creek, Mardi Creek and Deep Creek that ultimately drain into Tuggerah Lake. Tuggerah Lake is the largest of three interconnected coastal lakes that discharge to the Pacific Ocean via a single outlet at The Entrance.

The upper parts of the catchment include undeveloped forested areas, rural farms as well as the villages of Yarramalong, Cedar Brush Creek and Dooralong. East of the Pacific Motorway the catchment is more developed and includes the major township of Wyong as well as Tuggerah, Mardi and Tacoma. The lower sections of the catchment are home to a range of residential, commercial and industrial land uses including the Tuggerah Straight industrial area.

During periods of heavy rainfall within the catchment, there is potential for water to overtop the banks of the various watercourses and inundate the adjoining floodplain. The catchment has a long history of flooding including significant events in 1927, 1949, 1964 and 1977 as well as more recently in 2007.

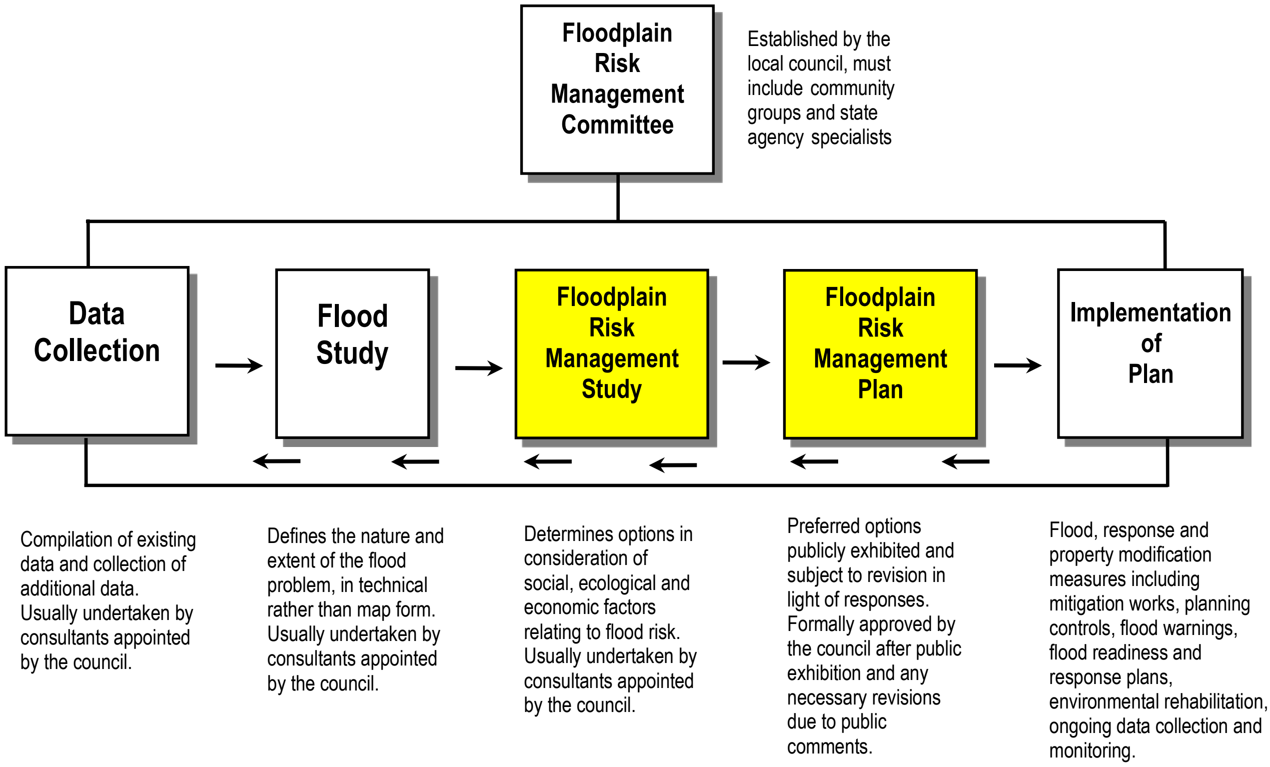
In recognition of the flooding problems confronting the Wyong River catchment, Central Coast Council resolved to prepare a Floodplain Risk Management Study and Plan for the catchment.

1.2 The Floodplain Risk Management Process

The Wyong River Floodplain Risk Management Study and Plan has been prepared in accordance with the requirements of the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005).* The '*Floodplain Development Manual'* guides the implementation of the State Government's *Flood Policy*. The *Flood Policy* is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005)*.

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 Local Government in its floodplain management responsibilities.

The Policy provides for technical and financial support by the State Government through the following stages:



Stages 1 and 2 of the process were previously completed culminating in the preparation of the *'Wyong River Catchment Flood Study'* (BMT WBM, 2014).

Central Coast Council engaged Catchment Simulation Solutions to prepare The Wyong River Catchment Floodplain Risk Management Study and Plan, which represent stages 3 and 4 of the process outlined above. The aim of the Floodplain Risk Management Study is to identify, assess and compare various options for managing the flood risk across the catchment. The Floodplain Risk Management Plan draws on the outcomes of the Study and provides a set of recommended options that will outline how to best manage the existing, future and continuing flood risk across the floodplain of the Wyong River catchment.

This floodplain risk management study and plan updates and expands upon the *'Lower Wyong River Floodplain Risk Management Study'* and *'Lower Wyong River Floodplain Risk Management Plan'* (Paterson Consultants), that was adopted by Council in 2010. These previous investigations focussed on the lower (i.e., downstream) sections of the Wyong River catchment only.

It should be noted that the Wyong River catchment includes Porters Creek. However, the Porters Creek subcatchment is not included in this study as it was previously considered in the *'Porters Creek Floodplain Risk Management Study'* (Cardno, 2011). Similarly, the Wyong River drains into Tuggerah Lake. Those areas located on the foreshore of Tuggerah Lake were previously considered as part of the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* (WMAwater, 2014) and are not included in this study.

1.3 Report Structure

The following report forms the Floodplain Risk Management Study and Plan for the Wyong River Catchment. The report is presented in two volumes:

- Volume 1 (this document) contains the report text and appendices; and,
- Volume 2 (separate A3 document) contains all complementary maps/figures.

Volume 1 has been divided into the following sections:

- Section 2 - Background Information: Provides general information regarding the catchment, including the history of flooding as well as existing planning and emergency response protocols
- Section 3 – The Existing Flood Risk: Describes the current impact of flooding on the community for a range of different floods. This includes an assessment of the impact of flooding on key facilities, the potential cost of flooding as well as the potential for floodwater to damage buildings and/or pose a danger to personal safety.
- Section 4 – Current Planning Measures: summarises the main legislation, policy and guidelines that affect the development of land.
- Section 5 – Current Emergency Management Protocols: provides an overview of emergency management measures that are currently implemented across the catchment to assist in managing the flood risk. Opportunities to improve these existing protocols are also discussed.
- Sections 6 to 9: discusses the merits of a range of flood, property and response modification measures that could be potentially implemented to manage the existing, future and continuing flood risk across the catchment
- Section 10 – Draft Floodplain Risk Management Plan: provides a preferred list of options that are considered appropriate for adoption by Council to manage the flood risk.

2 Catchment Information

2.1 Catchment Description

The Wyong River catchment is located on the Central Coast of New South Wales and occupies a total area of 440 km^2. The extent of the catchment is shown in **Figure 1**, which is enclosed in Volume 2.

The headwaters of the Wyong River are located at the foot of the Watagan Mountains. The river generally flows in a south and then south-easterly direction. The upper sections of the catchment are characterised by extensive forested areas. However, rural residential properties and small villages are also prominent. The villages include Cedar Brush Creek (population 278), Yarramalong (population 446), Lemon Tree (population 385), Dooralong (population 336), Wyong Creek (population 387) and Jilliby (population 1,766).

The Wyong River is joined by a number of tributaries across the upper catchment. This includes:

- Jilliby Jilliby Creek;
- Cedar Brush Creek;
- Porters Creek; and,
- Deep Creek.

The size of each of the major subcatchments contained within the Wyong River catchment are summarised in **Table 1**.

Table 1 Subcatchment Parameters for Major Wyong River Subcatchments

Subcatchment	Area	
	km^2	% of Total Catchment Area
Cedar Brush Creek	71	16%
Jilliby Jilliby Creek	100	23%
Porters Creek	55	13%
Deep Creek	9	2%
Mardi / Tuggerah Creek	12	3%

Downstream of the confluence of the Wyong River and Jilliby Jilliby Creek the topography flattens appreciably, and the floodplain becomes more expansive. Several major transportation routes are located across this section of the catchment including M1 Pacific Motorway, Pacific Highway and Main Northern Railway.

Urban development is more prominent across the downstream sections of the catchment. This includes the major township of Wyong (population 3,632) as well as Mardi (population 3,439), Tuggerah (population 1,017) and Tacoma / South Tacoma (combined population 751). Land use across each of these urban centres includes a mix of residential, industrial and commercial as well as open space.

The Tuggerah straight industrial area is also located immediately south of the Wyong River within the lower catchment (refer **Figure 1**). The majority of the industrial area drains into Mardi Creek and then into Tuggerah Creek which forms another tributary of the Wyong River. Mardi Dam, a water supply dam for Central Coast Council, is located within the headwaters of the Mardi Creek catchment. This dam does not currently function as a flood storage basin (i.e., its purpose is water supply).

The Wyong River ultimately discharges into Tuggerah Lake. Tuggerah Lake discharges to the Pacific Ocean across a sandy beach berm at The Entrance, which is intermittently open and closed. Tuggerah Lake also drains a number of other significant catchments including Ourimbah Creek as well as the Budgewoi Lake and Munmorah Lake catchments.

Figure 3 shows the variation in ground surface elevation across the catchment. As shown in **Figure 3**, elevations vary from 0 mAHD in the vicinity of Tuggerah Lake to over 300 mAHD in the headwaters of the catchment. The areas located east of the Pacific Motorway are typically located below 10 mAHD.

2.2 Flood History

The Wyong River catchment has a significant history of flooding although records for areas outside of the main township of Wyong are scant. Significant rainfall and flood events have occurred in the Wyong River catchment in June 1905, 1927, 1949, 1964, 1977, 1989, 1990, 20017 and 2015, to name a few.

As stated in the Lower Wong river Floodplain Risk Management Study and Plan, completed by Paterson Consultants in 2010, although reports of flooding in the Wyong River date back to 1867, reliable flood level data for historical flood events is available for very few of these events. The recorded flood level gauge level data is distributed over a wide area with no single location having a complete record of the historical flood events (Paterson Consultants, 2010).

As stated by BMT in the Wyong River Flood Study (2014) there are a large number of gauges recording continuous rainfall in the vicinity of the catchment, however most of these have only been installed within the last 25 years. There are further 22 daily rainfall gauges within the vicinity of the study catchment that can provide valuable information on the spatial variability of rainfall during significant rainfall events. The period of record for these gauges is much more extensive, with most gauges being at least 60 years old and many of which are still operational (BMT WBM, 2014). This information was used as part of the calibration and validation of the models developed for the flood study and are discussed in that report accordingly.

The largest flood on record with a recorded flood level in the vicinity of the Wyong township occurred in June 1949 and produced a peak water level of about 4.2 mAHD at the Wyong railway bridge (BMT WBM, 2014). Other significant events occurred in June 1964 (4.1 mAHD at the railway bridge) and March 1977 (3.6 mAHD at the railway bridge). The most recent flood occurred in June 2007 and produced a peak water level of about 2.6 mAHD at the Wyong railway bridge. A summary of peak historic water levels are provided in **Table 2**.

Table 2 Major Historic Flood Levels at the Wyong Railway Bridge (BMT WBM, 2014)

Year	Flood Level (mAHD)
1949	4.2 (estimated)
1964	4.1
1927	3.8
1977	3.6
1930	3.2
2007	2.6

The available historic flood information indicates that most significant floods tend to occur around June. Significant rainfall at this time of year is generally associated with east coast lows which produce significant rainfall over multiple days in conjunction with elevated ocean water levels. Consequently, the most significant flooding typically occurs as a result of extended periods of rainfall. Nevertheless, flooding across the Tuggerah straight industrial area can also occur as a result of relatively short duration rainfall bursts. **Plate 1** shows floodwaters across Anzac Road at Tuggerah during the 2007 flood.

Plate 1 Floodwaters in Anzac Road, Tuggerah during 2007 flood (photo provided by Mr Phil Hearne).

A range of flood photos were also provided by Council for the 2007 flood across other sections of the Wyong River catchment. A selection of these photos and are presented in **Plates 2** to **6**. As noted in **Table 2**, the 2007 flood was not a particularly large event relative to other past floods – the flood levels reached in the 2007 event were estimated to be roughly equivalent to a 10% AEP event in the Wyong River catchment (BMT WBM, 2014). However, the photographs show significant inundation extents and many roadways cut by water. Accordingly, it does not take a particularly large flood to produce significant impacts to those living and working within the catchment.

2.3 Local Environment

2.3.1 Soils

1:250,000 geological mapping for Sydney (LPI, 2002) indicates that the elevated sections of the Wyong River catchment are underlain by claystones, sandstone and shales while the lower sections of the catchment typically comprise alluvial material (sands, silts, gravels and clays).

The soil types across the lower sections of the catchment typically have a moderate to high water holding capacity, are poorly drained and are subject to seasonal waterlogging. The waterlogged nature of much of the floodplain area results in a low rate of organic matter breakdown leading to a significant presence of organic matter (Patterson Consultants, 2010). Despite the high levels of organic matter, the soils tend to have low fertility, owing to the low soil pH.

The Office of Environment and Heritage has also mapped the occurrence of Acid Sulfate Soils (ASS) along the coast of NSW, including the Wyong River catchment. When exposed to oxygen, ASS oxidise and sulphuric acid is released, reducing soil fertility, killing vegetation and reducing fish population. The ASS mapping indicates a large variation in ASS soil potential across the catchment from no known occurrence / low probability of occurrence in areas west of the Pacific Motorway to a high probability of occurrence ASS across the lower floodplain areas. Across the lower floodplain areas, the depth to ASS material is considered to range from less than 1 metre to between 1m and 3m. The potential for ASS across the lower floodplain has been confirmed by investigations across the Pioneer Dairy site (Patterson Consultants, 2010).

2.3.2 Vegetation

The upper sections of the Wyong River catchment have been partly cleared to allow for rural residential development. The residual forested areas typically comprise Stringybark, Mahogany and moist, layered forest. The riparian areas adjoining the major watercourses are generally classified as alluvial, gallery rainforest.

The lower sections of the catchment have been more extensively modified and cleared. In general, the remaining vegetation communities are contained in close proximity to watercourses and wetland areas. This includes estuarine swamp oak forest adjoining the banks of the Wyong River, Mardi Creek and Tuggerah Creek as well as blackbutt, melaleuca, paperbark and woollybutt forests in the upper reaches of the Mardi Creek catchment.

Plate 2 Looking east along Yarramalong Road from the old Maitland Road Intersection during 2007 flood (photo provided by the SES via Central Coast Council).

Plate 3 Looking south west from Mardi Road towards Pacific Motorway during 2007 flood (photo provided by the SES via Central Coast Council)

Plate 4 Looking south along McPherson Road towards Mardi during 2007 flood (photo provided by the SES via Central Coast Council)

Plate 5 Looking north from Collies Lane towards Wyong River during 2007 flood (photo provided by the SES via Central Coast Council)

Plate 6 Looking west along Collies Lane during 2007 flood (photo provided by the SES via Central Coast Council)

Much of the lower Wyong River floodplain is classified under State Environmental Planning Policy (SEPP) No. 71 Coastal Protection (refer **Figure 2**). Furthermore, areas located within 100 metres of the Wyong River plus adjoining wetlands (refer following section) are classified as "sensitive" coastal areas under SEPP71. This SEPP designation restricts development where there is potential for water quality to be adversely impacted (e.g., through stormwater or effluent discharge).

2.3.3 Wetlands

The Wyong River catchment includes several State Environmental Planning Policy (SEPP) No. 14 wetlands located to the east of the Pacific Highway. The location of the SEPP14 wetlands is shown in **Figure 2** and includes:

- SEPP 14 Wetland No. 896 (located north of Kooindah Waters Estate and east of the Wyong Race Club).
- SEPP 14 Wetland No. 897 (generally bound by Kooindah Waters Golf Course, McDonagh Road, Braithwaite Road and Pollock Avenue).
- SEPP 14 Wetland No. 899 (located to the south and east of Kooindah Waters Golf Course).
- SEPP 14 Wetland No. 899a (located to the west of Kooindah Waters Golf Course and to the north of Meander Village).

- SEPP 14 Wetland No. 900 (located on the southern floodplain of the Wyong River adjoining the Pioneer Dairy site). This wetland is also referred to as the "Tuggerah Oxbow".

The SEPP14 designation indicates that these areas have been formally classified as coastal wetlands and are protected in the environmental and economic interests of the State. This generally prevents clearing, filling, draining or the construction of levees within the wetland.

2.3.4 Heritage

A number of sites within the Wyong River catchment are currently protected through heritage listing under the Wyong Local Environmental Plan 2013. The location of heritage items are shown in **Figure 2**.

Several parcels of land are also subject to Aboriginal land claims and/or are the location of Aboriginal heritage sites. The location of the Aboriginal land claims and heritage items are shown in **Figure 2** and specific information on each item is provided in **Table 3**.

Table 3 Summary of Aboriginal Heritage Site

ID (refer **Figure 2**)	**Site Name**	**Site Features**
1	Wollombi Creek Warwallen Creek	Shelter with Deposit
2	KR 3	Axe Grinding Groove
3	KR 6	Axe Grinding Groove
4	KR 5	Axe Grinding Groove
5	Walkers Ridge	Shelter with Art
6	TD 4	Isolated Find
7	Null Road 1	Axe Grinding Groove
8	Brush ck. Falls	Axe Grinding Groove
9	triple l's	Shelter with Art
10	Stonehouse Shelter Bebeah	Shelter with Art
11	Metre Shelter Brush Creek	Shelter with Art
12	Orange Figure Brush Creek	Shelter with Art
13	Brush Creek	Axe Grinding Groove
14	Brush Creek Brush Creek Grooves 1	Axe Grinding Groove
15	Teralba Kooree Trig	Shelter with Art, Shelter with Deposit
16	Priests Ridge	Shelter with Art
17	Kooree	Axe Grinding Groove
18	Priests Ridge	Shelter with Art
19	Priests Ridge	Shelter with Art
20	Token Male Upper Mangrove Creek Catchment (UMC.134)	Shelter with Deposit

ID (refer **Figure 2**)	**Site Name**	**Site Features**
21	Yarramalong Madona Park Love's Cave	Axe Grinding Groove, Shelter with Art, Shelter with Deposit
22	SRG	Isolated Find
23	SR 5	Open Camp Site
24	SR 4	Isolated Find
25	SR 2	Open Camp Site
26	SR 3	Isolated Find
27	SR 1	Open Camp Site
28	WR 1	Open Camp Site
29	WR 2	Open Camp Site
30	WR 3	Isolated Find
31	WR 4	Open Camp Site
32	WR 5	Isolated Find
33	WR 6	Isolated Find
34	WR 7	Open Camp Site
35	WR 8	Isolated Find
36	WR 9	Isolated Find
37	Olney	Shelter with Art
38	Myrtle Creek/Maculata Rd #1 Wyong State Forest	Axe Grinding Groove
39	Myrtle Creek/Maculata Rd #2 Wyong State Forest	Axe Grinding Groove
40	Myrtle Creek/Maculata Rd #3 Wyong State Forest	Axe Grinding Groove
41	Mardi to Mangrove 1	
42	Tuggerah Sterland 1 (TS1)	
43	Wyong Creek 1 PAD	
44	Mardi to Mangrove 2	
45	Wyong Creek	Axe Grinding Groove
46	Wyong Creek Wen Mar	Shelter with Art
47	WRMD1	
48	Main Range	Shelter with Deposit
49	Wyong Creek	Shelter with Art, Shelter with Deposit
50	Mardi to Mangrove 3	
51	Tuggerah	Open Camp Site
52	WP1	
53	WP-4	
54	WP3	

ID (refer **Figure 2**)	**Site Name**	**Site Features**
55	WP2	
56	Tuggerah PAD 1	
57	Tuggerah	Open Camp Site
58	Hue Hue Road Surface Scatter Wyong	Open Camp Site
59	Bluetongue IF2 (Dooralong)	
60	Bluetongue IF1 (Dooralong)	
61	Bluetongue IF3 (Dooralong)	
62	Hue Hue Road	Open Camp Site
63	WS20/A	
64	WS20/B	
65	Lakes G ISO 14	
66	Lakes G OS 15	
67	Lakes G OS 13	
68	IF 1, Wyong	
69	Lakes G ISO 16	
70	Lakes G ISO 12	
71	OWP ISO 18	
72	Bitova ISO 11	
73	Bitova ISO 1	
74	Bitova OS 2	
75	Bitova ISO 5	
76	Bitova OS 6	
77	Bitova OS 7	
78	Bitova OS 9	
79	Bitova OS 10	
80	Bitova ISO 3	
81	Bitova OS 4	
82	Bitova ISO 8	
83	OWP ISO 17	
84	Kooindah Resort 2	
85	Kooindah Resort 1	
86	Tacoma SouthTacoma	Axe Grinding Groove, Open Camp Site
87	J 1	
88	Wadalba Hill Scar 1	
89	Wadalba Hill Grooves 2	

Notably, the Pioneer Dairy site falls under the heritage register as well as an Aboriginal lands claim (in addition to part sections of the site falling within a SEPP14 wetland and SEPP71 Coastal zone).

2.4 Demographics

Having an understanding of the characteristics of the population living and working within the catchment is an important component of developing and assessing potential flood risk management measures. For example, the availability of internet, the primary language spoken at home and the availability of a motor vehicle can have a strong bearing on the feasibility of different education, flood warning and evacuation strategies.

In this regard, the Australian Bureau of Statistics (ABS) provides a range of information for the various communities that are contained within the catchment that was collected as part the 2011 census. A summary of pertinent information extracted from the ABS website (http://www.abs.gov.au/) is provided in **Table 4**.

The information presented in **Table 4** shows that:

- English is the only language spoken at home in 97% of households.
- 83% of households have an internet connection with the majority (74%) having access to high speed broadband.
- The median age of residents within the catchment is 40.
- The Dooralong Valley shows a high level of address continuity with over 90% of the population residing at the same address over the past 5 years. Accordingly, most of the population in this area is likely to have experienced at least one large flood (e.g., 2007). Conversely, the Yarramalong Valley, Wyong and Tuggerah only shows 50% of the population residing at the same address for more than 5 years. This more transient population is less likely to have experienced a significant flood at the current place of residence leading to a reduced level of flood awareness.

2.5 Consultation

Consultation with community is an important part of the floodplain risk management process. Appropriate consultation helps to ensure that local flood risk management issues are identified and addressed as part of the project and that the study and plan is ultimately accepted by the community.

Consultation with the community was originally completed as part of the 'Wyong River Catchment Flood Study' (BMT WBM, 2014). This consultation yielded a significant amount of information regarding historic flood behaviour which was used to calibrate the flood models. Further discussion on the 'Wyong River Catchment Flood Study' (BMT WBM, 2014) is provided in Section 3.2.1.

Additional consultation was also completed as part of the current study. This included distribution of a community questionnaire as well as public information sessions and community drop-in sessions. The outcomes of each component of the consultation is provided in the following sections.

Table 4 Summary of Catchment Demographics

Statistic			Dooralong & Lemon Tree	Jilliby, Little Jilliby & Allison	Yarramalong, Cedar Brush Ck & Ravensdale	Wyong Creek	Wyong	Tuggerah	Tacoma & South Tacoma
			Village/Town						
Population Statistics		Median Age	44	42	40	45	45	32	37
Population Statistics	Education	Year 12 or equivalent	44%	45%	59%	57%	35%	46%	34%
Population Statistics	Education	Year 10 or equivalent	44%	40%	31%	32%	37%	41%	48%
Population Statistics	Education	Did not Complete Year 10	12%	15%	10%	11%	28%	14%	17%
Population Statistics	Address Continuity	Same usual address 1 year ago as in 2011	99%	84%	77%	87%	79%	76%	84%
Population Statistics	Address Continuity	Same usual address 5 years ago as in 2011	94%	63%	52%	67%	50%	50%	64%
Dwelling Statistics		Average No. Motor Vehicles per dwelling	2.2	2.4	2.0	2.4	1.3	1.5	2.1
Dwelling Statistics		Average persons per dwelling	3.0	3.1	2.4	2.8	2.2	2.7	3.1
Dwelling Statistics	Language spoke at home	Speaks English only	97%	99%	98%	96%	95%	96%	99%
Dwelling Statistics	Language spoke at home	Speaks other language:	3%	1%	1%	4%	5%	4%	1%
Dwelling Statistics	Occupier Status	Separate house	99%	98%	99%	94%	75%	77%	100%
Dwelling Statistics	Occupier Status	Semi-detached, row or terrace house, townhouse	0%	0%	0%	6%	13%	23%	0%
Dwelling Statistics	Occupier Status	Flat, unit or apartment:	0%	1%	1%	0%	11%	0%	0%
Dwelling Statistics	Occupier Status	Other dwelling (cabin, caravan):	1%	1%	1%	0%	2%	1%	0%
Internet Statistics	Type of Internet Connection	No Internet connection	12%	10%	15%	14%	35%	19%	15%
Internet Statistics	Type of Internet Connection	Broadband	79%	78%	78%	81%	53%	68%	78%
Internet Statistics	Type of Internet Connection	Dial-up	7%	6%	5%	0%	3%	3%	0%
Internet Statistics	Type of Internet Connection	Other	3%	3%	0%	2%	3%	7%	3%
Internet Statistics	Type of Internet Connection	Internet connection not stated	5%	3%	2%	3%	5%	2%	3%

2.5.1 Community Questionnaire

A community questionnaire was prepared as part of the current study and was distributed to approximately 2,500 residential and business properties in the catchment. A copy of the questionnaire is included in **Appendix E**.

The questionnaire sought information from the community regarding whether they had experienced flooding, their level of flood awareness and how they would respond in a future major flood. A total of 256 questionnaire responses were received and a summary of all questionnaire responses is provided in **Appendix E**. Most of the responses included addresses enabling spatial interpretation of the questionnaire responses (refer **Figure E1**).

The responses to the questionnaire indicate that:

- 77% of respondents have experienced some form of inundation or disruption as a result of flooding in the catchment. This includes (also refer **Plate 7** and **Figure E1**):
  -> Traffic disruptions (140 respondents);
  -> Garage inundation (49 respondents); and,
  -> House or business inundated above floor level (11 respondents).
- The population has a mixed level of flood awareness. Of those who answered question 5, about 31% of respondents admitted that they did not know whether their house or business was potentially flood liable or not. However, of the 34% who claimed to know that their house or business could *not* be flooded, more than half are located within the PMF extent (as defined in the *'Wyong River Catchment Flood Study'*). And, interestingly, of the 35% who claimed to know that their house or business could be flooded, about 14% are actually located beyond the PMF floodplain.
- People's understanding of flood risks can also be assessed through answers to question 6 and GIS analysis. About 70% of those who believed their house or business could be flooded in the 1% AEP event were correct. Most of the other respondents who incorrectly think they could be flooded in such an event are located in Mardi. About 84% of those who believed their house or business could be flooded in the PMF event were correct. But 61% of these houses or businesses are actually located within the 1% AEP extent – people could be flooded more frequently than they think.
- Questions 7-9 were designed to gain an understanding of people's likely behaviours during future flood emergencies. It was found that 63% of respondents indicated they would remain at home and only 8% indicated they would evacuate to an official evacuation centre. **Figure E2** shows the spatial distribution of those respondents that would evacuate versus seek refuge at home (considered further in Section 5.4.2). In order of priority, the reasons for remaining at home were:
  - residents felt confident that their home could not be flooded and they could cope with temporary isolation;
  - a need to care for animals;
  - the discomfort/inconvenience/cost of evacuating; and,
  - concern about security of an evacuated property.

  For those intending to evacuate, safety of the family was the overriding concern.

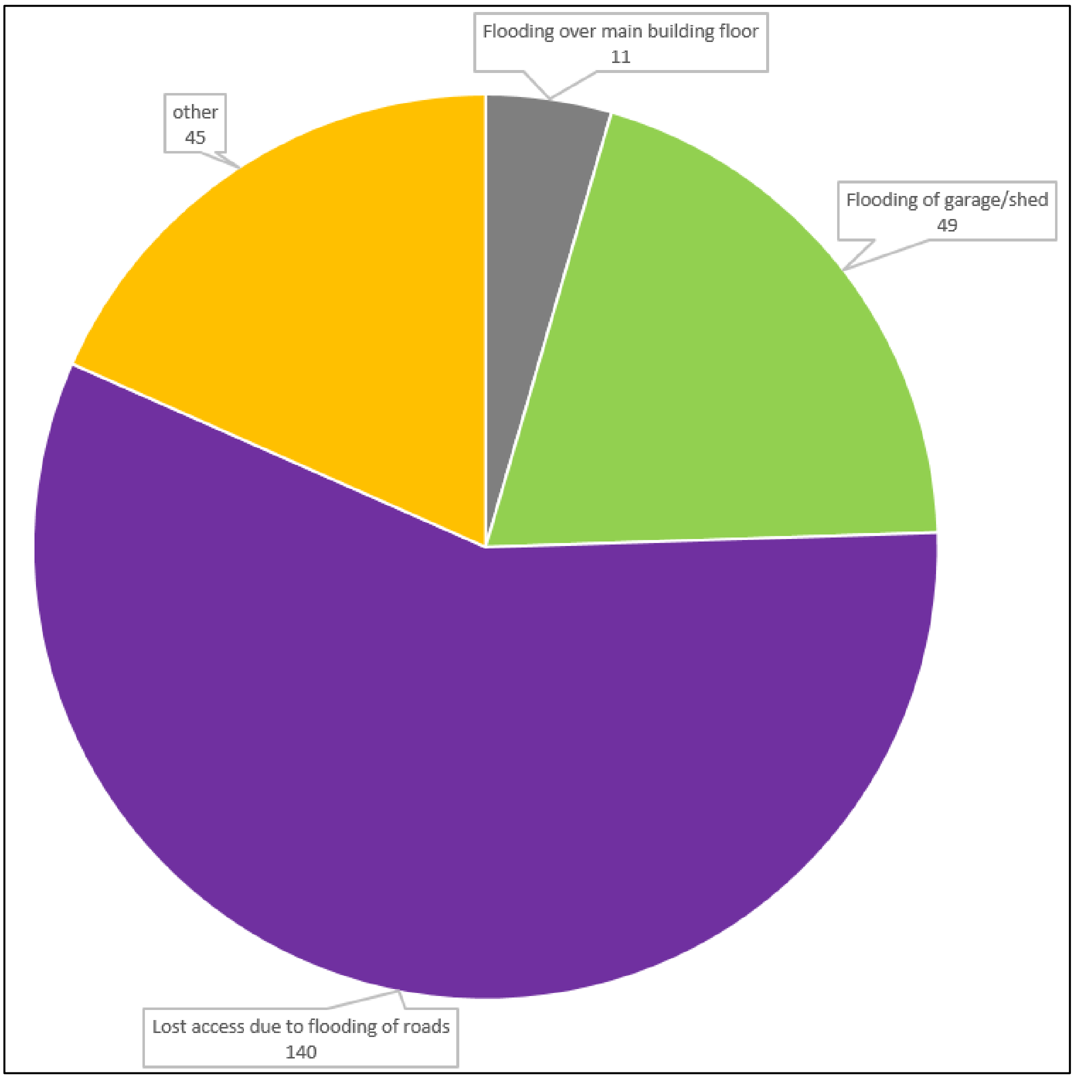


Plate 7 Types of flooding impacts reported by the community.

The questionnaire also sought feedback on a preliminary list of flood risk mitigation measures that were under consideration as part of the study. Further discussion on the community feedback on each option is presented in Sections 7, 8 and 9.

2.5.2 Key Stakeholder Consultation

Targeted consultation was also completed with key stakeholders as part of the project. This included:

- Central Coast Council Engineers;
- Central Coast Council Planners;
- Roads and Maritime Services;
- Office of Environment and Heritage;
- State Emergency Service;
- Department of Primary Industries;
- Ausgrid;
- Rail Corp;

- National Parks Association of NSW;

Key outcomes of the stakeholder consultation are provided below.

Council Engineers and SES

Council engineers noted the evacuation difficulties facing the Yarramalong and Dooralong Valleys during Wyong River floods. The valleys are narrow and incised so flood behaviour is most commonly characterised by deep and faster moving water. Council reported that most residents in the area are knowledgeable from a flooding perspective and will often track gauge levels to gain an understanding of whether they are safe to "stay put".

Council staff also noted that access to South Tacoma is provided by a single road (South Tacoma Road) and access is typically lost early during floods (the "low point" in the road occurs where South Tacoma Road passes beneath the railway and Pacific Highway). Furthermore, flooding in the vicinity of South Tacoma can last for several days if it coincides with elevated Tuggerah Lake levels. Reports of sewer pumping stations failing in this area is also common and indicates that properties may be without essential services for an extended period if evacuation is not completed early.

It was also noted by Council that most households in the Yarramalong and Dooralong Valleys have historically adopted a "shelter-in-place" approach. The Wyong Local Flood Plan (2007) also notes "shelter-in-place" (i.e., on-site refuge) as an appropriate strategy for the Yarramalong Valley, the Dooralong Valley and northern areas of Wyong primarily affected by flash flooding. However, discussions with the SES during the initial stages of the project indicate that the SES would prefer for residents to evacuate if it is safe to do so. Further discussion on potential response strategies across different parts of the catchment are provided in Section 5.4.

Council Planners

During the initial stages of the project Wyong Shire Council and Gosford City Council merged to form the Central Coast Council. At the time of preparing this report, Council planners noted that development applications within the study area would be assessed on the basis of the Wyong Shire policies. It is expected that the two former councils' LEPs and DCPs will be merged. As a result, the planners requested a review of the Wyong Shire LEPs and DCPs be completed to identify similarities and differences with the equivalent Gosford City policies, which the Central Coast Council can consider when it rationalises the two former councils' planning policies. The outcomes of this review are summarised in Section 4.4.

Ausgrid

Ausgrid operates the networks that are responsible for the supply of electricity to all properties within the Wyong River catchment. There is potential for inundation of the Ausgrid infrastructure to interrupt the supply of electricity to properties located within the Wyong River catchment as a result of Wyong River flooding. The two major pieces of electricity infrastructure within the catchment are:

- Transgrid Zone Sub – Wyong Zone No 112 (Lot 3 Pacific Hwy, Wyong)
- Transgrid Bulk Supply Point (Lake Rd, Tuggerah)

In recognition of the potential impact of flooding on the electricity infrastructure, Ausgrid requested that key electricity infrastructure be included on the flood mapping and the impacts of flooding on this infrastructure be quantified. The potential flooding impacts are discussed further in Section 3.2.8.

Roads and Maritime Services

A meeting was held with Roads and Maritime Services at their Woy Woy offices during the initial stages of the project. At the meeting, proposed upgrades to the Pacific Motorway and Pacific Highway were discussed. Both roadways serve as major transportation and, potentially, evacuation routes during Wyong River floods.

The Pacific Motorway upgrade will involve widening the existing roadway between the Tuggerah and Doyalson interchanges to provide three lanes in each direction of travel. The upgrade will involve widening the motorway into the median area. Therefore, the "footprint" of the motorway will not change as part of the upgrade. No substantial changes are proposed to the existing roadway profile of culvert/bridge crossing. Therefore, the Pacific Motorway upgrade is expected to have a negligible impact on existing flood behaviour or evacuation potential.

The Pacific Highway upgrade will include:

- Provision of two lanes for each direction of travel between Johnson Road, Tuggerah and Cutler Drive, Wyong.
- Construction of two new bridge crossings of the Wyong River (and demolition of the existing bridge).
- Modifications to South Tacoma Road and Panonia Road where they pass beneath the new bridges.

RMS completed an independent flood impact assessment as part of the design of the upgraded highway to quantify the potential impact of the proposed works. As part of the design, they looked at opportunities to reduce afflux through the bridge opening by increasing the waterway area beneath the bridge and aligning bridge piers. Computer flood modelling completed as part of the work indicated that the revised bridge arrangement is predicted to produce a small reduction in peak 1% AEP water levels upstream of the highway (in the order of 30mm). Therefore, the proposed highway upgrade is predicted to produce a very small reduction in flood risk upstream of the highway.

The new bridges will be elevated above the peak 1% AEP flood level, which provides a greater level of flood immunity relative to the existing bridge. However, the highway drops back down near the McPherson Road intersection which is predicted to be cut during a 5% AEP event. Therefore, although the proposed upgrade will increase the flood immunity of the Wyong River bridge crossing, the immunity of the overall highway will remain unchanged as a result of the upgrade.

The potential to modify the South Tacoma Road underpass was also discussed as a potential option for improving evacuation times for South Tacoma properties. Although the highway bridge would be elevated as part of the project, the railway bridge that runs parallel to the highway is to remain unchanged meaning that the elevation of South Tacoma Road (as well as Panonia Road) will remain essentially unchanged. Therefore, the proposed upgrade is unlikely to afford any significant changes to evacuation potential along either roadway.

2.5.3 Community Information Sessions

Two community information sessions were also conducted at Central Coast Council's Wyong office during the study. The sessions included:

- Information Session #1 (4 October 2016) – was held when developing the initial list of flood risk management options.
- Information Session #2 (23 November 2016) – was held following the detailed assessment of each option.

The information sessions included a brief presentation on the study and provided an opportunity for the community to ask questions about the study, suggest other potential flood risk management options and comment on issues of concern. Issues of concern that were raised at the information sessions include:

- Tuggerah Lake Entrance: A number of individuals felt the Tuggerah Lake entrance at The Entrance was a primary contributor to the flooding problems across the lower Wyong River catchment. They suggested that the entrance channel should be dredged and a breakwater constructed to maintain a permanent opening. A discussion on the Tuggerah Lake entrance is provided in Section 7.4.7. Dredging of the Wyong River channel was also raised and a discussion on this option is provided in Section 7.4.8.
- Lack of Maintenance in Drainage Channels: Several individuals stated that many of the smaller drainage channels (notably around Lake Road and McDonagh Road) have not been maintained for a significant amount of time. As a result, significant vegetation has built up along the drainage lines and many of the culverts are partly or fully blocked by debris preventing these areas from draining during local rainfall events. Furthermore, some drains around Lake Road were being obstructed by earthworks/fill and residents needed to dig out channels for themselves to drain the area. Further discussion on the potential impact of clearing of vegetation and regular maintenance is provided in Section 7.4.4.

2.5.4 Public Exhibition

The final draft 'Wyong River Catchment Floodplain Risk Management Study & Plan' was placed on public exhibition at Central Coast Council's Wyong and Gosford offices from 25 March 2019 until 26 April 2019. A digital version of the final draft report was also available on Central Coast Council's "Your Voice, Our Coast" website during the exhibition period.

The public exhibition provided the opportunity for the community and key stakeholders to review the final draft report and provide feedback on the report content. Community drop-in sessions were also held at the following times:

- Drop in Session #1 (28 March 2019); and
- Drop in Session #2 (2 April 2019).

The drop-in sessions were attended by a total 10 people and allowed the community to ask questions and raise any concerns that they may have.

A total of eight submissions were received during the exhibition period. A summary of the submissions that were received is provided in **Appendix G**. Also included in **Appendix G** are the actions that were taken to address each submission when preparing the final report.

3 THE EXISTING FLOODING PROBLEM

3.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is first important to have an understanding of the nature and extent of the existing flood risk. This is typically achieved through the preparation of a flood study, which provides information on key flood characteristics (e.g., flood depths, levels and velocities) for a range of floods up to and including the Probable Maximum Flood. Central Coast Council (then Wyong Shire Council) commissioned the "Wyong River Catchment Flood Study" (BMT WBM, 2014) to fulfil this requirement. Further information on the flood study and the associated outputs that were used to describe the existing flooding problem are provided in the following sections.

Once existing flood behaviour is defined, it is then necessary to use this information to gain an understanding of the risk to which the community may be exposed. This allows a targeted assessment of areas where the flood risk is considered to be unacceptable and where flood risk management measures may be best implemented to reduce the flood risk to more tolerable levels. In this regard, a flood risk and damage assessment was also prepared and is documented in the following sections.

3.2 Existing Flood Behaviour

3.2.1 Previous Flood Studies

A range of flood studies have been prepared in the past to assist in better understanding the extent of the existing flooding problem across the Wyong River catchment. These past studies include:

- Upper Wyong River Flood Study (Public Works, 1988);
- Lower Wyong River Flood Study Review (Webb, McKeown & Associates, 1992a);
- Mardi Creek Flood Study (Webb, McKeown & Associates, 1992b);

More recently, Central Coast Council (then Wyong Shire Council) commissioned the 'Wyong River Catchment Flood Study' (BMT WBM, 2014) to provide an updated description of existing flood behaviour across the full extent of the Wyong River catchment. The flood study utilised an XP-RAFTS hydrologic model to describe the transformation of rainfall into runoff and a TUFLOW hydraulic model to describe how that runoff would be distributed across the catchment. The models were used to simulate a range of historic and design floods and produce information on key flooding characteristics including floodwater depths, levels and velocities. Overall, it is considered that the information presented in the "Wyong River Catchment Flood Study" (BMT WBM, 2014) provides the best contemporary description of flood behaviour for the Wyong River catchment.

3.2.2 Flood Study Updates

The models that were developed as part of the "Wyong River Catchment Flood Study" (BMT WBM, 2014) were reviewed as part of this study to ensure they would serve as a suitable baseline for describing existing flood behaviour. In general, the models were found to be fit-for-purpose and would provide a suitable tool to use as part of the current study. Nevertheless, the review identified that some updates to the TUFLOW model would likely yield an improved description of flood behaviour. This included:

- The TUFLOW model did not extend a sufficient distance upstream along some minor tributaries to provide a reliable description of main stream flood behaviour. Therefore, the existing model was extended along these tributaries. Some updates to the XP-RAFTS model were also necessary to allow inflows to be defined at the new upstream model boundaries.
- The TUFLOW model was developed using topographic information that was gathered in 2007. Since that topographic information was collected, LiDAR data was gathered in 2014 and provides a better representation of contemporary topographic conditions across the catchment. Therefore, the model was updated to take advantage of the more recent LiDAR information.
- The TUFLOW model employed relatively broad-scale material/land use information to describe the variation in Manning's "n" roughness coefficients. This approach did not account for localised variations in land use (e.g., small clusters of dense trees across cleared areas). Recent advancements in aerial survey information permits a much more detailed description of land use and the associated hydraulic characteristics to be provided.
- The Wyong River catchment includes a significant number of bridges and culverts. All bridges and culverts were modelled assuming no blockage. However, as parts of the catchment area are significantly vegetated it was considered likely that some blockage of these structures would be experienced. Therefore, the model was updated to include blockage factors for each bridge/culvert in accordance with recommendations outlined in *'Blockage of Hydraulic Structures (Engineers Australia, 2015)'*.

A more detailed description of the updates that were completed to the XP-RAFTS and TUFLOW models are provided in **Appendix A**.

3.2.3 Floodwater Depths, Levels and Velocities

The updated TUFLOW model was used to simulate design flood behaviour for existing topographic and development conditions across the Wyong River catchment for the 20% AEP, 5% AEP, 1% AEP and Probable Maximum Floods (PMF). Peak floodwater depths, levels and velocities were extracted from the results of each design flood simulation and are presented in **Figures A1** to **A4** in **Map Set A**.

The depth and velocity maps indicate that flooding characteristics across the upper catchment differs significantly from flood characteristics across the lower catchment. More specifically:

- The upper catchment area (i.e., upstream of the confluence of the Wyong River and Jilliby Jilliby Creek) tends to be characterised by relatively narrow floodplains. As a result, flood behaviour across the upper catchment areas tends to be characterised by high floodwater depths and velocities.
- The lower catchment area comprises flatter terrain and a more expansive floodplain. Consequently, flooding across the lower catchment area is characterised by more

extensive inundation. The depths of inundation are still significant, however, the movement of water across the floodplain is much slower than the upper catchment.

The results of the hydraulic modelling also highlight the following areas as being significantly impacted by floodwaters:

- The Yarramalong Valley is exposed to rapid rises in water levels (i.e., limited warning time) and significant floodwater depth and velocities. Floodwaters are predicted to cut major roadways at multiple locations making evacuation difficult and potentially hazardous if people try to drive through floodwaters. Further information on roadway inundation is provided in Section 3.2.7.
- Rural residential properties located in the vicinity of Deep Creek including Yarramalong Road, Old Maitland Road, Collies Lane, McPherson Road and Mardi Road. Properties in this area can become isolated relatively early in floods. Floodwater depths are also significant making evacuation difficult if not impossible during large floods.
- The Tuggerah Straight industrial area is subject to inundation during relatively frequent events. Although the depths of inundation are generally not as significant as other areas of the floodplain, the highly populated/frequented nature of this area, the “flashy” nature of the Mardi Creek catchment and the lower floor level requirements relative to other areas across the area does result in a significant flooding problem.
- Properties in the vicinity of South Tacoma and Tacoma are typically low lying and have limited evacuation routes available. As a result, evacuation can be cut early in the flood (particularly South Tacoma Road) resulting in these properties becoming isolated.
- The Wyong Aged Care facility is predicted to be inundated above floor level during events equal to and greater than the 2% AEP event. Access to the property is also predicted to be cut before inundation of the property itself. Due to the lack of mobility of a significant proportion of the residents, evacuation difficulties are significant. Further discussion on the Aged Care Facility is provided in Section 3.2.8.

3.2.4 Flood Hazard Categories

Flood hazard defines the potential impact that flooding will have on development and people across different sections of the floodplain. More specifically, it describes the potential for floodwaters to cause damage to property or loss of life / injury (AIDR, 2017).

It is noted that flood precinct definitions specified by Council within the *Wyong Development Control Plan 2013* (Wyong DCP 2013) (discussed in detail in Section 4.4.2) adopts four flood risk precincts that relate to flood hazard categorisation in the 1% AEP event using Figure L2 of the Floodplain Development Manual (FDM) (2005).

However, for this study, the variation in flood hazard across the catchment was defined using flood hazard vulnerability curves presented in “*Australian Disaster Resilience Guideline 7-3 Flood Hazard”* (AIDR, 2017). This approach was selected over the hazard categorisation defined in the FDM (2005) as it is believed to represent the latest approach to flood hazard definition and provides better correlation between risk to life and flood hazard. The hazard curves are reproduced in **Plate 8** and are also described in **Table 5**.

As shown in **Plate 8**, the hazard curves assess the potential vulnerability of people, cars and structures based upon the depth and velocity of floodwaters at a particular location.

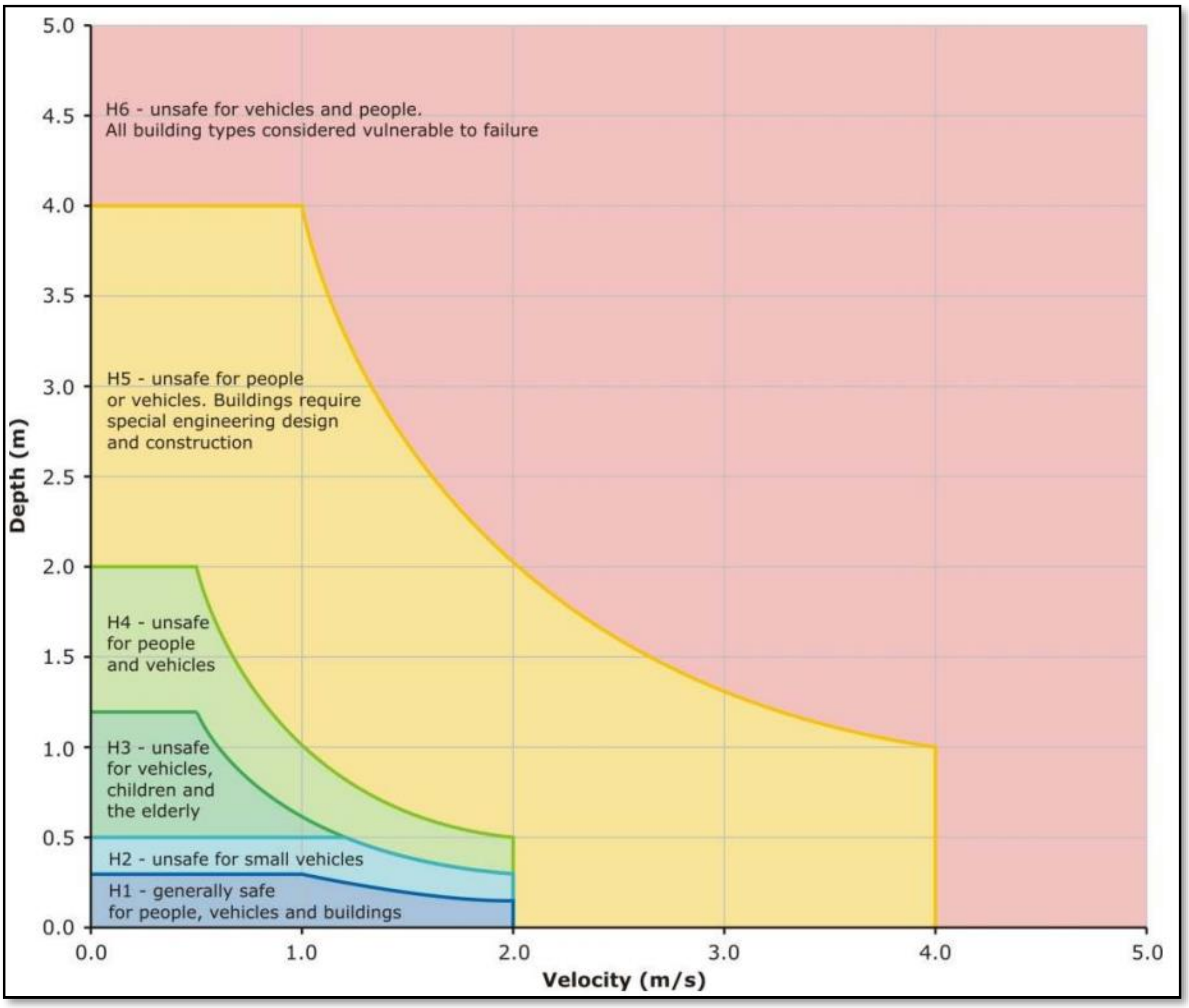


Plate 8 Flood hazard vulnerability curves (Australian Government, 2014)

Table 5 Description of Adopted Flood Hazard Categories (Australian Government, 2014)

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings. Relatively benign flood conditions. No vulnerability constraints
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Peak depth, velocity and velocity-depth product outputs generated by the TUFLOW model were used to map the variation in flood hazard across the Wyong River catchment based on the hazard criteria shown in **Plate 8** for the 1% AEP flood as well as the PMF. The resulting hazard category maps are shown in **Figures A5** and **A6**.

As discussed, Council's current DCP uses the "low" and "high" flood hazard categorisation presented in Figure L2 of the Floodplain Development Manual (FDM) (2005). Based upon comparison of the flood hazard curves presented in **Plate 8** with Figure L2 of the FDM, it is suggested that the following "conversions" be used until the current DCP is updated to reflect the new H1-H6 categories:

- Low Hazard: H1 – H2
- High Hazard: H3 – H6

3.2.5 Flood Emergency Response Precincts

In an effort to understand the potential emergency response requirements across different sections of the floodplain, flood emergency response precinct (ERP) classifications were prepared in accordance with the flow chart shown in **Plate 9** (Australian Emergency Management Institute, 2014). The ERP classifications can be used to provide an indication of areas which may be inundated or may be isolated during floods. This information, in turn, can be used to quantify the type of emergency response that may be required across different sections of the floodplain during future floods. This information can be useful in emergency response planning

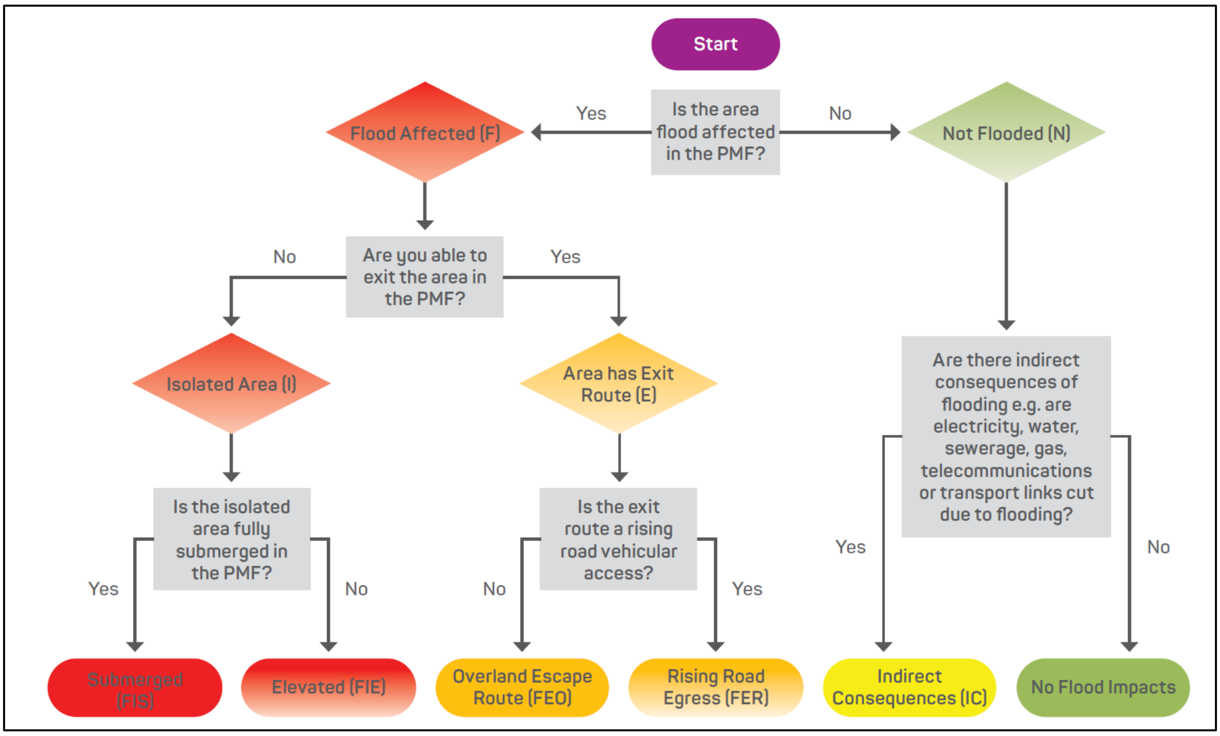


Plate 9 Flow Chart for Determining Flood Emergency Response Classifications (AEMI, 2014).

Each allotment within the Wyong River catchment was classified based upon the ERP flow chart shown above for the 1% AEP flood as well as the PMF. This was completed using the

TUFLOW model results, digital elevation model and a road network GIS layer in conjunction with proprietary software that considered the following factors:

- whether evacuation routes/roadways get "cut off" and the depth of inundation (a 0.2m depth threshold was used to define a "cut" road);
- whether evacuation routes continuously rise out of the floodplain;
- 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;
- if evacuation by car was not possible, whether evacuation by walking was possible (a 0.5 metre depth threshold was used to define when a route could not be traversed by walking).

The resulting ERP classifications for the 1% AEP flood as well as the PMF are provided in **Figures A7** and **A8**. A range of other datasets were also generated as part of the classification process to assist Council and the SES. This includes roadway overtopping locations, which are discussed in more detail in Section 3.2.7.

It should be noted that the automated application of the Flood Emergency Response Planning at allotment scales is a technique still under current research and development. For more information, please refer to the paper, Emergency Response Planning Classification at Sub-Precinct Scales (Ryan et al, 2014).

3.2.6 Hydraulic Categories

The NSW Government's *'Floodplain Development Manual'* (NSW Government, 2005) recommends subdividing flood prone areas according to the hydraulic categories presented in **Table 6**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour and highlights areas that should be retained for the conveyance of floodwaters.

Unlike hazard categories, the *"Floodplain Development Manual"* (NSW Government, 2005) does not provide quantitative criteria for defining hydraulic categories. This is because the extent of floodway, flood storage and flood fringe areas are typically specific to a particular catchment.

Criteria for establishing hydraulic categories for the Wyong River catchment were previously derived for the "Wyong River Catchment Flood Study" (BMT WBM, 2014). These criteria were reviewed as part of the current study and were determined to be suitable. The criteria are reproduced in **Table 6**.

The hydraulic category maps that were developed based upon the criteria listed in **Table 6** for the 1% AEP flood and PMF are shown in **Figures A9** and **A10**.

As noted in **Table 6**, filling of flood fringe areas should not have a significant impact on flood behaviour. Nevertheless, care will still need 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 (as required in Chapter 3-3 of Council's DCP – refer Section 4.4.2) that demonstrates the filling will not adversely impact on local flood behaviour. In this regard, a flood level increase of less than 0.01 metres across adjoining properties is suggested as a reasonable quantification of "no impact".

Table 6 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	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.	Velocity x Depth > 0.3
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.	Velocity x Depth < 0.3 and Depths > 0.5 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 or flood storage

3.2.7 Transportation Impacts

There are a number of major roadways and a major rail link within the Wyong River catchment which may be required for evacuation or emergency services access during floods. It is important to have an understanding of the impacts of flooding on these transportation links so that appropriate emergency response planning can occur.

The location where roads and railways are first overtopped was established by comparing peak design water levels against road/rail centreline elevations. The 1% AEP and PMF floods were also interrogated in more detail to determine:

- The time at which each roadway is first inundated;
- The maximum depth of inundation; and,
- The duration of inundation.

The location where transportation links are first overtopped during the 1% AEP and PMF events are shown on **Figures A7** and **A8**. The overtopping locations shown in **Figures A7** and **A8** also include labels describing the time the roads are first inundated (green label) and the total duration of inundation (blue label). Accordingly, this provides information describing the amount of warning time that would typically be available and how long the roadway would be cut by floodwaters after inundation first occurs.

Further detailed information describing inundation characteristics for major roadways within the catchment is provided in **Appendix B**.

The information presented in **Figures A7** and **A8** and **Appendix B** indicate that:

Upstream of M1 Pacific Motorway

- Brush Creek Road – Access would be cut during all design events at three different locations. Less than 8 hours of warning time would typically be available from the initial onset of rainfall before access is cut.
- Ravensdale Road – Access would be cut during all design events at two different locations. Less than 8 hours of warning time would typically be available before access is cut.
- Yarramalong Road – Access would be cut during all design events at multiple locations along the full length of the roadway. The roadway is first predicted to be overtopped near the Wyong Creek crossing. At least 12 hours of warning time would typically be available.
- Dooralong Road – Access would be cut during all design events at four locations. The depths of inundation are generally less than 1 metre during the 20% AEP event and more than 20 hours of warning time would be available during these more frequent events. However, the warning time is predicted to drop to less than 8 hours during more severe floods (e.g., 1% AEP event)
- Jilliby Road – Access is predicted to be cut at three locations during all design floods. However, more than 24 hours warning time would typically be available.
- Old Maitland Road – Access is predicted to be cut during events as frequent as the 20% AEP event near the Deep Creek culvert crossing. Over 30 hours of warning time would be available during the more frequent events decreasing to less than 3 hours during the PMF.
- Alison Road – is predicted to be overtopped during the 5% AEP event near the Porters Creek crossing. At least 20 hours of warning time would typically be available during all events up to and including the 1% AEP. The warning time would drop to less than 6 hours during the PMF.

- M1 Pacific Motorway – Not inundated during all events up to and including the 1% AEP event. Access is cut at several locations during the PMF although more than 16 hours of warning time would generally be available.

Downstream of M1 Pacific Motorway

- McPherson Road – is predicted to be overtopped in the 20% AEP flood near Old Maitland Road. Over 30 hours of warning time would typically be available during frequent floods. The available warning time is predicted to drop to less than 20 hours during the 1% AEP event and less than 5 hours during the PMF.
- Gavenlock Road – is predicted to be cut during the 20% AEP event near Johnson Road. More than 24 hours of warning time would be available during all events up to and including the 1%AEP event.
- Wyong Road – the west bound travel lanes of Wyong Road are predicted to be inundated near Gavenlock Road during the 5% AEP event. However, the east bound lanes would remain trafficable up to and including the 1% AEP event. Less than 6 hours of warning time would typically be available for the west bound lanes.
- Pacific Highway – Is predicted to be overtopped during the 5% AEP event near the South Tacoma Road intersection. In excess of 24 hours warning time would typically be available during more frequent floods, however, this is predicted to drop to less than 3 hours during the PMF.
- Railway Line – the railway line is typically elevated above the floodplain and is predicted to remain "flood free" during all events up to and including the 1% AEP event. However, overtopping depths in excess of 4 metres are predicted during the PMF with less than 2 hours of warning time.
- South Tacoma Road – is predicted to be overtopped during all design floods where it passes beneath the Pacific Highway / Railway bridges. The roadway at this point is located at approximately 1.2 mAHD. Less than 24 hours of warning time would typically be available before access along South Tacoma Road is cut.
- Panonia Road – access is predicted to be cut during the 5% where Panonia Road passes beneath the Pacific Highway / Railway bridges. More than 24 hours of warning time would typically be available during all events up to and including the 1% AEP event although only ~6 hours warning time would be available during the PMF.
- Boyce Avenue – is predicted to be inundated during the 1% AEP event near its intersection with McDonagh Road. More than 24 hours of warning time would typically be available during the 1% AEP event although only 6 hours would be available during the PMF.
- McDonagh Road – is predicted to be overtopped during the 5% AEP event immediately south of the Kooindah Waters Golf Course. At least 24 hours of warning time would generally be available during events up to and including the 1% AEP but less than 7 hours warning would be available during the PMF
- Pollock Avenue – access is predicted to be cut near the HopeTown school during the 5% AEP event. The available warning time is predicted to exceed 26 hours during all events up to and including the 1% AEP event. Approximately 4 hours of warning time would be available during the PMF.

It should be noted that the roadway inundation information is based on "design" flood information. No two floods are the same and future floods will likely exhibit different characteristics. Nevertheless, the information provides a good indication of the relative susceptibility of different roadways to inundation and can assist emergency services in evacuation planning.

3.2.8 Impact of Flooding on Key/Vulnerable Facilities

The Wyong River catchment is home to a range of property types and infrastructure. This includes facilities where the occupants may be particularly vulnerable during floods, such as schools, child care centres and aged care facilities. In addition, some facilities will play important roles for emergency response and evacuation purposes during future floods (e.g., hospitals & evacuation centres). Therefore, it is important to have an understanding of the potential vulnerability of these facilities during a range of floods.

A list of key and vulnerable facilities within the Wyong River catchment are summarised in **Table 7**. **Table 7** also summarises if the facility is predicted to be subject to inundation and if access to the facility will be cut during any of the design floods simulated as part of the study. The key and vulnerable facilities are also shown on **Figures A1** to **A10**.

The information summarised in **Table 7** indicates the Wyong Aged Care Facility is particularly susceptible to inundation. More specifically access would be cut and inundation of the property is predicted during each of the design flood events (however, above floor inundation is not anticipated until the 1% AEP event). Plate 10 also indicates that access to the aged care facility would be cut before inundation of the property occurs. As a result, the aged care facility is located within a 'low flood island'.

Plate 10 Wyong Aged Care Facility during 2007 flood showing all access roads inundated

Table 7 Impact of Flooding on Key and Vulnerable Facilities

Vulnerable Facility		20% AEP Flood			5% AEP Flood			1% AEP Flood			PMF		
		Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut
Aged Care	Meander Village *(18 Boyce Ave, Wyong)*				☑			☑	☑	☑	☑	☑	☑
	Strathavon Resort *(31 Boyce Ave, Wyong)*	☑			☑	☑		☑	☑	☑	☑	☑	☑
	Wyong Aged Care Facility *(35 McPherson Rd, Mardi)*	☑		☑	☑		☑	☑	☑	☑	☑	☑	☑
Emergency Services	Wyong Fire Station *(5 Hely St, Wyong)*												
	Yarramalong Rural Fire Station *(1619 Yarramalong Rd, Yarramalong)*										☑		☑
	Dooralong Rural Fire Station *(Dittons Rd, Dooralong)*									☑	☑	☑	☑
	Wyong Police Station *(22 Hely St, Wyong)*												
	Wyong SES *(12 Levitt St, Wyong)*												
Electricity	Transgrid Zone Sub – Wyong Zone No 112 *(Lot 3 Pacific Hwy, Wyong)*			☑			☑			☑	☑	☑	☑
	Transgrid Bulk Supply Point *(Lake Rd, Tuggerah)*							☑		☑	☑	☑	☑
Evacuation Centre*	Wyong Golf Club *(319 Pacific Hwy, Wyong)*												
	Wyong RSL Club *(Anzac Ave, Wyong)*												

Vulnerable Facility		20% AEP Flood			5% AEP Flood			1% AEP Flood			PMF		
		Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut
	Wyong Bowling Club *(3 Panonia Rd, Wyong)*	☑		☑	☑		☑	☑	☑	☑	☑	☑	☑
Pre-School	Wyong Pre-School *(9-13 Rose St, Wyong)*										☑		
	Wyong Cottage Kindergarten *(62-64 Alison Rd, Wyong)*												
	Small World Pre-School *(6 Byron St, Wyong)*												
	Mission Australia Early Learning *(4 Woodbury Park Dr, Woodbury Park)*				☑		☑	☑		☑	☑	☑	☑
Primary / High School	Wyong High School *(53 Alison Rd, Wyong)*										☑		
	Hopetown School *(177 Pollock Ave, Wyong)*	☑			☑	☑	☑	☑	☑	☑	☑	☑	☑
	Wyong Christian Community School *(100 Alison Rd, Wyong)*	☑		☑	☑		☑	☑		☑	☑	☑	☑
	Tacoma Public School *(Hillcrest Ave, Tacoma)*												
	Wyong Public School *(52 Cutler Dr, Wyong)*												
	St Cecilia's Catholic School *(Panonia Rd, Wyong)*	☑		☑	☑		☑	☑		☑	☑	☑	☑
	Wyong Creek Public School *(583 Yarramalong Rd, Wyong Creek)*	☑		☑	☑		☑	☑		☑	☑		☑
	St Peters Catholic College *(84 Gavenlock Rd, Tuggerah)*	☑		☑	☑		☑	☑		☑	☑		☑

Vulnerable Facility		20% AEP Flood			5% AEP Flood			1% AEP Flood			PMF		
		Property Flooded	**Above Floor Flooding**	**Access Cut**	**Property Flooded**	**Above Floor Flooding**	**Access Cut**	**Property Flooded**	**Above Floor Flooding**	**Access Cut**	**Property Flooded**	**Above Floor Flooding**	**Access Cut**
	Dooralong Public School *(1046 Dooralong Rd, Dooralong)*												
	Yarramalong Public School *(1560 Yarramalong Rd, Yarramalong)*												
	Jilliby Public School *(352 Jilliby Rd, Jilliby)*												
Sewer Pump Station	SPS 08 *(Corner Mildon Rd and Tindal Rd, Tuggerah)*							☑		☑	☑	☑	☑
	SPS 09 *(Gavenlock Rd, Tuggerah)*							☑	☑	☑	☑	☑	☑
	SPS 10 *(McPherson Rd, Tuggerah)*				☑	☑	☑	☑	☑	☑	☑	☑	☑
	SPS 11 *(150 Pacific Hwy, Wyong)*										☑	☑	
	SPS 16 *(361 Pacific Hwy, Wyong)*										☑	☑	
Sewage Treatment Plant	Wyong South STP *(Ibis Road, Tuggerah)*										☑		
Water Pumping Station	WPS 01 *(Old Maitland Rd, Mardi)*												
	WPS 04 *(Ithome St, Wyong)*							☑		☑	☑	☑	☑
	WPS 09 *(Corner of Cobbs Rd and Tonkiss St, Tuggerah*	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑

Vulnerable Facility		20% AEP Flood			5% AEP Flood			1% AEP Flood			PMF		
		Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut	Property Flooded	Above Floor Flooding	Access Cut
Water Treatment Plant	Mardi WTP (Old Maitland Rd, Mardi)												

NOTE: * Evacuation centres were extracted from Section 3.18.42 of the Wyong Shire Local Flood Plan

Table 7 also shows that all three aged care facilities located within the catchment would be impacted by floodwaters during the 1% AEP flood (i.e., access would be cut and the property would be inundated).

In general, the evacuation centres are not predicted to be impacted during any of the simulated design events. The only exception to this is the Wyong Bowling Club. During smaller events (i.e., 5% AEP event and less), inundation is restricted to the southern fringes of the site.

However, during larger events (i.e., 1% AEP event and above) significant property inundation is predicted and access to the property would be cut. Most notably, the suitability of the Bowling Club as a flood evacuation centre is questionable and could be reviewed by the SES for its suitability to remain as a food evacuation centre as part of the data update from this study. The SES could review the location and functionality of all flood evacuation centres in conjunction with the information presented in this study, and update to suit the constraints of that area where required.

In general, preschools and child care facilities are located outside of the PMF. However, some sections of the Mission Australia Early Learning property would be inundated during events larger than the 5% AEP event. Flooding of parts of a number of primary and high schools is also anticipated, most notably HopeTown School, Wyong Christian Community School, St Cecilia's Catholic School and Wyong Creek Public School.

Council could contact the owners and occupiers of these vulnerable developments and critical infrastructure providers located within the floodplain and make them aware of the updated flood information available from this floodplain risk management study and plan should they wish to redevelop or move them to a less flood constrained location. It is also recommended that the SES be contacted so they are aware of difficulties with some identified evacuation centres.

3.3 Flood Planning Area

Flood Planning Levels (FPLs) are an important tool in the management of flood risk. FPLs are typically derived by adding a freeboard to a specific design flood. This specific design flood is frequently referred to as the "planning" flood. The FPLs can be combined with topographic information to establish the Flood Planning Area (FPA). The FPL / FPA can then be used to assist in managing the existing and future flood risk by:

- Setting design levels for mitigation works (e.g., levees); and,
- Identifying land where flood-related development controls apply to ensure that new development is undertaken in such a way as to minimise the potential for flood impacts on people and property.

Central Coast Council has defined the flood planning level as "*the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard*" through the Wyong Local Environmental Plan 2013. This is consistent with the 'Floodplain Development Manual' (NSW Government, 2015), which suggests that a flood planning level consisting of the 1% AEP flood plus a 0.5 metre freeboard will generally be appropriate for new residential development unless exceptional circumstance exist. This "standard" is also echoed by the 'Guideline on

Development Controls on Low Flood Risk Areas – Floodplain Development Manual' (Department of Planning, 2007) which states that "*…unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development*".

The freeboard can be considered as a "factor of safety" that is used to cater for uncertainties in the estimation of the planning flood. This can include modelling uncertainties as well as items that can't be specifically represented in the computer model. A review of the sensitivity analysis completed as part of the "Wyong River Catchment Flood Study" (BMT WBM, 2014) indicates structure blockage can increase 1% AEP water level by in excess of 0.5 metres at some locations. However, the potential for a large bridge to become completely blocked by debris is considered to be very low. In addition, a blockage allowance was included in the revised "base" 1% AEP flood levels prepared as part of this report. As a result, it is considered that a 0.5 metre freeboard will suitably account for uncertainty.

A review of the suitability of the freeboard was also completed with regard to potential climate change impacts, such as rainfall intensity increases and increases in lake/ocean levels. The outcomes of the climate change simulations are discussed in more detail in Section 3.6. However, the results indicate that rainfall intensity increases are unlikely to increase existing 1% AEP flood levels by more than 0.5 metres across the majority of the catchment (i.e., areas upstream of Tacoma/South Tacoma). As a result, it is considered that a 0.5 metre freeboard will suitably account for climate change uncertainties across the majority of the catchment. However, the Tuggerah Lake foreshore area and, to a lesser extent, Tacoma and South Tacoma may be exposed to more significant flood level increases if existing lake levels were to increase by more than 0.5 metres (which may occur if existing sea levels increase). As this study was not concerned with Tuggerah Lake flooding, a precise understanding of the potential impacts of sea level rise on lake levels could not be completed as part of the current study. Therefore, it is recommended that a revised flood study should be prepared for Tuggerah Lake that takes advantage of modern flood modelling technology so that a better understanding of the impacts of sea level rise on lake levels and the suitability of the 0.5 metre freeboard across the foreshore areas can be established.

The 0.5 metre freeboard was added to the peak 1% AEP flood levels to develop a flood planning level layer. The flood planning level layer was extended laterally until the flood planning level encountered higher terrain. This formed the flood planning area for the catchment. The flood planning area is shown in **Figure A11**. Flood planning level contours are also included on **Figure A11**.

3.4 The Cost of Flooding

To assist in quantifying the financial impacts of flooding on the community, a flood damage assessment was also completed. The flood damage assessment aimed to quantify the potential flood damage costs incurred to private and public property during a range of design floods across the Wyong River catchment. A detailed description of the approach used to establish the flood damage cost estimates is provided in **Appendix C**.

As outlined in **Appendix C**, flood damage estimates were prepared using flood damage curves in conjunction with design flood level estimates and building floor levels for each of the following property / asset types:

- Residential properties
- Commercial / Industrial properties
- Infrastructure

As part of the damage cost calculations, the number of properties subject to above floor inundation was calculated. This information is summarised in **Table 8**.

The final flood damage estimates for each design flood are summarised in **Table 9** for existing topographic and development conditions. It indicates that if a 1% AEP flood was to occur, over $80 million worth of damage could be expected. Approximately half of that damage cost would be incurred across residential property.

Table 8 Number of Properties Subject to Above Floor Inundation

Flood Event	Residential	Commercial/ Industrial	Total Number
20% AEP	3	0	3
10% AEP	14	5	19
5% AEP	131	28	159
2% AEP	293	58	351
1% AEP	416	92	508
0.5% AEP	500	134	634
PMF	1358	370	1728

Table 9 Summary of Flood Damage Costs for Existing Conditions

Flood Event	Flood Damages ($ millions)			
	Residential	Commercial/ Industrial	Infrastructure	Total Damages
20% AEP	0.62	0.00	0.09	0.71
10% AEP	2.82	0.44	0.49	3.75
5% AEP	14.28	5.91	3.03	23.2
2% AEP	31.8	14.3	6.91	53.0
1% AEP	48.7	28.6	11.6	88.9
0.5% AEP	60.5	52.4	16.9	130
PMF	213	239	67.8	520

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD takes into consideration the frequency of a particular event occurring and the damage incurred during that event to estimate the average damage that is likely to occur each year, on average.

The individual AAD estimates for each property and asset were also summed to provide an estimate of the total damage likely to be incurred across the catchment on an annual basis for existing topographic and development conditions. The AAD for the Wyong River catchment was determined to be **$4.3 million**. Accordingly, if the "status quo" was maintained, residents and business owners within the catchment as well as infrastructure providers, such as Council, would likely be subject to cumulative flood damage costs of approximately $4.3 million per annum (on average).

3.5 The Existing Flood Risk

The depth and velocity of floodwaters can create hazardous conditions to which humans and property/structures may be vulnerable. However, if floodplains are not subject to any development or occupation, this hazard does not translate to a flood risk. This is because the floodwater will not pose a threat to people or property. A risk is created when there is interaction between floodwaters and people/property, which typically occurs through development on the floodplain (Australian Emergency Management Institute, 2013).

In order to understand the variation in flood risk across the catchment and where there may be an unacceptable flood risk, flood risk mapping was prepared. As shown in **Plate 11**, flood risk is defined as the likelihood of a particular flood occurring and the associated consequence of that flood when it occurs (Australian Emergency Management Institute, 2013).

Plate 11 Components of Flood Risk (Smith & McLuckie, 2015)

The likelihood of a particular flood occurring can be defined by the Annual Exceedance Probability (AEP) and describes how frequently the community is exposed to a particular flood hazard.

Consequences can be more difficult to define as they will vary depending on the magnitude of the flood, the spatial variation in the depth and velocity of floodwaters (i.e., the flood hazard), the vulnerability of the community, and the types and location of development and utilities across the floodplain. For the purposes of this assessment, consequences were defined based upon the potential for the floodwaters to pose a risk to life and damage property, as outlined in **Table 10**. The potential for property damage was defined based upon the depth of above floor flooding and flood hazard categories described in Section 3.2.4 and the potential for risk to life was defined based upon the flood hazard categories only.

The likelihood and consequences were combined to estimate the flood risk at each property within the catchment for each design flood based upon the risk matrix presented in **Table 11**. The resulting flood risk maps are presented in **Figures A12** to **A15**.

Table 10 Definition of Consequences (McLuckie, 2015)

Consequence	Description	Adopted Criteria
Insignificant	- Building surrounded by floodwaters but flooding limited to areas outside the dwelling, only external property damaged including gardens, fences and yard contents - No risk to human life	- Floodwater more than 0.3 metres below floor level and - Hazard category H3 or below
Minor	- Very shallow over floor flooding of garages / sheds but excluding the house (depth of above floor flooding <-0.3m). - No risk to human life	- No above floor flooding but floodwater less than 0.3 metres below floor level and - Hazard category H3 or below
Moderate	- Relatively shallow over floor flooding (less than 0.3 meters deep). Damage mostly limited to carpets, moisture absorbent furniture at ground level, low level fixtures and fittings and the lower part of walls. Damage limited to contents which cannot be raised or moved away. Repairs not critical and dwelling habitable with only clean-up. - No risk to human life	- Above floor flooding to a depth of less than 0.3 metres and - Hazard category H3 or below
Major	- Considerable damage likely to building itself, electrical services, fixtures such as kitchens and ovens, and white goods, furnishings and furniture (above floor flooding depth > 0.3m). Extensive repairs, replacement and clean-up essential requiring high costs and lengthy recovery over several months before the house is made habitable. - Potential for injury	- Above floor flooding depth to a depth of greater than 0.3m or - Hazard H4
Catastrophic	- Extensive damage to building structure, possibly resulting in total loss through collapse. Loss of all household contents not previously removed from the site. Serious, sudden, unexpected, uninsurable financial loss. - Potential for death	- Hazard H6 (structural failure) - Hazard H5 or H6 (potential for death)

Table 11 Flood Risk Matrix for the Wyong River catchment (Australian Emergency Management Institute, 2013)

Likelihood	Consequence				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost Certain (20% AEP)	Low	Medium	High	Extreme	Extreme
Likely (5% AEP)	Low	Medium	Medium	High	Extreme
Rare (1% AEP)	Very Low	Low	Medium	Medium	High
Extremely Rare (PMF)	Very Low	Very Low	Low	Medium	High

3.6 Climate Change Impacts

Climate change refers to a significant and lasting change in weather patterns arising from both natural and human induced processes. The Office of Environment and Heritage's *'Practical Consideration of Climate Change'* states that climate change is expected to have adverse impacts on sea levels and rainfall intensities in the future.

Increases in rainfall intensities would produce increases in runoff volumes across the catchment. This, in turn, would likely produce an increase in the depth, extent and velocity of floodwaters. Furthermore, increases in ocean levels are likely to produce a commensurate increase in Tuggerah Lake levels which may also increase the severity of flooding across the catchment.
Although there is considerable uncertainty associated with the impact that climate change may have on rainfall and ocean levels, it was considered important to provide an assessment of the potential impact that climate change may have on the current flood risk across the catchment.

Therefore, additional 1% AEP simulations were completed to reflect the following potential future rainfall intensity increases:

- 15% increases in rainfall and 0.4m increase in Tuggerah Lake water level
- 30% increase in rainfall and 0.9m increase in Tuggerah Lake water level

Peak 1% AEP inundations extents were extracted from the results of the climate change simulations and are presented in **Figures A16** and **A17**. The inundation extents for 'existing' conditions is superimposed for comparison.

A review of the peak flood level results shows that:

- Sea level rise tends to dominate the climate change results across the Tuggerah Lake foreshore areas as well as upstream to Tacoma and South Tacoma. For areas located upstream of Tacoma and South Tacoma, rainfall intensity increases dominate the climate change results.

- A 15% increase in rainfall is predicted to typically increase 1% AEP flood levels across the catchment areas by 0.1 to 0.2 metres.
- A 30% increase in rainfall is predicted to typically increase 1% AEP flood levels across the catchment areas by 0.2 to 0.4 metres. However, there are some areas where the differences approach 0.5 metres. However, there are very few locations (with the exception of the Tuggerah Lake foreshore) where the differences exceed 0.5 metres.

The total area exposed to inundation, the number of buildings exposed to above floor inundation as well as the total 1% AEP flood damages were also extracted from the results of each climate change simulation and are presented in **Table 12**.

As shown in **Figure A16**, **Figure A17** and **Table 12**, climate change has the potential to cause increases to existing inundation extents. The changes in inundation extents are relatively minor across the upper catchment, where the floodplain is quite narrow and are more noticeable across the flatter sections of the catchment downstream of the Pacific Highway.

Table 12 Predicted Climate Change Impacts

Metric	Existing	Climate Change	
		15% Increase in Rainfall & 0.4m Increase in Tuggerah Lake Level	30% Increase in Rainfall & 0.9m Increase in Tuggerah Lake Level
Inundated Area (km^2)	57.5	**59.4** (3.3% increase)	**61.4** (6.8% increase)
Buildings Flooded Above Floor Level	508	**663** (31% increase)	**955** (88% increase)
Flood Damage ($ millions)	77.3	**118** (53% increase)	**172** (123% increase)

Despite the relatively small changes in inundation extents, there are predicted to be some significant changes to the number of buildings predicted to be exposed to above floor inundation during the 1% AEP flood. The number of buildings exposed to above floor inundation is predicted to increase by nearly 90% during the 30% increase in rainfall scenario (with 0.9m increase in Tuggerah Lake level). Flood damages are predicted to increase by over 120% as a result of the additional inundation depths.

Accordingly, climate change does have the potential to significantly increase the existing flood risk and the potential financial impacts of future floods. It needs to be acknowledged that there is still considerable uncertainty associated with climate change predictions. Although current information suggests rainfall intensity and sea level rise increases are not predicted to reach the upper limits considered as part of this study by 2090, this will need to be closely monitored as the catchment does appear to be sensitive to any change in flood producing rainfalls and changes to Tuggerah Lake water levels.

3.7 Summary of Flooding "Trouble Spots"

The information presented in this section indicates that the following areas are likely to experience significant property damage, risk to life and/or evacuation difficulties during floods within the Wyong River catchment:

- Yarramalong valley
- Rural residential properties located in the vicinity of Deep Creek including Yarramalong Road, Old Maitland Road, Collies Lane, McPherson Road and Mardi Road.
- The Tuggerah straight industrial area
- Properties in the vicinity of South Tacoma and Tacoma.
- Properties in Wyong adjoining Panonia Road and Boyce Avenue
- The Wyong Aged Care facility

Climate change induced rainfall intensity and Tuggerah Lake level increases have the potential to further increase the flood risk across these areas above existing levels. More Specifically:

- A 15% increases in rainfall coupled with a 0.4m increase in Tuggerah Lake level is predicted to result in 155 additional properties being subject to above floor flooding during the 1% AEP event, increasing flood damage costs by 53% above "existing" levels
- A 30% increases in rainfall with a 0.9m increase in Tuggerah Lake level is predicted to result in 447 additional properties being subject to above floor inundation during a 1% AEP flood. Flood damage costs are also predicted to increase by over 120% relative to existing conditions.

4 CURRENT PLANNING MEASURES

4.1 Overview

Appropriate land use planning is one of the most effective measures available to floodplain managers, especially to control future risk but also to reduce existing flood risks as redevelopment occurs. The management and development of flood prone land must be undertaken within the current legislative, policy and planning framework. This chapter summarises the main, relevant legislation, policy and guidelines that affect the development of land in the Central Coast Council area (former Wyong Local Government Area).

4.2 National Provisions

4.2.1 Building Code of Australia

The 2013 edition of the Building Code of Australia (BCA) introduced new requirements related to building in flood hazard areas (FHAs), which provide a minimum construction standard across Australia for specified building classifications in FHAs up to the defined flood event (DFE). The newly released 2016 edition of the BCA retains the Performance Requirements and Deemed-to-Satisfy (DTS) provisions set out in the 2013 edition for construction in a FHA.

The DFE is analogous to the planning flood event previously described in Section 3.3 and is most commonly the 1% AEP flood. FHAs are defined in the BCA as encompassing land lower than the flood hazard level (FHL), which in turn is defined as 'the flood level used to determine the height of floors in a building and represents the DFE plus the freeboard'. Therefore, FHAs would typically be defined as those areas falling within the flood planning area previously described in Section 3.3.

Volume One, BP1.4 and Volume Two, P2.1.2 specify the Performance Requirements for the construction of buildings in FHA. They only apply to buildings or parts of Class 1, 2, 3, 4, (residential) and 9a health-care buildings and 9c aged-care buildings. These Performance Requirements require a building in a FHA to be designed and constructed to resist flotation, collapse and significant permanent movement resulting from flood actions during the DFE. The actions and requirements to be considered to satisfy this performance requirement include but are not limited to:

- flood actions;
- elevation requirements;
- foundation and footing requirements;
- requirements for enclosures below the flood hazard level;
- requirements for structural connections;
- material requirements;
- requirements for utilities; and
- requirements for occupant egress.

The DTS provisions of Volume One, B1.6 and Volume 2, 3.10.3.0 require buildings in the classes described above and located in FHAs to comply with the ABCB *Standard for Construction of Buildings in Flood Hazard Areas 2012* (the ABCB Standard).

The ABCB Standard specifies detailed requirements for the construction of buildings to which the BCA requirements apply, including:

- resistance in the DFE to flood actions including hydrostatic actions, hydrodynamic actions, debris actions, wave actions and erosion and scour;
- floor height requirements, for example that the finished floor level of habitable rooms must be above the flood hazard level (FHL);
- the design of footing systems to prevent flotation, collapse or significant permanent movement;
- the provision in any enclosures of openings to allow for automatic entry and exit of floodwater for all floods up to the FHL;
- ensuring that any attachments to the building are structurally adequate and do not reduce the structural capacity of the building during the DFE;
- the use of flood-compatible structural materials below the FHL;
- the siting of electrical switches above the FHL, and flood proofing of electrical conduits and cables installed below the FHL; and
- the design of balconies etc. to allow a person in the building to be rescued by emergency services personnel, if rescue during a flood event up to the DFE is required.

Building Circular BS13-004 (NSW Department of Planning and Infrastructure, 2013) summarises the scope of the BCA and how it relates to NSW planning arrangements. The scope of the ABCB Standard does not include parts of FHA that are subject to flow velocities exceeding 1.5 m/s, or are subject to mudslide or landslide during periods of rainfall and runoff, or are subject to storm surge or coastal wave action. It is particularly noted that the Standard applies only up to the defined flood event (DFE), which typically will correspond to the level of the 1% AEP flood plus 0.5m freeboard. The Building Circular emphasises that because of the possibility of rarer floods, the BCA provisions do not fully mitigate the risk to life from flooding.

The ABCB has also prepared an *Information Handbook for the Construction of Buildings in Flood Hazard Areas*. This Handbook provides additional information relating to the construction of buildings in FHA, but is not mandatory or regulatory in nature.

In the NSW planning system, the BCA takes on importance for complying development under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (see Section 4.3.2). Currently, certain development on the floodplain is also required to satisfy the requirements of the BCA under *Wyong Development Control Plan 2013*. The Building Circular also indicates that following development approval, an application for a construction certificate (CC) will require assessment of compliance with the BCA.

4.3 State Provisions

4.3.1 Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) creates the mechanism for development assessment and determination by providing a legislative framework for development and protection of the environment from adverse impacts arising from development. The EP&A Act outlines the level of assessment required under State, regional and local planning legislation and identifies the responsible assessing authority.

Section 117 Directions – Direction No. 4.3 (Flood Prone Land)

NSW flood related planning requirements for local councils are set out in Ministerial Direction No. 4.3 Flood Prone Land, issued in 2007 under section 117 of the EP&A Act. It requires councils to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy as set out in the NSW Floodplain Development Manual (NSW Government, 2005). It requires provisions in a Local Environmental Plan on flood prone land to be commensurate with the flood hazard of that land. In particular, a planning proposal must not contain provisions that:

- permit development in floodway areas;
- permit development that will result in significant flood impacts to other properties;
- permit a significant increase in the development of that land;
- are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or
- permit development to be carried out without development consent except for the purposes of agriculture, roads or exempt development.

The Direction also requires that councils must not impose flood related development controls above the residential flood planning level (typically the 1% AEP flood plus 0.5m freeboard) for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General.

Section 10.7 Planning Certificates

Planning certificates are a means of disclosing information about a parcel of land. Two types of information are provided in planning certificates: information under Section 10.7(2) and information under Section 10.7(5) of the EP&A Act. These were formally referred to as Section 179 Certificates prior to the amendments of the EP&A Act that commenced in 2018.

A planning certificate under Section 10.7(2) discloses matters relating to the land, including whether or not the land is affected by a policy that restricts the development of land. Those policies can be based on identified hazard risks (*Environmental Planning and Assessment Regulation 2000*, Clause 279 and Schedule 4 Clause 7), and whether development on the land is subject to flood-related development controls (EP&A Regulation, Schedule 4 Clause 7A). If no flood-related development controls apply to the land (such as for residential development in so-called 'low' risk areas above the flood planning level, unless exceptional circumstances have been granted), information describing the flood affectation of the land would not be indicated under Section 10.7(2).

A planning certificate may also include information under Section 10.7(5). This allows a council to provide advice on other relevant matters affecting land. This can include past, current or future issues.

Inclusion of a planning certificate containing information prescribed under section 10.7(2) is a mandatory part of the property conveyancing process in NSW. The conveyancing process does not mandate the inclusion of information under section 10.7(5) but any purchaser may request such information be provided, pending payment of a fee to the issuing council.

4.3.2 State Environmental Planning Policies

State Environmental Planning Policies or SEPPs are the highest level of planning instrument and generally prevail over Local Environmental Plans.

SEPP (Housing for Seniors or People with a Disability) 2004

State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 aims to encourage the provision of housing (including residential care facilities) that will increase the supply of residences that meet the needs of seniors or people with a disability. This is achieved by setting aside local planning controls that would prevent such development.

Clause 4(6) and Schedule 1 indicate that the policy does not apply to land identified in another environmental planning instrument (such as Wyong LEP 2013) as being, amongst other descriptors, a floodway or high flooding hazard.

SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent. *SEPP (Infrastructure) 2007* allows Council to undertake stormwater and flood mitigation work without development consent.

SEPP (Exempt and Complying Development Codes) 2008

A very important SEPP is *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008*, which defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria.

Clause 1.5 of the Codes SEPP defines a 'flood control lot' as 'a lot to which flood related development controls apply in respect of development for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing)'. These development controls may apply through a LEP or DCP. Exempt development is not permitted on flood control lots but some complying development is permitted.

Clause 3.36C states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a flood storage area, floodway area, flow path, high hazard area or high risk area. The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed), flood affectation, safe evacuation, car parking and driveways.

In addition, Clause 1.18(1)(c) of the Codes SEPP indicates that complying development must meet the relevant provisions of the Building Code of Australia (refer Section 4.2.1).

4.3.3 NSW Flood Related Manuals

Flood Prone Land Policy and Floodplain Development Manual, 2005

The overarching policy context for floodplain management in NSW is provided by the NSW *Flood Prone Land Policy*, contained within the *Floodplain Development Manual* (NSW Government, 2005). The Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods, using ecologically positive methods wherever possible. The Manual espouses a merit approach for development decisions in the floodplain, taking into account social, economic, ecological and flooding considerations. The primary responsibility for management of flood risk rests with local councils. The Manual assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

Guideline on Development Controls on Low Flood Risk Areas, 2007

The *Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual* (the Guideline) was issued on 31 January 2007 as part of Planning Circular PS 07-003 at the same time as the Section 117 Directive described previously. The Guideline is intended to be read as part of the *Floodplain Development Manual*.

It stipulates that 'unless there are exceptional circumstances, councils should adopt the 100 year flood as the flood planning level (FPL) for residential development' and that "*unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land … that is above the residential FPL*".

Flood related development controls are not defined but would include any development standards relating to flooding applying to land, that are a matter for consideration under Section 79C of the EP&A Act.

The Guideline states that councils should not include a notation for residential development on Section 149 certificates for land above the residential FPL if no flood related development controls apply to the land. However, the Guideline does include the reminder that councils can include 'such other relevant factors affecting the land that the council may be aware [of]' under Section 149(5) of the EP&A Act.

In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Justification for exceptional circumstances would need to be agreed by relevant State Government departments prior to exhibition of a draft local environmental plan or a draft development control plan that proposes to introduce flood related development controls on residential development.

4.4 Local Provisions

In NSW, local government councils are responsible for managing their flood risk. A Local Environmental Plan (LEP) is used to establish what land uses are permissible and/or prohibited on land within the local government area (LGA), and sets out high level flood planning objectives and requirements. A Development Control Plan (DCP) sets the standards, controls and regulations that apply when carrying out development or building work on land.

A merger between Wyong Shire Council and Gosford City Council to form the Central Coast Council was announced in May 2016. It is expected that in time this will mean the merging of the two former councils' LEPs and DCPs. At the time of preparing this report, development applications within the study area continue to be assessed on the basis of the Wyong Shire policies. So this section describes and reviews the flood-related controls within the existing Wyong Shire policies, but also offers a few preliminary observations on similarities and differences with the equivalent Gosford City policies, which the Central Coast Council may wish to consider when it rationalises the two former councils' planning policies.

4.4.1 Wyong Local Environmental Plan 2013

Wyong Local Environmental Plan 2013 (Wyong LEP 2013) outlines the zoning of land, what development is allowed in each land use zone and any special provisions applying to land. Wyong LEP is made up of a written instrument with maps. However, it is noted that the flood planning maps that accompany the written instrument (as provided on the http://www.legislation.nsw.gov.au website) do not reflect the latest flood mapping results (as defined in the 'Wyong River Catchment Flood Study' (BMT WBM, 2014)).

Flood planning and floodplain risk management are addressed in clauses 7.2 and 7.3. These are reproduced on the following page. Clause 7.2 relates to land at or below the flood planning level. Clause 7.3 relates to land between the flood planning level and the PMF. The flood planning level (FPL) is defined in Wyong LEP 2013 as 'the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard'.

Comparison with Gosford LEP 2014

Comparing these clauses to the equivalent clauses in Gosford LEP 2014, clause 7.2 appears to be identical. This is unsurprising since both are based on a model clause.

However, there are significant differences in clause 7.3, since Wyong LEP 2013 lists 17 land uses that prior to granting of development consent require council to be satisfied that the development will not, in events exceeding the FPL, affect the safe occupation of, and evacuation from, the land. In contrast, Gosford LEP 2014 only lists seven land uses (see **Table 13**).

On the whole, Wyong LEP 2013 adopts a more conservative approach, since child-care centres, schools, home-based child care and seniors housing are all listed, whereas proposals for such developments on flood prone land above the FPL would apparently not trigger the same degree of scrutiny in Gosford LEP 2014. One exception is for residential care facilities, which are appropriately included in clause 7.3(3) of Gosford LEP 2014 (but not in clause 7.3(3) of Wyong LEP 2013). Gosford LEP 2014 evidently views caravan parks and tourist and visitor accommodation as sensitive uses requiring higher scrutiny, whereas Wyong LEP 2013 does not.

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) is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and
- (c) incorporates appropriate measures to manage risk to life from flood, and
- (d) is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and
- (e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

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

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.

Table 13 Comparison of land uses in clause 7.3(3) of Wyong LEP 2013 and Gosford LEP 2014

Land use	Wyong LEP 2013	Gosford LEP 2014
Air strips	☑	
Air transport facilities	☑	
Caravan parks		☑
Child care centres	☑	
Correctional centres/facilities	☑	☑
Educational establishments	☑	
Electricity generating works	☑	
Emergency services facilities	☑	☑
Group homes	☑	☑
Helipads	☑	
Home-based child care	☑	
Hospitals	☑	☑
Hostels	☑	
Public utility undertakings	☑	
Residential care facilities		☑
Respite day care centres	☑	
Seniors housing	☑	
Sewerage systems	☑	
Tourist and visitor accommodation		☑
Water supply systems	☑	

Neither Council lists typical residential uses under clause 7.3(3). This is in keeping with the 2007 Guideline directing councils not to apply flood related development controls to residential development above the standard FPL.

4.4.2 Wyong Development Control Plan 2013

Wyong Development Control Plan 2013 (Wyong DCP 2013) sets the design and construction standards that apply when carrying out development within the LGA. It supports Wyong LEP 2013, which regulates the uses that are permissible on the land.

Chapter 3.3 Floodplain Management of Wyong DCP 2013 is reviewed below.

Flood precinct definitions

Wyong Council currently adopts four flood precincts. These are defined only in the matrix included under Section 3.1 Prescriptive Criteria, and really require more precise definition elsewhere in the chapter. The four precincts have been devised based on flood frequency, flood hazard categorisation in the 1% AEP event using Figure L2 of the Floodplain Development Manual (FDM), and hydraulic categorisation for which various methods have been employed in the various flood studies:

- Precinct 1: Land between the flood planning level or FPL (typically 1% AEP flood + freeboard, where the freeboard varies between 0.5m for mainstream flooding and 0.3m for overland flow inundation) and the probable maximum flood or PMF;
- Precinct 2: Land below the FPL that is low hazard, flood fringe;
- Precinct 3: Land below the FPL that is low hazard, flood storage;
- Precinct 4: Land below the FPL that is high hazard;
- Precinct 5 (not shown on the matrix): Land below the FPL that is floodway.

It is understood that the additional descriptors in the matrix headings for Precincts 3 and 4 refer to particular flood studies that have used alternative methods for mapping these categories – for Precinct 3, the 10% AEP extent, and for Precinct 4, the 50% AEP extent. The inclusion of this additional text in the matrix – particularly if it does not describe the global approach for mapping of precincts across the entire LGA – is misleading. It would be preferable to prepare a new section entitled 'Flood planning precincts' describing the meaning of the precincts, ideally accompanied by diagrams. Flood hazard and hydraulic categories need to be defined in the glossary.

The adopted categories are convenient for aligning with the *Floodplain Development Manual* and the Codes SEPP 2008. However, best practice for defining what might be called Flood Planning Constraint Categories (FPCCs) has evolved to now recommend consideration of flood function, flood hazard and emergency response constraints. Flood hazard definition now draws upon national guidance described in *Australian Disaster Resilience Guideline 7-3 Flood Hazard* (AIDR 2017), derived from research that more closely aligns combinations of hydraulic hazard with consequences for vehicles, pedestrians and buildings Emergency response constraint definitions are described in *Australian Disaster Resilience Guideline 7-2 Flood Emergency Response Classification of the Floodplain* (AIDR 2017), highlighting the risks of isolation and especially isolation then subsequent submergence. And a new guideline describing how these various kinds of inputs can be incorporated into FPCCs has been prepared – *Australian Disaster Resilience Guideline 7-5 Flood Information to Support Land-use Planning* (AIDR 2017). It is therefore recommended that Council reassess how it is defining and mapping its flood precincts. In particular, incorporating intrinsic topographical constraints based upon flood evacuation within its FPCCs may give more appropriate weight to emergency response issues.

Land use categories

The land use categories set out in the matrix are defined at greater length in Appendix A of the DCP chapter. One potential point of contention is the way residential uses have been split into either 'Single Dwelling Houses' or 'Medium to High Density Residential', since several types of housing included in the latter including attached dwelling, dual occupancy, rural workers dwelling, secondary dwelling and semi-detached dwelling are commonly regarded as forms of low density housing. The types of 'Critical Infrastructure and Facilities' and 'Sensitive Uses and Facilities' are consistent with those listed in clause 7.3(3) of Wyong LEP 2014. It is not immediately clear why camping grounds (listed under 'Tourist Development') are assessed separately from caravan parks providing short-term accommodation. Charter and tourism boating facilities are incorrectly listed both as a commercial use and as 'Not Listed'.

Risk compatibility categories
The matrix includes three categories, one of which is applied to each land use/flood hazard combination:

- 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)

No flood-related development controls apply for all land uses in Precinct 1 except for 'Critical or Sensitive Facilities' and 'Land Subdivision'. Flood-related development controls do apply for many land uses in Precincts 2 and 3. The third category applies to all land uses in Precinct 4 and many in Precincts 2 and 3 as well, being a requirement for a performance-based assessment. It appears that this third category is used to indicate higher flood risk where Council judges that the development opportunities are marginal, and/or where Council desires greater scrutiny of development applications. The wording for this 'orange' category could be amended to provide a stronger indication that development may not be compatible with the risk. Or, for the highest risks, Council could consider introducing another category that some other councils adopt: a red colour to indicate an unsuitable land use.

Existing prescriptive criteria: nature of controls
The type of development controls included in the prescriptive criteria is similar to most other flood risk DCPs known to the consultants. The scope of these controls and a commentary on their adequacy is set out below:

- **Minimum floor levels** for habitable and non-habitable rooms (controls 2ab, 3a). These are set to the 1% AEP flood level plus 0.5m freeboard (habitable), the 5% AEP level (non-habitable) or the PMF (for critical or sensitive facilities), which accords with common practice.
- **Minimum levels for electrical fittings**, internal sewer fixtures and external gully overflow rises, as per the Building Code of Australia (BCA) (2c). These explicit provisions go beyond those contained in many other flood risk DCPs. In relation to electrical fittings, it is noted that the ABCB Standard also requires waterproofing of any conduits or cables stored below the 'flood hazard level' (equivalent to the FPL).
- **Minimum levels of open car parking spaces**, carports and driveways (2d). These are set to the 5% AEP flood level, which accords with common practice. It is noted that the DCP chapter includes a separate section (4.2) on car parking, which requires a maximum of 300mm still water inundation (but does not specify which design event this is for). The need to consider both sections, with different standards, risks confusion.
- **Access and egress** for pedestrian and emergency services' vehicles during flooding, to an area of refuge (2fg, 3bc, 4bc). These criteria draw upon the concept of hydraulic hazard (combinations of depths and velocities). More precise definitions of the hazard specifically relating to pedestrian and vehicular stability and using the current understanding of best practice are required to support these clauses, lest the coarser understanding of hazard described in Figure L2 of the FDM (and which is currently used

for defining the flood precincts) be used instead. Secondly, the current criterion requiring low hazard access *during a 1% AEP flood* does not appear to adequately safeguard risk to life in rarer flood events. Other DCPs do not place a limit on flood frequency for safe evacuation, though they do allow for effective warning time. Thirdly, it is recommended that the current criterion requiring – for most land uses – pedestrian egress to an appropriate point of refuge located *above the FPL*, be amended to require egress to land *above the PMF*. In principle, it is desirable that people be able to evacuate out of the floodplain *entirely* to effectively manage the residual risk to life. Whilst the distance between the FPL extent and the PMF extent for the Wyong River floodplain is generally modest, the height difference between the two is substantial (e.g., > 2.5 metres for much of the floodplain between the Pacific Motorway and the Pacific Highway), which commends evacuation out of the floodplain.

- **Structural integrity** of the building (2h). This control is fairly standard. However, in the consultants' opinion, this control should be satisfied for the *PMF* for critical or sensitive facilities permitted to be built in the floodplain (i.e. it should be added to control 3). The floor level for sensitive uses is set at the PMF level, presumably to provide a refuge of last resort above the reach of floodwaters and to reduce the urgency of evacuation, so it makes sense that the building is also structurally capable of withstanding a PMF.
- **Flood compatible materials** (2i). It is recommended that this criterion be explicitly linked to Appendix B of the DCP chapter to better convey the full scope of building components that should be flood compatible. Also, in the consultant's opinion, this control should be satisfied for the *PMF* for critical or sensitive facilities permitted to be built in the floodplain (i.e. it should be added to control 3).
- **Flood effects** elsewhere in the floodplain (2j, 4e). This control is fairly standard. Arguably, criterion 2j should not be confined to flood effects in events up to the 1% AEP flood, since a development could have negligible effects in the 1% AEP flood but unacceptable effects in rarer floods. In the consultant's opinion, flood effects should be considered for the *PMF* for critical or sensitive facilities permitted to be built in the floodplain (i.e. it should be added to control 3).
- **The impacts of climate change** (2k, 3d, 4f). The requirement to consider the impacts of climate change is expressed more like an objective than a prescriptive criterion and provides no guidance on *how* the impacts of climate change should be considered. A section under 'Performance-based assessment' provides a little more detail, implying that appropriate (sea level rise?) benchmarks have been incorporated into (some?) design flood information, and suggesting that development controls might be relaxed for development proposals involving shorter asset lives. In consultation with the former Gosford City Council, and perhaps also with reference to Lake Macquarie DCP 2014 (Part 3, Section 2.9, Revision 6 adopted Dec 2015), it is recommended that Council review the climate-change related provisions of the DCP chapter. For example, higher FPLs incorporating a 2100 sea level rise could be justified for medium- and high-density development, since these are likely to have longer asset lives than low density housing.
- **Filling of floodplains** (5). This prescriptive criterion that applies to single dwellings in Precinct 3 requires 'No filling allowable apart from area of building footprint, open car parking areas and driveway'. However, the DCP chapter includes a separate section (4.3) on filling of flood prone land, which states that filling for any purpose including the raising of a building platform in flood-prone areas is not permitted in Precinct 3 (unless a

FRMP that allows filling has been adopted) and that filling of individual sites in isolation is not permitted. The prescriptive criterion appears to be inconsistent with the later section, risking confusion.

- **Evacuation plans** (6, 9). This criterion requires, for commercial/industrial uses in Precinct 2 and caravan parks with short-term sites in Precincts 2 or 3, the preparation of an evacuation plan ensuring safe evacuation of people in a 1% AEP flood. The NSW SES has indicated that it does not support a requirement for private evacuation plans as a condition for consent. The SES is concerned that plans may be used to justify new development that is inappropriate for the degree of flood hazard and provide only a false sense of security given the known difficulties with sustaining local commitment, ownership and systems to implement a private evacuation plan (see Section N7 of the *Floodplain Development Manual*, 2005). But in the case of the existing Wyong DCP's controls for commercial/industrial uses, the prescriptive control for flood evacuation plans is applied only to low hazard/flood fringe parts of the floodplain (below the Flood Planning Level), and is just one of a suite of controls, and therefore does not function as the kind of control causing particular concern to the SES, namely that an evacuation plan is trying to overcome an underlying flood risk that would otherwise be considered too high to permit approval' (S. Opper, *Developers' Guide*, 2013). In that context, the requirement for an evacuation plan to raise awareness and preparedness is considered fitting. Indeed, S43 of the *Work Health and Safety Regulation 2017* requires businesses in NSW to prepare, maintain and implement an emergency plan. As the SES recognises, however, a requirement for 'maintenance free' emergency management measures is spurious, because all systems will require maintenance to ensure the timely and safe evacuation of people. One regulatory mechanism to provoke maintenance of plans could be to require new plans to be submitted whenever there is a change of use of a business. In the case of caravan parks, Council could condition an annual approval to operate to require updated plans. There, a more robust assessment of evacuation capability (other than simple provision of a Plan) is recommended (see 'Caravan parks – short term sites'). It is also preferred that this clause be amended to require safe evacuation in the PMF, which may be faster rising as well as higher and faster than the 1% AEP event. It is considered fitting and simpler to require this to be prepared by a 'flood risk management professional'. It is noted that criterion 9 requires evacuation plans where single dwelling houses are used for short-term rental accommodation. But it is unclear what mechanism Council uses to invoke this control, since residents may not require Council's prior approval for this activity.[1] It is also unclear why this provision applies to single dwellings in Precinct 2 (which could qualify for complying development under the Codes SEPP 2008) and not Precinct 3.
- **Community awareness** (7). Criterion 7 includes an interesting requirement for signage indicating the flood hazard of an area. According to the matrix, this is required for single dwelling houses, agriculture and recreation and sheds/garages/ancillary residential uses in Precinct 3. In the consultants' opinion, it may be impractical to require this signage

[1] A dwelling containing 4 bedrooms or less may qualify as exempt development under Wyong LEP 2013.

on all the land uses included under 'Agriculture and Recreation' and 'Sheds etc', which include farm buildings and gazebos. It would also be of interest to learn how well the installed signage is displayed and maintained at single dwelling houses, since sellers could have an incentive to obscure the signage.

It is also noted that some development controls often listed as prescriptive controls are treated separately in Wyong DCP 2013, such as hazardous materials (4.5).

Currently, Wyong DCP 2013 does not promote **on-site refuge**. The merits of evacuation and on-site refuge as strategies for managing risk to life are assessed in Section 5.4.2. Early evacuation to areas above the PMF is the preferred emergency management response for much of the floodplain. It is noted that in places like Tacoma and South Tacoma where the duration of flooding can be long (especially from flooding of Tuggerah Lake) and where sewerage and water services may fail, 'sitting it out' is by no means comfortable or risk free, and it is possible that residents may need to be rescued or resupplied, which increases the burden on the SES.

However, judging by responses to the community questionnaire, existing behaviours are out of synch with desirable behaviours, with most people indicating they would remain at their homes in a flood emergency, including respondents from Tacoma and South Tacoma (see 'current responses' in **Table 15**).

One approach would be for sustained community education to persuade residents of the need for early evacuation. But while investments in community education are undoubtedly required, if the experience of Lismore in the March 2017 flood is any guide – where a majority of people did not evacuate despite significant investment in flood education (Gissing et al., 2017; K. Haynes, 16/5/17, pers. comm.) – education is no guarantee of changed behaviours. For the Wyong River floodplain, achieving higher levels of compliance with Evacuation Orders will also likely require strategies to manage animals and to provide security for evacuated properties (see Section **Error! Reference source not found.**). But whether the NSW Police F orce would have resources available to satisfy would-be evacuees that their properties would be secure is doubtful.

Another approach is to include controls in the DCP that enable safer on-site refuge, as the existing housing stock is redeveloped. Among the controls would be requirements for a portion of habitable floor area above the PMF (and not in an enclosed roof space but with opportunity for boat rescue from the refuge) and for the building to withstand the forces of floodwater, buoyancy and debris in a PMF. (Whether Department of Planning approval for 'exceptional circumstances' is needed for the application of such controls to dwellings located on land within the Flood Planning Area requires clarification). On-site refuge would not be permitted where PMF hazard conditions are such as to endanger building structures. The DCP could also be designed such that, for development on the floodplain, the option of on-site refuge is confined to infill and 'knock-down-and-rebuild' developments and proscribed from greenfield development sites (e.g. new subdivisions), for which evacuation along rising grades to land above the PMF would be required. A potential objection to the inclusion of controls for safer on-site refuge in the DCP is the disincentive it could provide to evacuation. This is possible but is not considered a persuasive reason for denying residents a back-up option in the event that for whatever reason evacuation is not completed in time.

Existing prescriptive criteria: risk considerations

The application of the existing prescriptive criteria to each land use is considered below:

- **Single Dwelling Houses**. One striking feature of the existing controls is the different controls applied to Precincts 2 and 3. Proposed single dwelling houses in Precinct 3 must obtain a professionally certified report meeting the full scope of controls described above with the exception of evacuation plans, whereas proposed houses in Precinct 2 must demonstrate that the proposal meets the requirements of the Building Code of Australia (BCA). In fact, there are substantial similarities between the controls and the requirements of the BCA, including the requirement that minimum habitable floor levels be at the level set by Council namely 1% AEP flood level plus 0.5m freeboard. Two concessions for proposed houses in Precinct 2 (since they are not requirements under the BCA) are (i) the absence of requirements to demonstrate safe access/egress in a 1% AEP flood; (ii) the absence of a requirement to ensure no adverse flood effects in the floodplain. It is unclear why these controls are not required for all single dwelling houses below the flood planning level.[2] Possibly the intention was to align with the Codes SEPP 2008, which can be used for proposed single dwelling houses in Precinct 2. But the requirement only to meet the requirements of the BCA requires less than the Codes SEPP 2008, since the latter does require safe evacuation and professional certification that the development will not have adverse flood effects. The BCA acknowledges that it does not completely address risk to life. It may also not be straightforward for a developer to discover the precise requirements of the BCA. These considerations suggest that the prescriptive criteria (2a-k) applied to single dwelling houses in Precinct 3 should also be applied to Precinct 2. For both precincts, it does not appear to be necessary that every criterion from 2a to 2k be certified in a joint report by a professional engineer who specialises in hydraulic engineering and a professional engineer who specialises in civil engineering. The Codes SEPP 2008 limits this requirement to the prescriptive controls related to structural stability and flood affectation. The text could be reworded to effect this change.
- **Agriculture & Recreation**. Farm buildings and minor structures associated with a recreational usage are often regarded as more risk-tolerant, which sometimes sees them permitted in high hazard zones and with lower minimum floor level (e.g. 5% AEP level). Wyong DCP 2013 requires a more onerous performance-based assessment for these to be approved within a high hazard area, though non-habitable rooms may be set at the 5% AEP flood level.
- **Sheds/Garages/Ancillary Residential**. These land uses are treated virtually the same as single dwelling houses. This might be considered somewhat conservative given the consequences of their inundation are likely to be less pronounced than for houses

[2] The absence of a control relating to flood effects for single dwelling houses in Precinct 2 is probably tied to the very definition of the precinct, being *flood fringe*, typically mapped by modelling whether the loss of flood storage or conveyance from development significantly affects flood behaviour elsewhere.

(though it is understood Council has received development applications for very large sheds in rural zones). A number of other DCPs, for example, set the minimum floor level of small garages at the 5% AEP level rather than the 1% AEP level.

- **Commercial and Industrial**. At first glance, it appears that the matrix treats commercial and industrial uses as less flood tolerant than single dwelling houses, since the 'orange' colour code triggering a performance-based assessment is used for commercial/ industrial but not for single dwellings. But Council has indicated that this is more a reflection of the desire for greater scrutiny of these development applications.
- **Medium to High Density Residential**. Medium and high density residential developments require closer scrutiny through a performance-based assessment, which is considered appropriate.
- **Critical or Sensitive Facilities**. These land uses are not necessarily excluded from the floodplain as they are in some other DCPs, but the controls do require floor levels above the PMF (and as argued above, should also require structural integrity, etc.).
- **Land Subdivision**. A fairly comprehensive clause sets out the prescriptive criteria for land subdivision, including consideration of risks in a PMF event. For a greenfield subdivision, the use of conservative climate change benchmarks could be justified.
- **Tourist Development**. At first glance it appears that the matrix treats tourist development quite conservatively, since the 'orange' colour code triggering a performance-based assessment is used for Precincts 2, 3 and 4. Possibly this is in recognition of the high vulnerability of tourists, who may lack an appreciation for local hazards such as flooding. Nevertheless, camping grounds might be more appropriately aligned with the following land use category – short-term sites in caravan parks. The risk to life will still require robust management.
- **Caravan Parks – Short-term Sites**. Apart from a limit on filling, the only control placed on the development of caravan parks with short-term sites in the DCP relates to ensuring safe evacuation in a 1% AEP flood. This could be strengthened by extending the controls on access and egress (2fg, suitably amended) to these caravan parks, and by explicitly requiring an evacuation capability assessment that compares the time available for evacuation to the time required for evacuation (given the proposed number of sites and resources available) and which may conclude that site-specific flood warning infrastructure is required to increase the time available. Also, often a PMF is typically faster rising than a 1% AEP flood, and the precautionary principle requires that safety be demonstrated in a worst-case scenario. For this reason, it is suggested that for a proposed caravan park (or caravan park expansion, or camping ground), timely and safe evacuation should be demonstrated for both a 1% AEP flood and the PMF. Also, it is understood that installations of relocatable homes on short-term caravan park sites and the provision of information to prospective short-term patrons of caravan parks are governed in the Wyong LGA through the *Local Government Act 1993* (see especially sections 68 and 94) and the *Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 2005* (see especially clauses 75 and 123). It may be prudent to include in the DCP language such as this: 'Where development applications do not involve the concurrent request for approval for the installation of moveable dwellings in accordance with Section 68 of the Local Government Act 1993, the applicant must demonstrate that the proposal could achieve

compliance with the Act and Regulation when seeking such approvals.' Council should also consider conditioning annual approvals to operate a caravan park to ensure that their Flood Emergency Plans, and any infrastructure required for effective evacuations, are suitably maintained.

Performance-based assessment

Section 3.2 of the DCP chapter and Appendix C set out requirements for seeking development approval using performance-based assessment. Section 3.2 may be used to justify minor variations to the prescriptive controls, whereas the weightier Appendix C needs to be addressed for large scale proposals or significant variations. Section 3.2 contains fairly standard provisions, though Council could include an additional item to gain confidence that risk to life will be satisfactorily managed, such as 'The proposal should only be permitted where effective warning time and reliable access is available for evacuation from an area potentially affected by floods to an area free of risk from flooding'. Appendix C appears to be in need of reworking to remove duplication and streamline the text.

Concessional development

Section 3.4 of the DCP chapter allows for minor additions to existing buildings at floor levels lower than the FPL. Any proposal to be considered as concessional development must also comply with the Building Code of Australia (excluding, presumably, the requirements in the BCA for minimum floor levels). The section includes a note to indicate that concessional development is not supported in high hazard areas.

Some other DCPs define concessional development more broadly, including rebuilding of dwellings or redevelopments that *substantially reduce the flood risk to life and property*. Council could consider including such a provision, which is aimed at reducing the existing risk even if not to the standards required for new development and is judged to be a better outcome than effectively sterilising the floodplain with the existing risk left untreated. What constitutes a *substantial* reduction in flood risk to life and property could be articulated, for example, a reduction in the number of people exposed to flood hazards through a less dense use, and reduced exposure through higher floor levels even if not quite meeting the level stipulated for new buildings. The installation of a site-specific flood warning system, or preparation of a private flood evacuation plan, or other systems to improve response, would not normally meet the threshold of 'substantial' reductions of existing flood risk.

Fencing

The DCP chapter includes a section (4.1) setting out objectives and requirements related to fencing on flood prone land. It may be desirable to prepare prescriptive criteria to indicate what flood planning precincts this issue pertains to (presumably not Precinct 1?). Also, diagrams presenting suitable fencing solutions (siting, materials, design) may assist developers to apply this provision.

Car parking

The DCP chapter includes a section (4.2) setting out objectives and requirements related to car parking on flood prone land. As noted earlier, the prescriptive controls matrix includes a requirement for the level of a car park that does not synch smoothly with this section. It is recommended that this text be reviewed to more precisely describe the requirements including the design flood in view (1% AEP?) and drawing upon the depth-velocity (hazard) criteria for vehicle stability. Also, the risk to life in low set basement car parks may require more robust controls by articulating minimum driveway crest levels (e.g. 1% AEP + 0.5m freeboard) and requiring adequate warning systems, signage and exits where basement floor levels are more than 0.8m below the 1% AEP level.

Comparison with Gosford DCP 2014

Flood risk in the former Gosford Council area is managed through chapter 6.7 of Gosford DCP 2014, being 'Water Cycle Management', which seeks to apply the principles of Water Sensitive Urban Design (WSUD), Integrated Water Cycle Management (IWCM) and flood mitigation in the LGA. One of these principles is to 'reduce risk to life and damage to property by restricting and controlling building and other development so that it minimises risks to residents and those involved in rescue operations during floods' (6.7.2). Section 6.7.7.6 sets out 'Flooding Targets' aimed at reducing the impact of flooding on flood prone property. The objectives of these targets are similar to – but not precisely the same as – the objectives of the Floodplain Management chapter of Wyong DCP 2013. Gosford DCP 2014 provides considerable detail for the preparation of local flood studies where catchment flood studies are not available to define flood behaviour. The policy explains how flood-related development controls may apply for any development on flood prone land (up to the PMF) for the purposes of subdivision, earthworks, the erection of a building etc., but will not apply for development for the purposes of residential accommodation (other than group homes and seniors housing) on flood prone land that is not in the flood planning area (i.e. land that is above 1% AEP + 0.5m freeboard but below the PMF).

Unlike Wyong's DCP, Gosford does not appear to differentiate flood planning precincts for the floodplain, which could make it more difficult to ascertain what residential development could qualify as complying development in the Codes SEPP 2008. While it uses a form of a matrix, this differs from most other matrices in that it does not relate flood planning categories to acceptable, tolerable or unacceptable land uses. Gosford's matrix lists six land uses in comparison to Wyong's ten. One noteworthy difference is the distinction Gosford makes between rural and urban residential buildings (with additional controls on access for the former), and Gosford's non-usage of a medium to high density residential category. Both DCPs allow for concessional development, but Gosford permits a smaller addition when the existing floor level is well below the FPL. Both DCPs require consideration of the PMF for subdivisions, but Gosford's DCP is more conservative in explicitly stating that 'Subdivision of land will not be permitted for the purpose of creating additional lots within the flood planning area', whereas subdivision in Wyong could conceivably be permitted even at the 5% AEP level. Gosford's controls on access for sensitive developments are more conservative than Wyong's, since for Gosford the access roads and driveways must be above the PMF. Gosford's controls on fencing are more detailed and prescriptive than Wyong's.

Gosford's matrix includes a control 'C' entitled 'Flood impacts' that appears to function as a kind of organic catch-all, with 30 controls that must be considered for all proposed land uses within the flood planning area (and for some land uses, within the PMF floodplain). Some of these controls (e.g. most of the first 10) are expressed in the language of performance criteria, which could make for lengthier DA assessment as Council staff consider each application on its merits with fewer prescriptive criteria to guide the assessment. Nonetheless, Gosford's DCP utilises a similar scope of controls to Wyong's including minimum habitable/non-habitable floor levels, flood-compatible building components, flood effects and filling. Two differences are Gosford's requirements for detailed assessment and management of overland flow paths, and, for low lying land, assessment of the ongoing viability of the land including road access associated with an adopted sea level rise of 0.9m for the year 2100, assuming a design life for the development.

This brief review has shown that while the objectives of the two former council's flood risk management DCP chapters are similar, the location differs (Gosford's being more aligned with water cycle management), the approach to floodplain mapping differs (Gosford effectively adopting two precincts being land in the flood planning area and land between the flood planning level and the PMF level), the style of the controls differs (Gosford not explicitly using an objectives–performance-based–prescriptive criteria hierarchy) and the judgments about the tolerability of risk differ (Gosford on the whole adopting a more conservative approach e.g. with respect to concessional development, subdivisions, access to sensitive developments, and the incorporation of sea level rise benchmarks). To combine the two approaches into one is likely to require considerable discussion to pick and choose elements of both that best accord with industry best practice, mindful of the particular issues pertinent to the Central Coast LGA.

In considering ways to join the two flood DCP chapters into one, it is also worth noting that some LGAs adopt different flood risk matrices for different styles of flooding within their LGAs, since varied responses might be appropriate. In the case of Central Coast LGA, it might be appropriate to have matrices for the following types of floodplains:

- Land adjacent to the large lakes where the flood height range is relatively low, the time to peak is relatively long, flood duration is relatively long, and sea level rise is likely to influence future flood levels;
- Land subject to flash flooding from creeks and rivers where the flood height range is higher, the time to peak is short and debris loads may be high;
- Land subject to Hawkesbury River flooding where the flood height range is high (from Wisemans Ferry to Spencer) and the time to peak for catchment-derived flooding is relatively long;
- Possibly, areas where due to particular floodplain characteristics or the potential for blockage of hydraulic structures, the flood height range is so large that 'exceptional circumstances' should be sought for the application of development controls for residential usage on land between the flood planning level and the PMF;
- Land subject to overland flows where the flood height range is low.

4.4.3 Section 10.7 Planning Certificates in former Wyong LGA

The former Wyong Council issued Section 149 (now referred to as Section 10.7) certificates under the *Environmental Planning and Assessment Regulations 2000* (Clause 279 and Schedule 4(7A)). The primary function of the Section 10.7 certificate notation is as a planning tool for notification that the land is affected by a policy that restricts development due to the likelihood of a risk, in this instance, flood hazard (see Section 4.3.1).

At the current time, for the former Wyong LGA, Council issues one of the following two annotations under Section 10.7(2) of the EP&A Act:

- Lot affected by flood controls – 1% AEP
- Lot affected by flood controls – PMF (note, these are not issued to standard residential dwellings, since these are not subject to development controls when located beyond the flood planning area)

No annotations are issued under Section 10.7(5).

5 CURRENT EMERGENCY MANAGEMENT PROTOCOLS

It is generally not affordable to treat all flood risk up to and including the PMF through flood modification and property modification measures. Emergency management measures such as flood warning systems, evacuation planning and community flood education are aimed at increasing resilience to reduce risk to life and property, both for frequent flood events and for very rare flood events.

The following chapter outlines current emergency management strategies for the Wyong River catchment and sets out some context for the detailed evaluation of emergency management and response modification measures in Section 9.

5.1 Wyong Shire Local Flood Plan

The *Wyong Shire Local Flood Plan* (NSW SES, 2013) covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the former Wyong Shire area.

The current Local Flood Plan (LFP) is reviewed in **Table 14**. Volume 1 was prepared in June 2013. It details organisational responsibilities for managing flooding hazards, and sets out tasks related to the preparedness, response and recovery phases of disaster management. The main recommendations for Volume 1 relate to checking the currency of the lists of areas subject to active reconnaissance during a flood and whether the listed evacuation centres are sufficient to service local or remote communities in the catchment.

Volume 2 was last updated in December 2007. While it contains much good flood intelligence, it is in need of an update, both to align the structure and contents with the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. Also, this process could strengthen the Local Flood Plan by better locating some information (e.g. clause 24 of Annex B in the current LFP deals with the isolation of Yarramalong but is located under a heading 'Sewers'). There is considerable scope to include flood intelligence for the Wyong River from this study into the LFP. In order to comply with the new template, considerable work is needed to describe flood hazard and exposure for specific risk areas. Sections are also needed to describe road closures and isolation.

Volume 3 was last updated in December 2007. It describes response arrangements including flood warning systems and evacuation protocols. The list of gauges monitored needs to be reviewed. The emergency response arrangements for each location and sector (especially whether to evacuate or seek refuge on-site) need to be reviewed (see Section 5.4) and considerable effort is needed to provide the detail consistent with the new SES LFP template. The list of caravan parks also needs to be updated.

Table 14 Comments on Current Wyong Shire Local Flood Plan

Section	Description	Comment
Volume 1		
1.5.6	Responsibilities for Bureau of Meteorology	Noted that this includes issuing height-time predictions for Wyong River at Wyong Bridge.
1.5.20	Responsibilities for NSW Rural Fire Service	This could include a specific mention of the Yarramalong and Dooralong RFS units.
1.5.25	Responsibilities of Roads and Maritime Services	The list of roads for which RMS exercises responsibility should be checked for currency.
3.8.4	List of problem areas for active reconnaissance during flooding	The list currently includes Yarramalong Rd from Wyong Creek to Yarramalong Township and Dooralong Rd at Dooralong, past cricket oval. Depending on resources available for reconnaissance, the list of roads could be supplemented by reference to Section 3.2.7 of this report, focussing on the greater risks in terms of likelihood and consequences of inundation. Beneficial additions include Jilliby Rd near Jilliby Creek, McPherson Rd at Wyong and South Tacoma Rd at Tuggerah.
3.18.42	List of evacuation centres	In the Wyong River FRMS&P study area, both Wyong RSL Club and Wyong Golf Club are listed and are located beyond the PMF extent. Evacuation centres may need to be added for Yarramalong (e.g. School of Arts, 1640 Yarramalong Road, for properties west of Bumbles Creek, or Yarramalong Public School, 1560 Yarramalong Road, for properties east of Bumbles Creek). Similarly, it could be prudent to consider a local evacuation centre for Mardi, such as Woodbury Park community centre.
Volume 2	***Hazard and Risk in Wyong***	
1.1	Landforms and River Systems	Ok
1.2	Storage Dams	Ok
1.3	Weather Systems and Flooding	Scope for more analysis of historical floods.
1.4	Characteristics of Flooding	Scope for considerably expanded description of flooding characteristics for Wyong River floodplain including flow travel times.
1.5	Flood History	Scope for expanding list of historical floods using National Library of Australia's digital newspaper database and State Library of NSW microfilm. The design flood levels currently listed in this section need to be updated[3] and would be better located under Section 1.4 of the LFP. The description of the 2007 flood timings currently located at clause 8 of Annex F of volume 3 would be better located under this section of the LFP.
1.6	Flood Mitigation Systems	Nothing currently described.

[3] Design flood levels reported at Wyong Bridge in the 2013 LFP are 5% AEP 3.77m, 2% AEP 3.93m, 1% AEP 4.05m and Extreme 4.80m. The current flood study yields 5% AEP 3.1-3.2m, 1% AEP 3.7-4.0m, 0.5% AEP 3.9-4.2 and PMF 5.4-6.7m. The range in levels is from the upstream side of the Pacific Highway road bridge to the downstream side of the railway bridge, taken about halfway over each bridge.

Section	Description	Comment
1.7	Extreme Flooding	Scope for considerably expanded description of extreme flooding characteristics for Wyong River floodplain including flow travel times.
1.8	Coastal Erosion	Ok
2.1	Community Profile	Should be updated using 2016 Census.
2.2f	Specific Risk Areas	The list could be expanded to include sections on Yarramalong Valley and Deep Creek/Mardi rural area. The template LFP requires significant detail for each distinct community including cultural and linguistic diversity, schools and childcare centres, facilities for the aged and infirm, utilities and infrastructure, culturally significant sites, classification of floodplains, inundation, isolation, characteristics of flooding, flood mitigation systems and dams.
2.7	Road Closures	The current LFP does not include such a list. This information is available in Section 3.2.7 of this study.
2.8	Summary of Isolated Communities and Properties	Isolation could be prolonged for rural communities such as Yarramalong and will need to be recorded.
maps		The current LFP includes maps showing design flood contours from the 2001 study. These would be better replaced by flood depth/level/velocity maps as well as hazard maps from the current study.
Volume 3	***SES Response Arrangements***	
Ch. 1	Flood Warning Systems and Arrangements	The list of gauges monitored needs to be reviewed. See Table 35 and Table 36 of this report for a list of current automatic gauges in the Wyong River study area. It may also be easier to read by separating rain gauges from water level recorders, and to arrange the latter according to catchment.
Ch. 2	SES Locality Response Arrangements	The current LFP breaks down Wyong Shire into six evacuation sectors, including Wyong town, Yarramalong, Dooralong, and the Lakes. The stated strategies for each sector (evacuate or seek on-site refuge above PMF) and the evacuation triggers require re-evaluation (see Section 5.4 of this report). The evacuation trigger for Wyong Aged Care Facility is currently stated to be a predicted 1.2m at Wyong Bridge. But Cardno (2015) suggests that a better trigger would be the 5 year ARI level at the Yarramalong water level recorder.
Ch. 3	SES Dam Failure Arrangements	Nothing currently described.
Ch. 4	SES Caravan Park Arrangements	The current LFP lists flood prone caravan parks in Annex G. This list needs to be reviewed. Although full of manufactured homes and marketed as affordable over 50s accommodation, Meander Village in Wyong is technically a caravan park that could be added to this list.

5.2 Wyong Bridge Flood Intelligence Card

A Flood Intelligence Card is known to exist for the Wyong Bridge site but has not been viewed. This will need to be revised in order to incorporate outputs from the latest design flood modelling as well as changes to the gauges and hydraulic behaviour that result from a proposed Pacific Highway bridge upgrade. Given the gradient of the flood surface from the upstream edge of the road bridge to the downstream edge of the railway bridge, particularly in rarer events, care will be required in choosing precisely what point the FIC should relate to. Probably it should be consistent with the gauge location used for automatic monitoring and flood forecasting.

5.3 Emergency Services' Capability

At the current time, the Wyong SES unit has about 80 members, trained to various levels for rescue including some at level 3 (swift-water rescue capability). If a forecast highlights Wyong as a likely 'hotspot' for flooding, there is also potential to call in out-of-area units to supplement local resources. NSW Police and Fire and Rescue NSW also have some personnel trained for rescue.

However, given the size of the at-risk communities in the LGA, and given the remoteness of some of these communities, adverse consequences are likely to occur across some sections of the catchment before emergency services personnel can be deployed. There may be opportunity for helicopter rescues depending on the weather. But it will be critical that the at-risk communities are able to anticipate and cope with flooding, without reliance on the emergency services.

5.4 Response Strategy

5.4.1 Theory

A major point of contention in contemporary flood emergency management planning relates to the advantages and disadvantages of evacuation compared to on-site refuge.

AFAC's (2013) '*Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events'* is considered to represent best practice on this issue. While flooding from the Wyong River is not typically *flash* flooding – where this is defined as flooding that occurs within six hours or less of the flood-producing rainfall – the guideline still provides important principles. It recognises that the safest place to be in a flood is well away from the affected area. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome.

However, AFAC recognises that evacuating too late may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater.

Nevertheless, AFAC argues that remaining in buildings likely to be affected by flooding is not low risk and should never be a default strategy for pre-incident planning*: 'where the available warning time and resources permit, evacuation should be the primary response strategy'* (p.4).

The risks of an on-site refuge strategy include:

- Floodwater reaching the place of refuge (unless the refuge is above the PMF level);

- Structural collapse of the building that is providing the place of refuge (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with no known basis for determining a tolerable duration of isolation;
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment);
- People's immobility (not being able to reach the highest part of the building);
- The difficulty of servicing medical emergencies (pre-existing condition or sudden onset e.g. heart attack) during a flood;
- The difficulty of servicing other hazards (e.g. fire) during a flood.

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater (Opper et al., 2011). Pre-incident planning therefore needs to include a realistic assessment of evacuation timelines (both time available and time required for evacuation), including assessment of resources available. Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

5.4.2 Wyong Shire Practice

It is noted that the current Wyong Local Flood Plan (Volume 3 Annex F clause 10, dated 2007) endorses "shelter-in-place" (i.e., on-site refuge) as the appropriate strategy for the Yarramalong Valley, the Dooralong Valley and northern areas of Wyong primarily affected by flash flooding in the catchment areas of Jilliby Creek and Porters Creek. Plus, the Local Flood Plan (Volume 2 Annex B clause 23) recognises that the failure of the sewerage system may not be sufficient grounds for initiating evacuation.

Factors pertaining to the general suitability of on-site refuge or evacuation are summarised for several sectors, for the 20% AEP, 1% AEP and PMF events, in **Table 15**. These factors include:

- the number of dwelling floors that are inundated;
- the number of dwellings that have a second storey to which people could potentially evacuate if the ground level was flooded;
- the number of other dwellings that are not flooded and which might serve as refuges for neighbours (though a safe public evacuation centre is preferred);
- the number of dwellings exposed to H5 or H6 hazard conditions that could endanger the dwelling structure;
- the effective warning time prior to loss of evacuation routes;
- the duration of isolation by road; and
- the flood emergency response classification.

The appropriateness of a on-site refuge strategy was semi-quantified for each sector using the following logical expressions, based on the PMF:

IF single storey house flooded over floor to depth ≥ 0.8m OR IF any house affected by H5 or H6 hazard conditions	EVACUATION ESSENTIAL
IF single storey house flooded to depth over floor ≤ 0.8m OR two storey house AND IF house NOT affected by H5 or H6 hazard conditions	POTENTIAL ON-SITE REFUGE

The outcomes of this assessment are summarised in **Table 15**.

It is emphasised that buildings that were identified by this method as having potential for on-site refuge may, on closer inspection, not be suitable for on-site refuge, since it is not possible to account for every factor that influences a building or a household's ability to tolerate on-site refuge. Older buildings in this catchment are generally not tied down and are therefore prone to floating in significant floods (and so would clearly be dangerous places in which to seek refuge), but a 'building age' metric is not readily available to incorporate into the assessment. Also, essential services such as electricity, water and sewerage may be lost, or water may be contaminated, which again means that on-site refuge is, at the very least, undesirable. Personal circumstances may also mean on-site refuge cannot be tolerated (e.g. people requiring unbroken access to medical facilities). And people who are isolated for extended periods may engage in dangerous behaviours, such as entering floodwater.

For dwellings assessed as requiring evacuation, the required timing will depend on the flood emergency response classification and the intended destination.

Table 15 also includes suggested short-term and long-term flood risk 'treatment' options for each sector.

Yarramalong Valley

The Yarramalong Valley sector is a large sector extending from the upper reaches of the floodplain in Cedar Brush Creek and Ravensdale, past Yarramalong village to the eastern limit of Wyong Creek where it meets Wyong and Mardi. An estimated 49 dwellings in this sector are flooded above floor in the 1% AEP event, although most of these have a second storey that could provide a means of reducing damages to contents. While roads are flooded very early cutting access within the valley and to Wyong, most housing is located beyond the floodplain or towards the edge of the floodplain with access to higher ground by foot if not by road or track. But there are some exceptions where access is lost prior to inundation of the house footprint (i.e. the dangerous FIS or 'Flooded Isolated Submerged' category). Plus, for people who do evacuate to higher ground, the duration of isolation is considerable.

The appropriateness of a strategy also needs to consider what could happen in an extreme event. Of particular concern for many dwellings is the high hydraulic hazard experienced in the PMF, which could threaten building integrity and make it very unsafe for on-site refuge. Plus, the design PMF event for the Wyong River catchment is particularly fast-rising.

Table 15 Assessment of Response Strategies by Sector

	Yarramalong Valley	Dooralong Valley	Wyong west of Pacific Hwy	Wyong east of Pacific Hwy[1]	Tacoma	Mardi rural	Mardi urban	Tuggerah industrial[2]	Tuggerah residential	South Tacoma
General										
Total no. dwellings	167+	61+	65+	417+	141+	43+	375+	238	16+	97
Local public evacuation facility	Potentially yes for Yarramalong village; No elsewhere	Potentially yes	Yes (east of Porters Ck); No (west of Porters Ck)	Yes	Potentially yes (Braithwaite Ave, Hillcrest Ave); No (Wolseley Ave)	No	Potentially yes	Yes	Potentially yes	No
Evacuation routes	Yarramalong Rd east to Wyong	Dooralong Rd-Jilliby Rd south to Wyong or Mandalong Rd east to Pacific Mwy or Morriset	Alison Rd east to Wyong or Alison Rd west to Hue Hue Rd and north to Pacific Mwy	Boyce Ave-Warner Ave or Panonia Rd west to Wyong	Hillcrest Ave to Tacoma PS, or Wolseley Ave-Mcdonagh Rd west to Wyong	Old Maitland Rd south to Wyong Rd or north to Yarramalong Rd, or McPherson Rd east to Pacific Hwy	Woodbury Park Dr west to community centre, or Woodbury Park Dr-Wyong Rd to Pacific Mwy	Pacific Hwy north to Wyong	Lake Rd-Bryant Dr	South Tacoma Rd east to Tuggerah; secondary route through Pioneer Dairy
20% AEP										
No. dwellings flooded over floor	3	0	0	0	3	0	0	0	0	1
No. of *multistorey* flooded dwellings	3	0	0	0	3	0	0	0	0	1
No. dwellings *not* flooded over floor	164+	61+	65+	417+	138+	43+	375+	238	16+	96
Total no. dwellings with floor above flood[3]	167+	61+	65+	417+	141+	43+	375+	238	16+	97
No. dwellings in H5 hydraulic hazard	0	0	0	0	0	0	0	0	0	0
No. dwellings in H6 hydraulic hazard	0	0	0	0	0	0	0	0	0	0
Road first cut (hrs after rain starts)	Various incl. 13.5 hrs Yarramalong Rd	Various incl. 5.5 hrs Dooralong Rd, 11 hrs Mandalong Rd	n/a	n/a (except eastern end Mcdonagh Ave)	39 (Mcdonagh Ave)	33 to 39	n/a	6	n/a	32.5
Expected warning time before road cut (hrs)[4]	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)	None (flood warning may not be issued)

	Yarramalong Valley	Dooralong Valley	Wyong west of Pacific Hwy	Wyong east of Pacific Hwy[1]	Tacoma	Mardi rural	Mardi urban	Tuggerah industrial[2]	Tuggerah residential	South Tacoma
Duration of lost access (hrs) [5]	Various incl. 26.5 hrs Yarramalong Rd	Various incl. 10 hrs Jilliby Rd, 29 hrs Mandalong Rd	n/a	n/a (except eastern end Mcdonagh Ave)	1	1 to 7	n/a	Mostly none; 34 hrs at one low-point in Ace Cres	n/a	7.5
20% AEP flood emergency response classification	Very few FIS; mostly FIE and IC	Very few FIS; mostly FIE, FER and IC	FER and FEO	Few FIS; mostly FIE, FER, FEO and IC	Few FIS; mostly FIE and FER	Much FIE; some FER	Flood free	Some FIE, FEO; much flood free	Flood free	Mostly FIE and IC
1% AEP										
No. dwellings flooded over floor	49	5	10	222	78	27	0	64	2	53
No. of *multistorey* flooded dwellings	29	1	3	77	29	6	0	5 *	0	27
No. dwellings *not* flooded over floor	118+	56+	55+	195+	63+	16+	375+	174	14+	44
Total no. dwellings with floor above flood[3]	147+	57+	58+	272+	92+	22+	375+	179 *	14+	71
No. dwellings in H5 hydraulic hazard	5 (3 in Yarramalong, 2 in Wyong Creek)	0	1 (Hargrave St)	0	0	1 (Collies Ln)	0	0	0	0
No. dwellings in H6 hydraulic hazard	0	0	0	0	0	0	0	0	0	0
Road first cut (hrs after rain starts)	Various incl. 6.5 hrs Yarramalong Rd	Various incl. 6.5 hrs Dooralong Rd, 7.5 hrs Mandalong Rd	20	22.5	22.5	16.5 to 19	22 hrs for access to Pacific Hwy via Woodbury Park Dr	Various incl. 5 hrs near Mardi Creek, 27 hrs Pacific Hwy	28.5 (1 house) 30 (3 houses) n/a (others)	17
Expected warning time before road cut (hrs)[4]	-14	-14	-0.5	2.0	2.0	-4 to -1.5	1.5	-15.5 to 6.5	8 (1 house) 9.5 (3 houses) n/a (others)	-3.5
Duration of lost access (hrs)[5]	Various incl. 32 hrs Yarramalong Rd	Various incl. 31.5 hrs Jilliby Rd, 32.5 hrs Mandalong Rd	16.5	17.5	17.5	21 to 23.5	16.5 hrs Woodbury Park Dr nr Gavenlock Rd	Various incl. 35 hrs near Mardi Creek, 13 hrs Pacific Hwy	11.5 (1 house) 2 (3 houses) n/a (others)	23
1% AEP flood emergency response classification	Considerable FIS (some in Linga Longa Rd); mostly FIE or IC	Few FIS; mostly FIE or IC	Much FIS along Alison Rd W of Porters Ck; much FER elsewhere	Mostly FIS; some FIE, FER, FEO; much not impacted	Mostly FIS	Generally FIS or FIE	Mostly IC; some FIE	Mostly FIE, some FIS	Mostly not impacted, one FIS	Mostly FIS, some FIE

	Yarramalong Valley	Dooralong Valley	Wyong west of Pacific Hwy	Wyong east of Pacific Hwy[1]	Tacoma	Mardi rural	Mardi urban	Tuggerah industrial[2]	Tuggerah residential	South Tacoma
PMF										
No. dwellings flooded over floor	140	48	52	404	127	43	232	210	12	87
No. of *multistorey* flooded dwellings	66	11	14	92	46	11	77	26 *	1	32
No. dwellings *not* flooded over floor	27+	13+	13+	13+	14+	0+	143+	28	4+	10
Total no. dwellings with floor above flood[3]	93+	24+	27+	105+	60+	11+	220+	54 *	5+	42
No. dwellings in H5 hydraulic hazard	72	11	25	200	18	33	1	68	2	1
No. dwellings in H6 hydraulic hazard	29	0	8	1 (Strathavon Heritage Resort)	0	8	0	7	0	0
Road first cut (hrs after rain starts)	Various incl. 1 hr Yarramalong Rd	Various incl. 1 hr Dooralong Rd, 1.5 hrs Mandalong Rd	5	5.5	6	3 to 3.5	1.5	1 to 2	1	2.5
Expected warning time before road cut (hrs)[4]	-5.8	-5.8	-1.8	-1.3	-0.8	-3.8 to -3.3	-5.3	-5.8 to -4.8	-5.8	-4.3
Duration of lost access (hrs)[5]	Various incl. 39 hrs Yarramalong Rd	Various incl. 37.5 hrs Jilliby Rd, 38.5 hrs Mandalong Rd	35	34.5	34	35.5 to 37	21 hrs Woodbury Park Dr nr Wyong Rd; 38.5 hrs Woodbury Park Dr nr Gavenlock Rd	38 to 39	18.5	37.5
PMF flood emergency response classification	Much FIS incl. in Yarramalong village and in Wyong Creek, mostly FIE	Some FIS; much FIE and IC	Much FIS along Alison Rd W of Porters Ck, some FIE, FER	Mostly FIS; small area not impacted towards station	Much FIS	Mostly FIS	FIS along E and N fringes; mostly IC	Mostly FIS	Mostly FIS	FIS

	Yarramalong Valley	Dooralong Valley	Wyong west of Pacific Hwy	Wyong east of Pacific Hwy[1]	Tacoma	Mardi rural	Mardi urban	Tuggerah industrial[2]	Tuggerah residential	South Tacoma
Risk treatment										
Current responses (from questionnaire)	90% remain at home (38/42 respondents)	100% remain at home (18/18 respondents)	64% remain at home (7/11 respondents)	77% remain at home (41/53 respondents)	90% remain at home (9/10 respondents)	80% remain at home (4/5 respondents)	54% remain at home (15/28 respondents)	83% evacuate (5/6 respondents)	Unknown (no respondents)	100% remain at home (12/12 respondents)
Fitting responses[6]	24% evacuate 76% potential on-site refuge	49% evacuate 51% potential on-site refuge	61% evacuate 39% potential on-site refuge	90% evacuate 10% potential on-site refuge	42% evacuate 58% potential on-site refuge	100% evacuate 0% potential on-site refuge	13% evacuate 87% potential on-site refuge	96% evacuate 4% potential on-site refuge	44% evacuate 56% potential on-site refuge	28% evacuate 72% potential on-site refuge
Proposed short-term risk treatment[6]	Community education and provision of specific hazard information to promote early evacuation to high ground	Community education and provision of specific hazard information to promote early evacuation to high ground	Residents west of Porters Creek to evacuate early	Evacuation to Wyong centres	Generally, evacuation to Wyong centres	Develop a warning system using upstream gauges; all residents to evacuate very early	Generally, on-site refuge above PMF; establish local evacuation centre at Woodbury Park community centre if required	Evacuation, with existing businesses preparing flood emergency management plans setting evacuation triggers	Evacuation from two houses at eastern end of Lake Road and others where PMF depths >1.2m; others on-site refuge above PMF	Community education and provision of specific hazard information to promote very early evacuation to Wyong
Proposed long-term risk treatment	Revise DCP controls to ensure new development provides for safe evacuation or on-site refuge above the PMF	Revise DCP controls to ensure new development provides for safe evacuation or on-site refuge above the PMF	Consider voluntary purchase of highest risks; revise DCP controls to ensure redevelopment provides for safe evacuation or on-site refuge above the PMF	None	Revise DCP controls to ensure redevelopment provides for safe evacuation or on-site refuge above the PMF	Consider voluntary purchase of highest risks; revise DCP controls to ensure redevelopment provides for safe evacuation or on-site refuge above the PMF	Increase immunity of Woodbury Park Drive towards Wyong Road	None	Encourage commercial/ industrial uses rather than residential	Revise DCP controls to ensure redevelopment provides for on-site refuge above the PMF

[1] Excludes Kooindah Waters estate and Meander Village. Note, this sector contains significant number of commercial/industrial premises, which have not been assessed.

[2] The numbers described for the Tuggerah industrial sector are for commercial/industrial buildings, not dwellings.

[3] Assuming depths do not reach the second storey.

[4] The NSW State Flood Sub Plan indicates that the Bureau aims to provide 6 hours' warning prior to 2.7m at the Wyong Bridge gauge. The times at which this occurs are estimated from the 1% AEP and PMF design flood hydrographs upstream of Wyong Railway Bridge. These times are compared to the time at which the road is first cut to establish the effective warning time. Where the time is negative, the road is cut before a prediction may be issued.

[5] The duration of lost access does not include time lost due to flooding of Tuggerah Lakes, as this would make the time significantly longer, especially for the Tacoma and South Tacoma Sectors.

[6] Assessment is at sector level, based only on the logical expressions for the PMF as described in the text, and do not consider other factors such as loss of services or building structure / household-specific limitations. This assessment does not prescribe appropriate individual householder responses to floods.

* It is not known whether a business premises within a multi-storey building has ready access to higher levels for the evacuation of assets or staff.

The potential duration of isolation commends very early evacuation from the valley to Wyong of any persons with a known medical condition (including imminently expecting mothers), and storing of supplies for the many houses located above the PMF level. The potential depth and velocity of floodwaters especially in extreme floods commends early evacuation of many other residents living on flood prone land. This goes against current behaviours – the responses to the community questionnaire indicate that most people in the Yarramalong Valley tend to 'sit out' floods (**Table 15**). Changing this culture may be difficult. It will require concerted education to persuade people that extreme floods outside their previous experience do occur (e.g. Lockyer Valley 2011, Dungog 2015) and the provision of specific flood hazard information for each flood prone property to help residents understand what conditions they could face in an extreme flood and plan how they should respond when severe weather is forecast.

In the long-term, Council could strengthen its planning and development controls to proscribe residential development in Precinct 4, and to ensure that any future houses in the floodplain provide for safe evacuation to higher ground or on-site refuge above the PMF. (This may require an application for the granting of 'exceptional circumstances' from the Department of Planning and Environment).

Dooralong Valley

The Dooralong Valley sector extends from the upper reaches of Jilliby Jilliby Creek's floodplain in Lemon Tree, through Dooralong and Jilliby to the Wyong River. Compared to the Yarramalong Valley, significantly fewer existing houses are estimated to be flooded above floor level for both the 1% AEP and PMF events, fewer are subject to H5 hazard conditions, and none are subject to H6 hazard conditions even in the PMF. But the same problems of very limited warning and lengthy disruption to access prevail.

In general, the same emergency management strategy proposed for the Yarramalong Valley is recommended: anyone with a higher likelihood of needing medical treatment should evacuate early before the forecast storm commences; people whose houses are located on land beyond the floodplain should prepare for a day or two's isolation; and people with dwellings in the floodplain should enact their family plan (likely involving early evacuation, contra existing behaviours – **Table 15**), prepared in advance of flooding and based on flood intelligence specific to each property.

In the long-term, Council could strengthen its planning and development controls to proscribe residential development in Precinct 4, and to ensure that any future houses in the floodplain provide for safe evacuation to higher ground or on-site refuge above the PMF. (This may require an application for the granting of 'exceptional circumstances' from the Department of Planning and Environment).

Wyong west of Pacific Highway

The 'Wyong west' sector extends between the Pacific Motorway and the Pacific Highway. It includes houses in the main urban area of Wyong fronting the Wyong River, as well as houses along Alison Road west of Porters Creek bridge. Relatively few dwellings are flooded over floor in the 1% AEP event. All buildings that are inundated above floor level are located along Alison Road, which can be cut at Porters Creek before a formal flood warning is issued.

Provided evacuation commences before flooding, these houses generally have rising road access towards the Pacific Motorway.

The flood height range between the 1% AEP flood level and the PMF level is at a maximum between the Pacific Motorway and Pacific Highway, reaching about 3.75m at some houses along Alison Road west of Porters Creek. As a consequence, the hydraulic hazard in the PMF is high, reaching H5 at 25 dwellings and H6 at eight dwellings. This degree of hazard could threaten building integrity, making it unsafe for on-site refuge, even if floor space above the PMF were available.

For houses in this sector located west of Porters Creek, the recommended emergency management strategy is evacuation (**Table 15**), either eastwards towards Wyong if the route is open or westwards towards the Motorway. For houses in this sector located east of Porters Creek, local evacuation to high ground appears to be possible from most sites, although the inundation of the low-set entry level at some unit blocks requires the early evacuation of residents there.

In the long-term, consideration might be given to redevelopment with planning controls that improves the safety of on-site refuge as a measure of last resort (e.g., structural stability during the PMF and a location within the building above the level of the PMF). (This may require an application for the granting of 'exceptional circumstances' from the Department of Planning and Environment).

Wyong east of Pacific Highway

The 'Wyong east' sector extends from the Pacific Highway to the eastern end of McDonagh Road. A large number of dwellings would be flooded above floor level in the 1% AEP event, but not to depths-velocities expected to threaten the structural integrity of standard buildings, and a short window should be available for people's evacuation.

In the PMF about 400 dwellings are estimated to be flooded above floor level, and H5 hazard conditions would be experienced at about half of these, indicative of the likelihood of structural damage or even failure. In such a fast-rising flood, roads could be cut before a formal flood warning is issued.

The recommended emergency management strategy for houses in this sector is evacuation to centres in Wyong. As noted in **Table 15**, at least 2 hours of warning time is expected to be available during the 1% AEP Wyong River flood before access is lost. However, an upgraded flood warning system could be considered to provide additional flood warning time and maximise the opportunities to evacuate before access is cut. Additional information describing upgrades that could be completed to the existing flood warning system is provided in Section 9.3.1.

Kooindah Waters Estate, Wyong

Kooindah Waters estate is accessed via Pollock Avenue. It contains 105 dwellings at the time of the aerial photography (2014) used for the damages assessment. None of these would be flooded over floor in events up to and including the 0.5% AEP flood, but all are estimated to be flooded over floor (to a maximum depth of 1.2m) in the PMF. Nevertheless, none of these would be subject to such hazardous flooding conditions as to threaten their structural integrity, 44 have a second storey, and the maximum depths suggest that people who fail to evacuate before the flood might survive until rescued (assuming mobile adults, based on depths in **Plate 8**).

Tacoma

Tacoma sector includes an estimated 78 dwellings subject to above floor flooding in the 1% AEP event. Fortunately, some warning time may be available for evacuation prior to the loss of evacuation routes in this design event.

In the PMF, almost all dwellings on the floodplain would be flooded above floor level, about 18 would be subject to H5 hazard conditions (these are mainly located along Wolseley Avenue west of Hillcrest Avenue) and roads could be cut before a formal flood warning is issued.

The recommended emergency management strategy in this sector is <u>evacuation</u> to Wyong or Tacoma Public School before roads are cut. On-site refuge may be tolerable for the 58% of dwellings not located in H5 or H6 (PMF) areas, and which have available floor areas (including upper levels) limiting PMF depths over floor (**Table 15**). However, the significant period of isolation is noted (1–1½ days from Wyong River flooding, but potentially longer if affected by flooding from Tuggerah Lake, and with a loss of sewerage service), which may demand rescue or resupply from the emergency services.

In the long-term, Council could strengthen its planning and development controls to ensure that for redeveloped houses on the floodplain, evacuation to higher ground or on-site refuge above the PMF can be achieved. (This may require an application for the granting of ‘exceptional circumstances’ from the Department of Planning and Environment).

Mardi Rural Residential

The ‘Mardi rural’ sector includes rural residential properties along Old Maitland Road, Collies Lane, McPherson Road (including Wyong Aged Care Facility) and Mardi Road. Even in the 1% AEP event, this area has a significant flood risk, with 27 dwellings flooded above floor and with evacuation routes likely to be flooded even before a formal flood warning is issued. This means that evacuation would need to commence based on another trigger such as issuance of a Flood Watch or Severe Weather Warning. But this could be unsustainable socially if residents evacuate in response to those triggers but serious flooding fails to eventuate in Mardi, which is possible. People failing to evacuate could be isolated for about a day in the 1% AEP event.

Of particular concern for these properties is the high hydraulic hazard experienced at most dwellings in this area in the PMF, which could threaten building integrity as well as make it unsafe to seek on-site refuge. And this event provides even more of a warning time deficit because the floodwater would rise very rapidly.

On-site refuge might be tolerable for some properties in the 1% AEP flood, but the flood conditions would render this very unsafe in a PMF. During a rising flood it is difficult to know how large a flood will be. In the short-term, <u>early evacuation</u> of all flood prone dwellings is necessary (**Table 15**), perhaps better informed through linkages to an upstream gauge (e.g., Yarramalong).

In the long-term, consideration might be given to voluntary purchase of some properties, or redevelopment with planning controls that improves the safety of on-site refuge as a measure of last resort (e.g., structural stability during the PMF and a location within the building above the level of the PMF). (This may require an application for the granting of 'exceptional circumstances' from the Department of Planning and Environment).

Mardi Urban

The 'Mardi urban' sector includes land in Mardi zoned for residential use. Its flood exposure is relatively modest, with no dwellings anticipated to flood over floor in the 1% AEP event, and access via Woodbury Park Drive to Wyong Road in that event is subject to negligible disruption by floodwaters from Mardi Creek.

In the PMF, a large number of houses on the eastern side of the suburb would be flooded over floor, though not to depths and velocities expected to threaten dwelling integrity. Access to the suburb would be lost very early in such a flood and would continue for 21 hours at Woodbury Park Drive near Wyong Road.

It may be difficult to persuade residents from this area to evacuate early given they are only flooded over floor in events rarer than the 0.5% AEP (although, surprisingly, about half the respondents to the community questionnaire from Mardi indicated they would evacuate – **Table 15**). And in a PMF, only eight single storey houses are estimated to be flooded over floor to depths greater than 1.2m (maximum 1.4m), which suggests that, in general, <u>on-site refuge</u> may be a tolerable risk. Establishing a local evacuation centre at Woodbury Park community centre could cater for people from flooded residences.

Tuggerah Straight Industrial

The Tuggerah Straight industrial area contains about 238 industrial buildings, 64 of which are flooded above floor in the 1% AEP event and 210 in the PMF. In the PMF, 68 are subject to H5 hazard conditions and seven to H6 hazard conditions, which could threaten buildings' structural integrity. Some warning time (up to 6.5 hours) could be available for the evacuation of assets and personnel towards the Pacific Highway in the 1% AEP event, but not in the PMF.

With very few exceptions, the appropriate emergency management response for businesses in this area is <u>evacuation</u>, which is consistent with current behaviours as assessed from questionnaire returns **(Table 15**). But the setting of evacuation triggers will need to be considered by each business, reflecting the time required and resources available to evacuate or raise their assets.

Tuggerah Residential

Relatively few houses are located in Tuggerah, mostly in Lake Road. Only two of these, located at the eastern end of Lake Road, are estimated to be flooded over floor in the 1% AEP event, and in this event, these have a relatively long time before access is cut, which should allow time for evacuation.

In the PMF, 12 houses would be flooded over floor, including four single-storey houses to depths (>1.2m) that would oblige the residents to evacuate. Given the very rapid rise of such a flood, which would cut egress early, it is important that the risk exposure of these houses be explained to the residents in attempt to persuade them of the need for early evacuation.

Ideally in the long-term, the houses located in this area would be displaced by commercial and industrial uses more in keeping with the area's current zoning for Business Development or Light Industrial. A benefit of this would be to reduce risk to life in this area and free NSW SES resources to assist elsewhere.

South Tacoma

The South Tacoma sector includes 97 dwellings, 53 of which are subject to above floor flooding in the 1% AEP event. Evacuation in advance of flooding is difficult because South Tacoma Road is flooded at ~1.2m AHD as it passes under the Pacific Highway and railway bridges. Even though the Bureau provides six hours' warning of minor floods, egress could still be lost 3½ hours before the warning is issued.

An alternative evacuation route may be available from South Tacoma Road to Lake Road via the Pioneer Dairy site (**Plate 12**). Although it is far from an ideal route, and is likely to require considerable assessment and upgrades to make it suitable for use (refer Section 9.3.2), it does offer greater immunity against flooding. Unlike the South Tacoma Road route under the Pacific Highway and railway bridges, it is not expected to be cut in the 20% AEP flood, and is modelled to be cut about 10 hours later than the standard route in the 1% AEP event. It would provide negligible additional evacuation time in the PMF.

Even if a superior flood evacuation route could be fashioned, however, current resident behaviours are strongly in favour of 'sitting it out' at their houses for a few days (**Table 15**). And for most dwellings in South Tacoma, their decisions may not have catastrophic consequences, since even in the PMF, 10 houses are not flooded over floor, 32 are two storeys where a refuge above the floodwaters should be available, others are flooded to depths less than 0.8m, and none are subject to H5 or H6 conditions (**Table 15**). The balance of houses, however, are manifestly not suitable for on-site refuge, so for these, very early evacuation to Tuggerah/Wyong is recommended. And even houses where on-site refuge might be tolerable, based only on the limited logical expressions described earlier, require assessments of structural integrity to ensure they would not become buoyant during a flood. The likely loss of sewerage and water also commends early evacuation. Education and the provision of house-specific hazard information could promote people's willingness to evacuate early. The reality however, is that people may not evacuate in time, so a 'Plan B' could be to take refuge in neighbours' houses that do provide floor space above the PMF.

In the long-term, Council could strengthen its planning and development controls to ensure that as houses in South Tacoma are redeveloped, more and more of the housing stock provides for on-site refuge above the PMF as a 'Plan B' should they fail to evacuate in time. (This may require an application for the granting of 'exceptional circumstances' from the Department of Planning and Environment).

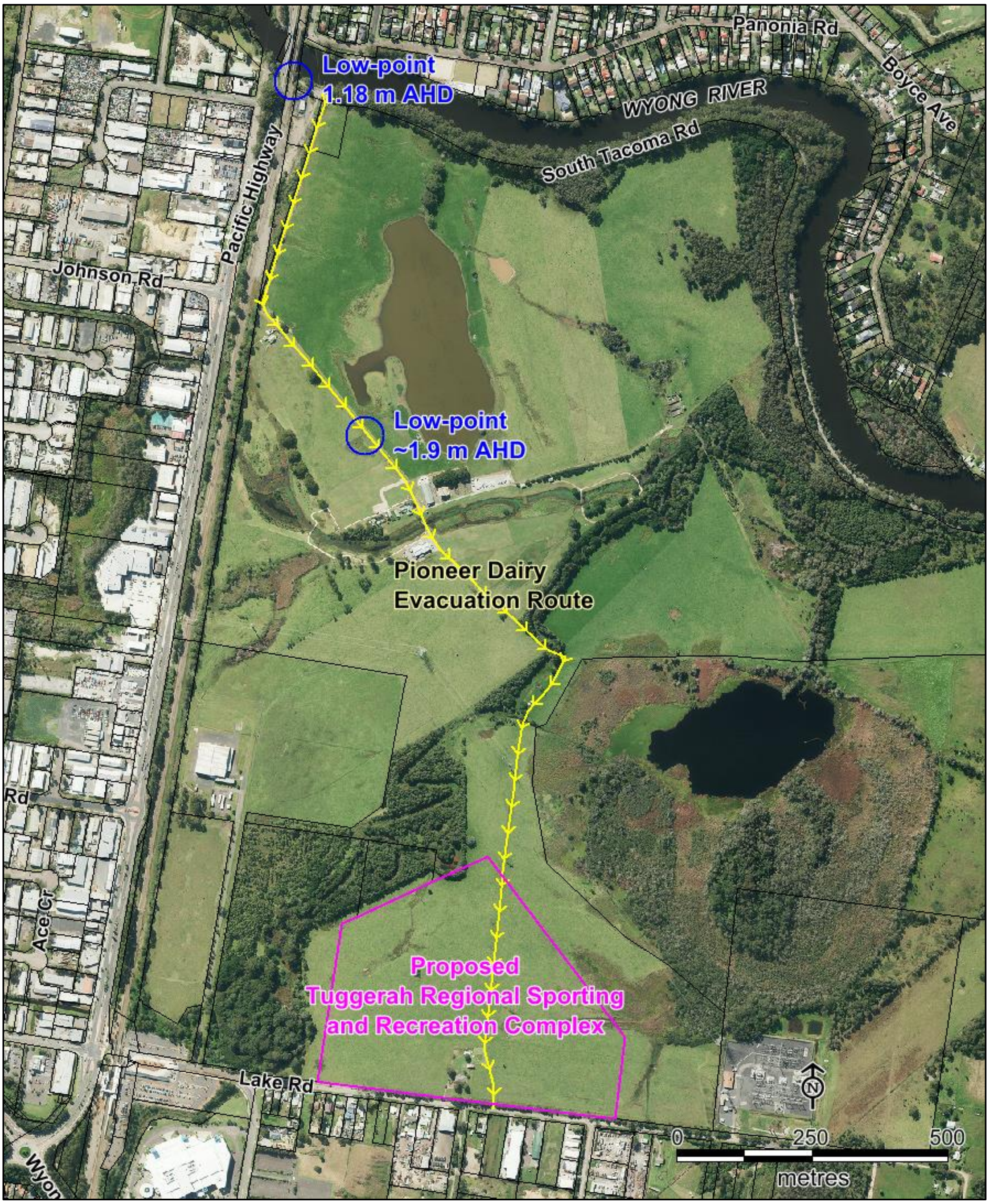


Plate 12 Potential Pioneer Dairy Flood Evacuation Route

Summary

The ideal emergency response strategy for much of the floodplain is early evacuation. But changing a culture of 'sitting it out' may be very difficult, especially to manage the risk of extreme events that are beyond community experience and memory. Council and the SES may need to assign appropriate resources, on an annual basis, for flood education in these areas to promote 'culture change'.

The residual risk could be reduced for places like South Tacoma which loses access early and is not subject to H5 or H6 conditions, by requiring safe PMF refuges (typically just a 2-storey brick dwelling) as redevelopment occurs. Although not ideal, unless either residential development can be removed from places like the 'Mardi rural' sector or the culture change to one of very early evacuation, this risk could be reduced by requiring a PMF refuge able to withstand H5 conditions in the PMF (doubtful this could be made safe in H6 areas) as redevelopment occurs.

6 Options for Managing the Flood Risk

6.1 General

As outlined in Section 3, a number of existing properties within the Wyong River catchment are predicted to be exposed to a significant flood risk and/or significant financial impacts during floods within the catchment. Accordingly, the following chapters outline options that could be potentially implemented to build upon current emergency response protocols to better manage this flood risk.

6.2 Potential Options for Managing the Flooding Risk

6.2.1 Types of Options

Options for managing the flood risk can be broadly grouped into one of the following categories:

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across flood liable areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk. Flood Modification Options are discussed in Section 7.
- **Property Modification Options**: refers to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties is typically used to manage existing flood risk while planning measures (e.g., land use/development controls) are employed to manage future flood risk. Property Modification Options are discussed in Section 8.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Response modification measures are the key measures employed to manage the continuing flood risk. Response Modification Options are discussed in Section 9.

6.2.2 Options Considered as Part of Current Study

An initial list of potential flood risk management options was prepared for consideration by Council. The risk management measures were developed based upon consideration of the following factors:

- Location of high flood risk / high flood damage properties
- Recommendations in previous reports
- Council recommendations
- Community recommendations

The list of options that was initially compiled is summarised in **Table 16**.

A qualitative assessment of each option was completed to provide an initial assessment of the potential feasibility of each option and to determine which measures showed merit for perusal as part of the detailed option assessment. The adopted evaluation criteria / scoring system is summarised in **Table 17** and the outcomes of the assessment are provided in **Table 18**.

Table 16 Initial List of Options Considered for Managing the Flood Risk

Flood Modification Options	Property Modification Options	Response Modification Options
Installation of flood gates near Anzac Road	Voluntary purchase of select properties	Flood education
Construction of Mardi Creek detention basins upstream of Pacific Motorway	Raising of select residential properties	Upgrade flood warning system
Upgrade of railway culverts draining Mardi Creek	Flood proofing of select properties	Installation of barriers at roadway low points to prevent vehicular access during floods
Installation of debris control structures along Mardi Creek	Updates to flood risk management DCP	Local flood plan and flood intelligence card updates
Mardi Creek relief floodway between Pacific Highway and Railway		Develop template for private flood plans for Tuggerah Industrial area
Mardi Creek channel modifications downstream of railway		Improve flood access to/from South Tacoma
Regular maintenance / clearing of vegetation across the lower floodplain		Improve flood access along Yarramalong Road
Earthworks south of South Tacoma to provide relief floodway for Wyong River		Bridge between Tacoma and South Tacoma
Levee at northern end of Tuggerah Industrial area		Improve flood access along McPherson Road
Levee around South Tacoma		
South Wyong Levee		
Tuggerah Lake entrance modifications		
Wyong River dredging		
Increase Pacific Highway / Railway bridge opening		
Pacific Highway /Pacific Motorway debris control structures		
Main northern railway culvert upgrades		
Install floodgates on pipes draining to the Wyong River		
Footbridge from Wyong Aged Care facility		
Yarramalong levee		
Wyong Aged Care levee		
Meander Village levee		

Table 17 Adopted Evaluation Criteria and Scoring System for Qualitative Assessment of Flood Risk Management Options

Score:	Change in Flood Levels / Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance
-2	Significant increases in levels / extents	Significant disbenefit to emergency services	Significant technical challenges	Significant impacts	BCR <0.5	Majority of community opposed
-1	Minor increases in levels / extents	Slight disbenefit to emergency services	Some technical challenges	Minor impacts	0.5 < BCR < 0.8	Some opposed
0	Negligible changes in levels / extents	No impact on emergency services	Minor technical challenges	No impacts	0.8 < BCR < 1.2	Neutral
1	Minor decreases in levels / extents	Slight benefit to emergency services	Negligible technical challenges	Some benefits	1.2 < BCR < 1.5	Some support
2	Significant decreases in levels / extents	Significant benefit to emergency services	No technical challenges	Significant benefits	BCR > 1.5	Majority of community support

Table 18 Qualitative Assessment of Initial List of Flood Risk Management Options

Potential Measures		Evaluation Criteria / Score						
		Change in Flood Levels / Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Flood Modifications Option	Anzac Road Flood Gates	1	1	1	0	0	2	**5**
	Mardi Creek debris control structures	0	1	1	0	0	1	**3**
	Lower floodplain maintenance / clearing	0	0	1	1	0	1	**3**
	Pacific Highway / Motorway debris control structures	0	1	1	0	0	0	**2**
	Mardi Creek Detention Basin	1	1	1	-1	-1	1	**2**
	Mardi Creek floodway	0	1	-1	-1	0	1	**0**
	South Tacoma relief floodway	1	0	0	-2	0	2	**1**
	Footbridge from Wyong Aged Care facility	0	1	0	-1	-1	0	**-1**

Potential Measures		Change in Flood Levels / Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
		Evaluation Criteria / Score						
	Upgrade of Mardi Creek Culverts	0	0	-1	0	-1	1	**-1**
	Main northern railway culvert upgrades	1	1	-1	0	-1	1	**1**
	Floodgates on drainage pipes to Wyong River	1	0	0	0	-1	1	**1**
	Meander Village levee	1	-1	-1	-1	-1	1	**-2**
	Increase Pacific Highway / Railway bridge opening	1	1	-2	-1	-2	1	**-2**
	North Tuggerah industrial levee	-1	1	-1	-1	-1	1	**-2**
	Tuggerah Lake entrance modifications	0	0	-1	-2	-1	2	**-2**
	Wyong River dredging	0	0	-1	-2	-2	2	**-3**
	Mardi Creek Channel Modifications	0	0	-1	-2	-1	1	**-3**
	South Wyong levee	0	1	-1	-1	-1	-1	**-3**
	Wyong Aged Care levee	-1	-1	-1	-1	0	1	**-3**
	South Tacoma levee	1	-1	-2	-1	-1	-2	**-6**
Property Modification	Updates to DCP	0	1	2	0	2	0	**5**
	Voluntary flood proofing	0	0	1	0	1	1	**3**
	Voluntary house raising	0	-1	1	0	1	0	**1**
	Voluntary house purchase	0	1	1	1	-2	1	**2**

Potential Measures		Evaluation Criteria / Score						
		Change in Flood Levels / Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Response Modification Options	Flood Education	0	2	2	0	2	1	**7**
	Upgrade flood warning system	0	2	2	0	2	1	**7**
	Install flood barriers at road overtopping points	0	2	1	0	1	1	**5**
	Local flood plan updates	0	1	2	0	1	1	**5**
	Private flood plans for Tuggerah industrial area	0	1	1	0	-1	2	**3**
	Improve flood access along McPherson Road	0	1	1	0	-1	1	**2**
	Improve flood access to/from South Tacoma	0	1	1	-1	-1	1	**1**
	Improve flood access along Yarramalong Road	0	2	0	0	-2	1	**1**
	Bridge between Tacoma and South Tacoma	0	1	0	0	-2	1	**0**

As shown in **Table 18** each measure was evacuated against six criteria. The expected performance of each measure against each criterion was scored between -2 (significant negative impact) and +2 (significant positive impact). Each cell in **Table 18** is also colour coded with shades of either green indicating beneficial impacts or shades of orange/red indicating a negative impact. Those with negligible positive/negative impacts are not shaded.

The qualitative scores were subsequently summed to provide an overall score for each option and enable a means of comparing the different options as well as provide an initial assessment of whether specific options would provide a net positive outcome. The options listed in **Table 18** are grouped according to whether they are a flood modification, property modification or response modification option and are then sorted from highest overall score to lowest overall score.

6.3 Flood Risk Management Options Assessed in Detail

Based upon the qualitative assessment presented in Section 6.3.2, the options listed in **Table 19** were selected for detailed assessment.

Table 19 Options Adopted for Detailed Investigations

Flood Modification Options	Property Modification Options	Response Modification Options
Mardi Creek Detention Basin	Updates to DCP	Flood Education
Anzac Road Flood Gates	Voluntary flood proofing	Upgrade flood warning system
Mardi Creek floodway	Voluntary house raising	Install flood gates at road overtopping points
South Tacoma relief floodway	Voluntary house purchase of select properties	Local flood plan updates
Lower floodplain maintenance / clearing		Private flood plans for Tuggerah industrial area
Mardi Creek debris control structures		Improve flood access for South Tacoma
Pacific Highway / Pacific Motorway debris control structures		Improve flood access along Yarramalong Road
Tuggerah Lake Entrance dredging		Improve flood access along McPherson Road
Wyong River dredging		
Main northern railway culvert upgrades		
Floodgates on drainage pipes to Wyong River		

6.4 Options Assessment Approach

Each flood risk management option will generally be a compromise as it is unlikely that an option will provide only benefits (e.g., there may be an adverse environmental impact or significant costs associated with the implementation of the option). In general, if the advantages associated with implementing the option outweigh the disadvantages, it will afford a net positive outcome and may be considered viable for future implementation. Therefore, each option was evaluated against a range of criteria to provide an initial appraisal of the potential feasibility of each option.

Each flood and property modification option was evaluated against the following criteria, where sufficient information was available:

- Hydraulic impacts
- Change in number of buildings inundated above floor level
- Financial feasibility
- Community acceptance
- Environmental impacts
- Emergency responses impacts
- Technical feasibility

Further details on each of these evaluation criteria is presented below. The scoring system that was used to rank each option against these criteria is also provided in **Table 20**.

6.4.1 Hydraulic Impacts

Each mitigation measure will alter the distribution of floodwaters. Although this aims to reduce the extent and depth of inundation across populated areas, it may divert floodwaters elsewhere, thereby increasing the flooding risk across other areas. Therefore, it is important that the potential flood impacts associated with implementing each option is understood.

To assess the hydraulic impact of each flood modification option, the TUFLOW hydraulic model that was used to define existing flood behaviour was updated to include each of the preferred flood modification options. The updated TUFLOW models were then used to re-simulate each of the design floods. The flood level and extent results from the revised simulations were compared against the flood level and inundation extent results from the existing conditions / do nothing scenario to prepare "difference mapping". The difference mapping shows the magnitude and location of changes in flood levels and inundation extents associated with implementation of the option.

6.4.2 Change in Number of Buildings Inundated Above Floor Level

An assessment of the change in the number of buildings subject to above floor inundation during each design flood was also completed for each option. A focus was placed on the change in number of buildings inundated during the 1% AEP flood. However, smaller and larger floods were also considered in the assessment.

6.4.3 Financial Feasibility

A preliminary economic assessment of each flood modification and selected property modification options was completed to assist in determining the financial viability of each option. The assessment was completed by estimating the 'costs' and 'benefits' that could be expected if the option was implemented. This enabled a benefit cost ratio (BCR) to be prepared for each option. A BCR of greater than 1.0 shows that the present value of benefits outweighs the present value of costs of the option and provides an indicator that the option may be financially viable.

From a flooding perspective, economic 'benefits' were quantified as the reduction in flood damage costs if the option is implemented. The benefits of each option were estimated by preparing damage estimates for each design flood event with the option in place and using this information to prepare a revised average annual damage (AAD) estimate. In order for a BCR to be estimated, it is necessary to modify the 'base' AAD estimates (which reflect the average damage that is likely to be incurred in a single year) to a total damage that could be expected to occur over the life of each flood risk management option. Accordingly, the AAD estimates were accumulated over a 50-year period and then discounted to a present-day value by applying a discount rate of 7%.

Cost estimates have also been prepared for each option. The cost estimate includes capital costs as well as ongoing costs (e.g., maintenance) to provide a total life cycle cost for each option. It was assumed that each option has a design life of 50 years for the purposes of establishing the life cycle cost.

The cost estimates were prepared using the best available information. However, precise cost estimates can only be prepared following detailed investigations and once design plans have been prepared. Therefore, the cost estimates presented in this report should be considered approximate only. Nevertheless, they are considered suitable for providing an initial appraisal of the financial viability of each option.

6.4.4 Community Acceptance

Floodplain risk management options do have the potential to impact on the broader community in both beneficial and adverse ways. For example, a levee may reduce the potential for inundation of a property but may also remove water views. Therefore, the community's attitudes towards each option can have a significant impact on the viability of an option.

A community questionnaire was distributed to approximately 2,400 residents and business owners within the catchment. The questionnaire provided the community with a preliminary list of flood risk management options that were being considered as part of the study and sought feedback from the community regarding each of these options (i.e., whether they opposed or supported the option). A summary of the responses to the questionnaire are included in the discussion on each option to gain an understanding of the community's attitudes towards each option.

6.4.5 Environmental Impacts

Any flood risk management option that involves structural works on the floodplain has the potential to impact on local flora and/or fauna. At the same time, some options may provide an opportunity to improve the local environment (e.g., some options may reduce gross pollutants reaching downstream waterways). Therefore, the potential environmental impact was considered as part of the evaluation of each structural option.

6.4.6 Emergency Response Impacts

Emergency response is arguably one of the most important measures for managing the continuing flood risk across any catchment, particularly during very large floods where flood modification options may not be effective. Therefore, the potential for each option to impact on current emergency response processes was considered as part of the assessment of each option.

6.4.7 Technical Feasibility

If a structural option is proposed, it needs to be physically possible to construct the option giving consideration to the option itself as well as any local constraints. Therefore, an assessment of any technical impediments was completed for each option to determine if there would be any "show stoppers" that may render the option impractical.

Table 20 Adopted Evaluation Criteria and Scoring System for Assessment of Flood Risk Management Options

Criteria	Ranking/Score				
	--	-	-N-	+	++
Hydraulic Impacts	Significant increases in levels (>0.1m) / extents	Minor increases in levels (<0.1m) / extents	Negligible changes in levels / extents	Minor decreases in levels (<0.1m) / extents	Significant decreases in levels (>0.1m) / extents
Change in Number of Inundated Buildings during 1% AEP flood	Significant increase in number of inundated buildings (>10)	Small increase in number of inundated buildings (<10)	No Change in number of inundated buildings	Small decrease in number of inundated buildings (<10)	Significant decrease in number of inundated buildings (>10)
Financial Feasibility	BCR <0.5 and / or high capital / ongoing costs	0.5 < BCR < 0.8	0.8 < BCR < 1.0	1.0 < BCR < 1.2	BCR > 1.2 and / or low capital / ongoing costs
Community Acceptance	Majority of community opposed	Some opposed	Neutral	Some community support	Majority of community support
Environmental Impacts	Significant negative environmental impact	Small negative environmental impact	Negligible environmental impacts	Small opportunity for environmental enhancement	Significant opportunity for environmental enhancement
Emergency Response Impacts	Significant adverse impact on emergency response	Small adverse impact on emergency response	Negligible impact on emergency response	Small improvement to emergency response	Significant improvement to emergency response
Technical Feasibility	Significant technical challenges	Moderate technical challenges	Minor technical challenges	Negligible technical challenges	No technical challenges

6.5 Summary

The options that were considered for managing the existing, future and residual flood risk are discussed in the following chapters:

- Flood Modification Options: Chapter 7.
- Property Modification Options: Chapter 8.
- Response Modification Options: Chapter 9.

7 FLOOD MODIFICATION OPTIONS

7.1 Introduction

Flood modification options are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across developed floodplain areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk.

Flood modification options considered as part of the study included:

- Detention Basins
- Levees
- Channel Modifications
- Drainage Upgrades

Further discussion on the flood modification options that were considered to assist in managing the existing flood risk are presented in the following sections.

7.2 Detention Basins

7.2.1 General

Detention basins are structures that reduce downstream discharges by temporarily storing flows from the upstream catchment. They can be implemented on small scales (e.g., for individual development sites) through to large scales, where they approximate small dams.

In addition to providing flow attenuation benefits, detention basins can also be designed to incorporate water quality improvement features (e.g., constructed wetland). As such, a well-designed basin can afford environmental benefits, improved visual amenity as well as recreational facilities for the community (e.g., sporting fields). At the same time, the basin outlet should be carefully designed so that 'environmental flows' are met and the basin does not adversely impact on downstream flora and fauna.

Some basins can be particularly large structures. In such instances, they may be considered as dams and would be subject to the same safety standards. This may include the need to quantify the potential impacts associated with failure of the detention basin on downstream properties and infrastructure.

Basins are often incorporated into areas of open space. As such, areas in the immediate vicinity of basins can include sporting fields, playgrounds and recreation areas. Accordingly, users of the facilities (e.g., children) may be particularly vulnerable during any floods or should the basin fail. This emphasises the need for ensuring the basin is appropriately designed to cater for a range of different rainfall events (e.g., different temporal patterns & runoff volumes) and maintained to ensure it does not fail (Australian Emergency Management Institute, 2013).

Basins often require a significant area of land to provide a sufficient storage volume to attenuate flood flows. As a result, the acquisition of land from a space and cost standpoint can be significant.

Basins may also need to provide a significant storage depth, which can potentially present a hazard to children as well as adults. In such cases, fencing may be required to mitigate the potential for drowning. In addition, significant storage depths can increase the potential impacts on adjoining properties. If these impacts are too significant, these properties may also need to be acquired or protected, further increasing the capital costs.

Basins will rarely be designed to contain the PMF. Therefore, the basin should be designed to include an appropriate spillway that safely discharges flows up to the PMF and the downstream impacts associated with spillway overtopping must be carefully considered. In this regard, it is important to acknowledge that a residual risk remains, which will typically be managed through appropriate emergency response plans and community education activities (particularly for those properties located immediately downstream of the basin, where warning time may be negligible).

7.2.2 Previous Investigations

Detention basins have been previously considered at the following locations as part of past studies:

- Mardi Creek (south arm): considered viable but put “on hold” pending the expansion of Westfield Tuggerah.
- Mardi Creek (north arm) upstream of the M1 Pacific Motorway: a “pseudo” basin has been previously suggested by reducing the size of the existing culverts draining beneath the motorway. This was shown to produce reductions in flood levels across the Tuggerah Straight industrial area. However, this proposal was opposed by the RTA/RMS as the motorway embankment was not designed to function as a basin wall.
- Lowering the water level within Mardi Dam to provide flood storage capacity: this was determined to provide minimal benefits as the upstream catchment area is relatively small.

Basins across the upper Wyong River catchment have also been considered as part of past studies, but the size of the basin necessary to afford any significant benefits was considered to be prohibitively large/expensive. Moreover, the environmental and social impacts would be significant (e.g., significant areas of “sterilised land” upstream of each basin). Therefore, flood detention basins for the Wyong River are not considered to be a feasible flood risk mitigation option and were not considered as part of the current study.

7.2.3 Mardi Creek Detention Basin

As noted above, a basin upstream of the Pacific Motorway was previously determined to afford flood benefits across the Tuggerah straight industrial area. However, the RMS (then RTA) did not support the use of the Pacific Motorway as a pseudo detention basin wall. Therefore, an alternate basin configuration was investigated as part of the current study that does not make use of the motorway embankment. The potential location of the detention basin is shown in **Figure B1**, which is enclosed in **Map Set B**. As shown in **Figure B1**, the concept design for the detention basin incorporates:

- Dedicated basin wall with top elevation of 15.9 mAHD and 25-metre-wide spillway at 15.4 mAHD
- 0.45 metre diameter outlet pipe
- GPT to assist in preventing blockage of outlet
- New access road from water treatment plant to allow vehicular access for maintenance and cleaning of GPT and basin outlet

As shown in **Figure B1**, the option also takes advantage of potential flood storage capacity within the existing Mardi Dam. For the assessment, it was assumed that the full supply level of Mardi Dam would remain at or below 39.66 mAHD which would make approximately 10% of the total dam capacity available for flood storage.

A cost estimate was prepared for the basin and is included in **Appendix D**. This determined that the detention basin would cost approximately $440,000 to implement and maintain. This cost estimate includes allowances for regular maintenance of the GPT as well as replacement of the GPT after 25 years.

The site of the proposed basin is located on Council owned land between Old Maitland Road and the Pacific Motorway. The existing site is generally vegetated and includes Woollybut and Melaleuca, which would need to be removed. Therefore, implementation of this option has the potential to reduce vegetation as well as habitat for local fauna. Although there is no evidence of endangered/protected flora or fauna within the basin footprint, this would need to be confirmed.

It is noted that an Aboriginal Heritage site (Site ID: 45-3-1108 – Open Camp Site) is located near to, but outside of the proposed basin footprint. Although not contained within the footprint of the proposed basin, it is likely that an Aboriginal Heritage Assessment (or similar) will need to be carried out and care will need to be exercised during construction to ensure this site is not disturbed.

The hydraulic benefits of the detention basin were quantified by including the basin in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the basin in place are provided for the 20% AEP and 1% AEP events in **Figures B2** and **B3** respectively.

Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the basin. The difference mapping is presented in **Figures B4** and **B5** for the 20% AEP and 1% AEP events respectively.

The flood level difference mapping shows that the detention basin will reduce existing flood levels and extents along Mardi Creek as well as adjoining floodplain areas during both the 20% AEP and 1% AEP floods. In general, the flood level reductions are within close proximity to Mardi Creek and are typically around 0.1 metres in the vicinity of Anzac Road and Ace Crescent.

The results of the revised flood simulations indicate that the basin would not reduce the number of buildings subject to above floor inundation during the 20% AEP event. However, during the 1% AEP event, four fewer properties in the Tuggerah industrial area are predicted to be inundated above floor level. A review of the results of all design flood simulations indicate the number of properties subject to above floor inundation is predicted to reduce during all design floods in excess of the 20% AEP events (e.g., 3 fewer properties during 5% AEP and 4 fewer properties during the PMF).

The potential financial benefit associated with implementation of the Mardi Creek detention basin was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin in place. The outcomes of the revised damages assessment estimates that the detention basin would reduce flood damage costs by $770,000 over the 50-year design life of the basin. This yielded a preliminary benefit-cost ratio of 1.75. Accordingly, the financial benefits of implementing the basin outweigh the costs.

This option was generally supported by the community (over 50% of the community supported the option and only 6% were opposed). In addition, the reduced inundation depths and extents across roadways within the Tuggerah industrial area may afford some improvement to existing emergency response. However, floodwater depths are still predicted to exceed 0.5 metres during the 20% AEP event along Anzac Road and Ace Crescent indicating vehicular access will not be possible along these roadways at the peak of most floods even with the basin in place.

Overall, the Mardi Creek detention basin appears to afford some significant benefits. However, further investigations are recommended to confirm the feasibility of this option. This should include a flora/fauna impact assessment and Aboriginal Heritage Assessment.

Table 21 Evaluation Outcomes for Mardi Creek Detention Basin

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	++	Beneficial reductions in flood levels and extents across the southern section of the Tuggerah Industrial area during large and smaller floods
Inundated Buildings	+	Four fewer buildings inundated above floor level during 1% AEP event
Financial Feasibility	++	High BCR and relatively low capital cost. Relatively low ongoing costs.
Community Acceptance	+	Over 50% of the community indicated support for this option and only 6% were against
Environmental Impacts	-	Will involve removal of some vegetation to construct and implement. May be opportunities to reinstate vegetation after construction
Emergency Response	+	Reduced inundation depths across some Tuggerah Industrial area roadways
Technical Feasibility	-N-	No substantial technical limitations identified.

Recommendation: Further detailed feasibility assessment recommended.

7.3 Levees

7.3.1 General

Levees are man-made structures that aim to prevent inundation of floodplain communities by providing a physical barrier between the waterway and the community. The barrier can take the form of a permanent earthen embankment/wall or a temporary structure that can be assembled/disassembled before/after a flood. In general, temporary levees are only suitable when there is sufficient warning time available to erect the levee.

A levee will be designed to provide a specific level of protection (e.g., protection from a 1% AEP flood). A freeboard is also typically included in the design height of the levee to account for uncertainties in the estimation of the design flood level as well as construction tolerances (e.g., settlement).

The construction of a levee (regardless of the height) will generally provide a reduction in the existing flood risk. However, there are a number of other factors that need to be carefully considered when evaluating the suitability of a levee to reduce the flood risk, including:

- Levees provide a physical barrier to the flow of water. Although this is beneficial in terms of reducing the potential for inundation from major watercourses, it can also provide a physical barrier to local overland flow. Accordingly, care needs to be exercised to ensure local overland flooding is not exacerbated (e.g., through installation of pumps or flood gates).
- Levees can also prevent flood flows from reaching existing environmental areas (e.g., wetlands). This, in turn, may adversely impact on flora and fauna living in these environmental areas. Accordingly, the potential environmental impacts of any levee needs to be carefully considered, particularly if endangered species are at risk.
- There is potential for water that is displaced by the levee to be diverted across other floodplain communities, particularly if the levee is located in a major conveyance area.
- Levees typically require a significant up-front capital investment. Funds must also be available for the ongoing maintenance of the levee to ensure it fulfils its design intent.
- It is typically not possible to design a levee to provide protection during all floods up to and including the Probable Maximum Flood (PMF). As a result, many levees will be overtopped during their design life. Therefore, it is important that the levee is designed to withstand the potential for overtopping without failure and appropriate emergency response measures are in place for those located behind the levee.
- Levees are typically highly visible, which can be reassuring for the population located behind the levee. At the same time, the presence of a levee can also provide a false sense of security and may lead to complacency by those who it protects, which can arguably increase the continuing flood risk. It may also provide a significant visual obtrusion and remove water views.

7.3.2 Previous Investigations

Levees have been considered at various locations across the catchment as part of previous studies. This includes:

- Levee along the northern edge of the Tuggerah straight industrial area;

- Levee along the northern bank of Mardi Creek to protect southern section of Tuggerah straight industrial area;
- Levee along the northern edge of the Wyong River downstream of the railway line; and,
- Levee to prevent flows from Ourimbah Creek "spilling" near the railway line into the Tuggerah Creek system.

In general, the levees that were investigated as part of the previous studies were not considered viable as they generated unacceptable impacts on flood behaviour across areas outside of the levee (e.g., the Tuggerah straight industrial levee increased water levels across the Wyong aged care facility). Therefore, they have not been investigated further as part of the current study.

7.3.3 Anzac Road Levee and Flood Gates

As discussed in Section 3, the Tuggerah industrial area is predicted to be subject to frequent inundation from Mardi Creek as well as the Wyong River. In particular, Anzac Road is low lying and susceptible to flooding from "backwater" inundation from Mardi Creek. Flooding of this area occurs frequently and has adversely impacted on many businesses in the area to the point where some have been forced to close (E. Smith, 2013). Therefore, Council requested that a levee embankment across a "feeder" channel adjoining Anzac Road be investigated to reduce the potential for floodwaters "backing up" from the Mardi Creek channel and inundating properties located near the McDonalds and Hungry Jack's restaurants.

The design concept for the levee is shown in **Figure C1**, which is enclosed in **Map Set C**. As shown in **Figure C1**, the proposal includes a levee embankment across the channel with a gated culvert through the embankment. The gated culvert will allow runoff from Anzac Road to travel north along the channel and into Mardi Creek but will prevent elevated water levels from Mardi Creek from "backing up" through the culvert. The elevation of the adjoining channel embankments will only allow the crest of the levee to be elevated to approximately 4.45 mAHD (i.e., providing protection during events up to and including the 20% AEP event).

It is expected that the levee and gated culvert would have a capital cost of about $122,000. Regular maintenance as well as replacement of the flood gates after 25 years would add an additional $27,000 to the life cycle cost. Overall, it is expected that this option will cost about $150,000 to fully implement. A detailed breakdown of the cost estimate is provided in **Appendix D**.

The construction of the levee at this location will occur in and adjacent to water. Therefore, the levee will present some construction challenges. There is also potential for acid sulfate soils in the area. However, it is considered that these challenges can be overcome.

Construction of the levee will also necessitate the removal of some vegetation along the existing channel. Although the vegetation is not considered particularly sensitive, there may be a small reduction in habitat. It is suggested that a detailed review of the area be completed to ensure that no endangered species are present before completing any works.

The TUFLOW computer model that was used to define existing flood behaviour across the Wyong River catchment was updated to include the levee and gated culvert. The updated

TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures C2** and **C3** for the 20% AEP and 1% AEP flood respectively. The difference maps for the 20% and 1% AEP floods are provided in **Figures C4** and **C5**.

Figure C4 shows that the Anzac Road levee and flood gates will prevent inundation of Anzac Road during the 20% AEP flood. Accordingly, significant benefits are predicted during frequent floods.

Figure C5 shows that the levee will not prevent inundation across Anzac Road during larger floods, such as the 1% AEP event. However, it will reduce peak 1% AEP water levels by around 0.1 metres across most of the Anzac Road area. There is predicted to be a small increase in water levels along the main Mardi Creek channel as a result of the water that is being displaced by the levee. However, the magnitude of the increases is only predicted to be about 0.02 metres. No flood level differences were identified in the PMF as the levee is "drowned out" during very large floods.

The results of the revised flood simulations also indicate that the levee would not reduce the number of buildings subject to above floor inundation during the 20% AEP event. However, during the 1% AEP event, two fewer properties in the Tuggerah industrial area are predicted to be inundated above floor level.

A revised damages assessment was also completed based on the results of the revised flood simulations. This determined that implementation of the levee would reduce flood damage costs by approximately $60,000 over the projected life of the levee system (i.e., 50 years). This yields a preliminary BCR of 0.37. Therefore, the costs of implementing the option are predicted to outweigh the reductions in flood damage costs. Nevertheless, the relatively low capital and ongoing costs and the financial benefits of businesses being exposed to less frequent inundation may be sufficient financial evidence to support the option

However, it should be noted that the estimation of flood damages to businesses may not adequately account for the actual damages to businesses as a result of flooding in this area. There are also impacts of flooding on business owners that are not accounted for in the damages, such as nuisance and inconvenience, psychological impacts (e.g, stress), as well as loss of patronage after a business has been closed for a period. Therefore, the BCR for this option could be higher.

This option was also generally supported by the community (over 40% of the community supported the option and only 8% were opposed). In addition, the reduced inundation depths and extents across Anzac Road may afford some improvements to evacuation potential across this area during smaller as well as larger floods.

It is recommended that design plans for the levee are prepared and construction of the levee is pursued.

Recommendation: Recommended for implementation.

Table 22 Evaluation Outcomes for Anzac Road Levee

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Reductions in levels and extents occur across Anzac Road during most events
Inundated Buildings	+	2 less buildings inundated above floor level in 1% AEP event
Financial Feasibility	-	Low capital & ongoing costs are beneficial although the relatively low BCR does reduce financial viability of option.
Community Acceptance	+	Over 40% of the community indicated support for this option and only 8% were against
Environmental Impacts	-	Potential for small impact on flora and any associated fauna
Emergency Response	+	Reduced inundation across Anzac Road
Technical Feasibility	-	Work within and adjacent to water will present some construction challenges

7.4 Channel Modifications

7.4.1 General

Channel modifications refer to alterations that aim to improve the flow carrying capacity of waterways or the creation of new flow paths. This aims to increase the amount of flow that can be carried by the channels, thereby reducing the depth, extent and velocity of flows across the adjoining floodplain. These works may include:

- Removal of vegetation
- Removal of blockages
- Construction of auxiliary floodways
- Dredging

The effectiveness of channel modification works is largely dependent of the local flood and channel characteristics. But in general, channel modification works will be most effective on relatively small, steep streams with dense vegetation and relatively narrow floodplains (NSW Government, 2005).

As channel modification works aim to improve the conveyance of flood flows, there is potential that this may increase downstream flooding problems. The works may also permanently impact or destroy riverine habitat. Therefore, appropriate environmental investigations must be completed to ensure the potential for environmental impacts is quantified. Furthermore, every effort should be made to ensure that a suitable riparian ecosystem is provided post-construction to promote the establishment/re-establishment of flora and fauna. In this regard, concrete channels should be avoided.

To ensure the conveyance capacity of the channel is maintained throughout its design life, it is necessary for continual maintenance of the channel to ensure vegetation does not become overgrown and restrict flow. This can add significantly to the maintenance costs and the overall life cycle costs of these options. Care must also be exercised to ensure that the modifications to the flow carrying capacity of the channel do not adversely impact on upstream or downstream bank and bed stability.

7.4.2 Mardi Creek Relief Floodway

The Mardi Creek relief floodway would aim to provide an additional flow path starting near the Mardi Creek channel east of the Pacific Highway, through the existing railway embankment and re-joining Mardi Creek east of the railway line. The current Mardi Creek alignment would remain active and would convey flows during frequent rainfall events in the catchment. The new floodway would serve as an auxiliary flow path during larger floods.

Key features of the floodway are shown in **Figure D1** in **Map Set D** and includes:

- New 15 m long and 8 m wide open channel between the Pacific Highway and railway line
- Installation of ten 1.5 m diameter culverts through the railway embankment
- New 16 m long and 8 m wide open channel between the eastern side of the railway line and existing Mardi Creek channel

It is expected that the floodway would cost approximately $1.5 million to implement. A detailed breakdown of the cost estimate is provided in **Appendix D**. The majority of this cost is associated with the new railway culverts.

This option will involve disturbing some existing vegetation to facilitate construction of the new channel. But it is anticipated that the new channel would be revegetated upon construction resulting in no significant loss of flora/fauna.

A major challenge associated with this option would be the construction of the culverts beneath the railway line. It is unlikely that the rail line can be shut down for a significant length of time. Therefore, the pipes will likely need to be installed via "jacking" the pipes through the embankment. Although this is not a "show stopper", it does add to the technical challenges and cost associated with implementation of this option.

The TUFLOW computer model that was used to define existing flood behaviour across the Wyong River catchment was updated to include the floodway. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures D2** and **D3** for the 20% AEP and 1% AEP flood. The difference maps for the 20% and 1% AEP floods are provided in **Figures D4** and **D5**.

Figure D4 shows minimal changes in existing flood levels and extents are predicted during the 20% AEP event. This indicates that the existing Mardi Creek channel and railway culverts already have sufficient capacity to convey smaller floods, such as the 20% AEP event.

Figure D5 shows that some more notable differences are predicted during the 1% AEP event. This includes reductions in flood level of around 0.05 m along the western side of the railway line. Reductions in flood levels are also predicted west of the Pacific Highway but they are generally less than 0.02 m.

During the PMF, flood level differences are typically less 0.01 metres across those properties that adjoin Mardi Creek. That is, the floodway is predicted to afford negligible hydraulic benefits during particularly large floods.

The results of the revised flood simulations also indicate that the floodway would not reduce the number of buildings subject to above floor inundation during frequent floods (e.g., 20% AEP event). However, during the 1% AEP event, one fewer property in the Tuggerah Industrial area is predicted to be inundated above floor level and nine fewer would be inundated above floor level during the PMF.

A revised damages assessment was also completed based on the results of the revised simulations. This determined that flood damages could be expected to reduce by $160,000 over the 50-year design life of the floodway. This provides a preliminary BCR of 0.1, which indicates that the financial gains associated with implementation of the floodway do not outweigh the costs.

This option was generally well supported by the community (75% of the community supported the option and only 8% were opposed). Emergency response is predicted to remain largely unchanged as a result of this option.

Overall, the low financial benefits of the floodway make this option difficult to support from an economic perspective. However, it is recommended that Council initiate discussions with Railcorp to gain an understanding of the likelihood of any railway upgrade works planned for this area, and determine opportunities to incorporate flood mitigation works. If Railcorp can contribute to the flood mitigation costs it will significantly improve the financial viability of this option.

Table 23 Evaluation Outcomes for Mardi Creek Relief Floodway

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Small reductions in flood level upstream of railway line during larger mardi Creek floods
Inundated Buildings	+	1 less building inundated above floor level in 1% AEP event
Financial Feasibility	--	BCR<0.5. Feasibility could be improved if Railcorp contributed to funding
Community Acceptance	++	75% of the community indicated support for this option and only 4% were against
Environmental Impacts	-N-	Will require some removal of vegetation to construct. However, this could be largely reinstated post-construction.
Emergency Response	-N-	Small reductions in flood depths across Pacific Highway, but evacuation potential elsewhere largely unchanged.
Technical Feasibility	-	The new culverts beneath the railway line will likely need to be installed via "jacking"

Recommendation: Not recommended for implementation. However, it is recommended discussions be held with Railcorp to confirm likelihood of upgrade works in the area and the opportunity to include flood mitigation works as part of this.

7.4.3 South Tacoma Relief Floodway

A review of the design flood modelling results showed a significant "jump" in water surface elevations across the Wyong River floodplain south of South Tacoma. The elevated water levels at this location appear to be primarily associated with a ridge of higher ground that impedes the path of water travelling from the river towards Tuggerah Lake. The South Tacoma floodway would involve regrading of this floodplain to allow a more streamlined transfer of water between the river and lake via a secondary flow path. The main river would continue to be the primary conveyance area with the floodway only becoming active once the water levels within the river are sufficiently high to overtop South Tacoma Road.

Key features of the floodway are shown in **Figure E1**, which is included in **Map Set E**. As shown in **Figure E1**, the floodway would involve earthworks across a ~250 metre width and ~400 metre length of floodplain. This would involve excavating up to a 1 metre depth of material from the floodplain to provide a floodway that grades from approximately 1.5 mAHD near South Tacoma Road down to 1.3 mAHD approaching Tuggerah Lake (although typical excavation depths are closer to 0.5 metres). Approximately, 42,000 m^3 of floodplain material would need to be removed to create the floodway.

All of the proposed earthworks are contained on land that is not owned or managed by Council. Most of the works are contained on land that forms part of the Tuggerah Lakes Reserve Trust with the eastern portion of works contained on land owned by the National Parks and Wildlife Service. The need to modify non-Council owned land and, in particular, the need to remove vegetation from this area serves as a significant impediment to the implementation of this option. The floodway also traverses part of a SEPP71 coastal/sensitive area as well as an aboriginal land claim area, which provides another hurdle for implementation.

As shown in **Figure E1**, the site of the proposed floodway lies within an area identified as having a high potential for acid sulfate soils. Accordingly, Council commissioned a geotechnical assessment to be completed for the area. The findings of this assessment are documented in the *Proposed Flood Mitigation Works, South Tacoma Road, Tuggerah NSW. Preliminary In-situ Water Classification, VENM Assessment and Acid Sulfate Soil Assessment* (Coffey, 2017). This report is reproduced in **Appendix F**.

The geotechnical assessment confirmed that acid sulfate soils are located within the proposed floodway footprint at a depth of 0.8 metres. As construction of the floodway will involve excavating up to a 1 metre of soil from the floodplain, acid sulfate soils will likely be exposed. The potential environmental impacts of the acid sulfate soils are significant and the costs associated with management of this spoil would be large.

It is expected that the floodway would cost about $2.54 million to implement (refer **Appendix D**). Ongoing maintenance costs would be low once the capital works are completed.

The hydraulic impacts associated with the floodway were quantified by including the floodway channel within the TUFLOW model. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures E2** and **E3** for the 20% AEP and 1% AEP flood respectively. The flood level difference maps for the 20% and 1% AEP floods are also provided in **Figures E4** and **E5**.

As shown in **Figure E4**, the effectiveness of the floodway is limited during smaller Wyong River floods. This is associated with South Tacoma Road which controls the elevation at which water can "spill" from the river and into the floodway (i.e., water is only predicted to "spill" across South Tacoma Road and into the floodway during events larger than the 20% AEP event). As a result, the floodway is not predicted to reduce the number of building subject to above floor inundation during the 20% AEP event.

However, **Figure E5** shows some significant reductions in flood levels during the 1% AEP event. This includes reductions in flood levels of around 0.05 metres across large sections of the Wyong River floodplain located east of the Pacific Highway. This is predicted to result in 18 fewer properties being exposed to above floor inundation during the 1% AEP event. Therefore, the floodway is predicted to afford some significant benefits during larger floods.

Revised flood damage calculations were prepared based on the results of the revised simulations. The damage calculations determined that flood damage costs would be reduced by approximately $2.49 million over the 50-year design life of the floodway. This provides a BCR of 0.98 indicating the reductions in flood damage costs are roughly equal to the costs to implement the option. The major financial limitation associated with this option is the relatively high capital cost which may be difficult to fund.

This option was generally well supported by the community (more than 75% of the community supported the option and only 5% were opposed). Further additional support for this option was received during the public exhibition of the final draft of the Wyong River Floodplain Risk Management Study and Plan in April 2019.

Pioneer Dairy is listed as a site of Local Heritage Significance, on the (former) Wyong Local Environment Plan. As stated in Section 2.3.4, Pioneer Dairy is also currently under an Aboriginal Land Claim. As such, any proposed works on this site would need to commence with discussions with the current landowners, and take the Aboriginal and Heritage issues into consideration during these discussions and during any subsequent detailed design investigations.

Although the hydraulic and financial benefits of this option are significant, the presence of acid sulfate soils and the associated environmental impacts and cost implications are considered to be significant. Preliminary cost estimates have been prepared based on the current information available regarding the extent and treatment of the potential acid sulfate soils. However, further investigations will have to be made on site to gain a greater understanding of the final potential cost of this option.

There is opportunity for the position and size of the floodway to be refined based on the detailed site investigations. For example, if acid sulfate soils are found less than 0.5 metres below the surface, the earthworks could focus on just the elevated portions of land which is still likely to afford some hydraulic benefits while reducing the need for extensive earthworks and treating of acid sulfate soils.

The potential benefits of this option are considered to be sufficient to warrant further detailed investigation and design by council. This will also require Council to work with the landowners where the land is recommended to be modified, as well as a detailed assessment of the impacts these changes may have on the adjacent environment, including the flora and fauna downstream. This detailed investigation will also need to consider the provisions of the NSW Coastal Management State Environmental Planning Policy (SEPP) (Coastal Management) 2108, as this land may be located on areas included in the *Coastal Wetlands and Littoral Rainforest Area Map* of the SEPP.

Table 24 Evaluation Outcomes for South Tacoma Relief Floodway

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Negligible impacts during frequent events but more significant reductions during larger floods across a wide area.
Inundated Buildings	++	18 less buildings inundated above floor level in 1% AEP event
Financial Feasibility	-	BCR ~ 1.0. However, high capital cost reduces financial feasibility
Community Acceptance	++	76% of the community indicated support for this option and only 5% were against
Environmental Impacts	--	Acid sulfate soils mean high potential for adverse environmental impacts. In addition, this option will involve removal of vegetation near Tuggerah Lake.
Emergency Response	+	Reduced inundation depths and durations across South Tacoma Rd
Technical Feasibility	-	Acid sulfate soils, works in around waterlogged soils.

Recommendation: Not recommended

7.4.4 Vegetation Removal across Lower Floodplain

Several residents noted that many waterways and drainage gullies within the catchment had become significantly overgrown with vegetation. The vegetation can serve to restrict the flow of water, thereby elevating upstream water levels. Parts of the vegetation (e.g., branches) may also be mobilised during floods leading to blockage of downstream culverts/bridges, further inhibiting the drainage of the area. Therefore, the potential benefits associated with removing vegetation/debris from major waterways across the lower Wyong River floodplain were investigated.

An initial review of endangered ecological communities (ECC) across the lower Wyong River floodplain indicates extensive areas of potentially endangered species (refer **Plate 13**). Therefore, complete clearing of all vegetation along major waterways is unlikely to be supported.

Nevertheless, a reduced clearing option involving just the removal of non-native plant species could be investigated. This may assist in reducing the resistance to flow afforded by the vegetation and provide improvements to local flora and fauna. However, it would require expert involvement to ensure that endangered species are not removed or damaged.

The extent of the area where vegetation removal was investigated as part of the study is shown in **Figure F1** in **Map Set F**. As shown in **Figure F1**, the vegetation removal included sections of Tuggerah and Mardi Creeks as well as two drainage gullies located on the northern floodplain of the Wyong River. Removal of vegetation in the vicinity of the existing railway culverts was also included as part of the option.

Plate 13 Endangered Ecological Communities across lower Wyong River Floodplain

A preliminary cost estimate for the vegetation removal was prepared and is included in **Appendix D**. This determined that vegetation removal would cost approximately $1.7 million to implement over 50 years. The relatively high costs are associated with the considerable ongoing maintenance costs which would be required to maintain the selective vegetation clearing.

In general, this option is strongly supported by the community with 84% of the community supporting the option. Only 1% of the community were opposed to the option.

The hydraulic impacts associated with the vegetation removal were quantified by including it within the TUFLOW model. This involved reducing the Manning's "n" roughness across the areas identified in **Figure F1** to 0.08 (down from 0.1). This reflects retention of existing trees but removal of a limited amount of undergrowth. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures F2** and **F3** for the 20% AEP and 1% AEP flood respectively. The flood level difference maps for the 20% and 1% AEP floods are also provided in **Figures F4** and **F5**.

Figures F4 and **F5** shows that the vegetation removal will have negligible impact on flood levels across the northern floodplain during major Wyong River floods. However, some more significant reductions in flood levels are predicted along Tuggerah and Mardi Creeks. These reductions are predicted to extend across part sections of the Tuggerah Industrial area. In general, the reductions in flood levels are predicted to be less than 0.1 metres. However, this is sufficient to reduce the number of buildings exposed to above floor inundation by seven during the 1% AEP flood. **Figure F4** also shows that the flood level reductions are sufficient to significantly reduce roadway inundation across the southern sections of the Tuggerah Industrial area. Therefore, vegetation clearing is also likely to afford some improvements to evacuation/emergency response across the Tuggerah Industrial area during smaller floods.

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the vegetation clearing. This determined that vegetation clearing would reduce flood damage costs by $0.8 million over 50 years. This provides a BCR of 0.47. Therefore, the financial benefits associated with vegetation clearing are lower than the costs to implement and maintain this option.

The primary disadvantage associated with this option is the potential for adverse environmental impacts. As discussed, experts would be required to identify and remove only select species which will add to the cost of implementing this option. There may also be adverse water quality impacts (i.e., less vegetation to "filter" nutrients and sediments from runoff) as well as increased potential for erosion. The need to remove and maintain only select species will also add to ongoing maintenance costs once the initial vegetation removal is complete.

There may also be opportunities for local land care groups to be involved in clearing of non-native species which may assist in reducing the up front and ongoing costs of implementation of this option. But, as discussed, this would need to be guided by experts.

Overall, the high capital and ongoing costs and comparatively lower financial benefits mean that vegetation clearing is not supported for implementation as part of this floodplain risk management plan. However, there is potential to include these works in the annual asset management program for this area. Details would have to be clarified on the ownership and subsequent maintenance responsibility for each of these different vegetation areas, and vegetation could be removed as approved from each area, with costs borne by the asset owner as part of general asset management. It is anticipated that year 1 of such an asset management program would have a higher cost than the following years, with lower annual costs remaining low so long as the vegetation management regime is maintained on a regular basis.

Riverbank collapses were also reported during the community consultation phase of the project. Riverbank collapses increase the amount of sediment deposited in the river channel which reduces the flow carrying capacity of river, particularly during small floods. Therefore, opportunities could be explored as part of the management plan for liaison with appropriate authorities/landowners to ensure banks are supported and/or vegetated adequately to reduce the potential for erosion and bank collapse during and after floods.

These ongoing works would also provide a positive community outcome, as the community consultation phases of this study included a lot of negative comments related to the perceived non-existent maintenance of the existing channels and creeks, and the community's concern this has on the localised flooding (particularly during relatively frequent rainfall events).

Therefore, maintenance works on the vegetation (and silt and debris) would be seen in a positive light by the community as a means to addressing these concerns.

Table 25 Evaluation Outcomes for Removal of Vegetation

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+	Reductions in flood levels <0.1m during most design floods across Tuggerah Industrial area
Inundated Buildings	+	7 fewer building inundated above floor level during 1% AEP flood
Financial Feasibility	--	BCR<0.5 plus high ongoing costs.
Community Acceptance	++	84% of the community support the option
Environmental Impacts	--	Potential for significant adverse impacts to flora, fauna, water quality, erosion etc
Emergency Response	+	Reduced roadway inundation depths/extents during smaller floods.
Technical Feasibility	-	Access to some waterway sections may be limited plus the need to identify and remove only select species will present challenges

Recommendation: Not recommended for implementation as part of this plan, however, could be implemented as part of the annual asset management of these areas. Opportunities for riverbank stabilisation could also be explored as part of these management activities.

7.4.5 Mardi Creek Debris Control Structures

Several community questionnaire responses noted that flooding across the Tuggerah industrial area is exacerbated when the channels, bridges and culverts become blocked by debris. This can include vegetation (e.g., leaf litter, branches) as well as urban debris (e.g., shopping trolleys, wheelie bins, fence palings). The installation of debris control structures (e.g., GPTs, trash racks) would aim to collect such debris in less populated areas to ensure the efficiency of the existing drainage infrastructure is maximised and the existing flooding problem is not increased.

Debris control structures were initially investigated at the following locations:

- North-west of the intersection of Wyong Road and Woodbury Park Road
- South-west of the intersection of Wyong Road and Tonkiss Street (would involve two separate debris control structures)

Hydraulic analysis shows implementation of debris control structures at these locations would reduce downstream water levels marginally but would direct additional water into Wyong Road, Tonkiss Street and Woodbury Park Road. Therefore, structures at these locations were not investigated further.

Ultimately the location shown in **Figure G1** was selected as the preferred location of the debris control structure. This location is situated downstream of the confluence of Mardi Creek and the culvert from the Westfield Tuggerah site. Therefore, it should be capable of capturing debris from both the upper Mardi Creek catchment and Westfield sites before it reaches Gavenlock Road, the Pacific Highway and the railway line.

In general, there are likely to be negligible adverse environmental impacts associated with installation of the debris control structures. However, small amounts of vegetation may need to be removed to facilitate installation of the structure. Installation of the debris control structure may afford some environmental benefits by reducing the quantity of gross pollutants entering downstream waterways. However, as the catchments upstream of the structures are primarily undeveloped, these benefits are likely to be minimal.

The installation of debris control structures was generally supported by the community. 76% of the community supported this option and 4% of the community opposed it.

A cost estimate for the installation of the debris control structures was prepared and is included in **Appendix D**. This determined that the total cost to implement this option over 50-years would be about $60,000. The majority of this cost is associated with maintenance/cleaning of the structure, which was assumed to occur 4 times per year.

The hydraulic impacts associated with the installation of debris control structure was quantified by including it within the TUFLOW model. This involved including a 0.6 m high trash rack at the location shown in **Figure G1** (represented in TUFLOW as a weir) and removal of all blockage from downstream culverts/bridges. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures G2** and **G3**. The flood level difference maps for the 20% and 1% AEP floods are also provided in **Figures G4** and **G5**.

Figures G4 and **G5** shows that water levels along Mardi Creek upstream of the structure are predicted to increase by up to 0.5 metres as far upstream as Woodbury Park Road. **Figures G5** shows that this is predicted to divert floodwaters into some adjoining properties fronting Green Cl. Accordingly, the hydraulic benefits associated with implementing this option are minimal.

However, it should be recognised that it is not known which structures will develop what percentage of blockage during any flood. The hydraulic impacts documented in this report are based upon assumptions of potential blockage factors that were calculated by considering the size of each structure along with the potential size and mobility of upstream debris. Any variations to these blockage factors will alter the outcomes of the hydraulic assessment.

The revised modelling results were used as a basis for undertaking a revised flood damage assessment. This determined that implementation of the debris control structures is predicted to generate negligible changes to existing flood damages. Therefore, the BCR for the debris control structures was determined to be zero. This indicates that there is no obvious financial benefit associated with implementing this option.

Nevertheless, it is acknowledged that there are many different types of debris control structures available, including those that are designed to "push" debris up and over the culvert thereby minimising the potential for adverse impacts associated with debris accumulation.

Therefore, there may still be merit in Council exploring other types of debris control structures for this area as part of its stormwater asset management program.

Table 26 Evaluation Outcomes for Debris Control Structures

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	Reduced water levels along main channel but increased inundation across adjoining roadways.
Inundated Buildings	-N-	No change in number of buildings subject to above floor flooding
Financial Feasibility	-	High ongoing costs and BCR < 0.5
Community Acceptance	++	76% of community supports this option
Environmental Impacts	-N-	Limited vegetation removal required
Emergency Response	-	Increased inundation depths and durations across multiple roadways
Technical Feasibility	-N-	No major technical hurdles

Recommendation: Could be further explored as part of Council's stormwater asset management program.

7.4.6 Pacific Highway / Pacific Motorway Debris Control Structures

Debris controls structures were also investigated at other locations where blockage of bridges/culverts have the potential to significantly impact on upstream properties. In this regard, debris controls structures were investigated upstream of the Wyong River crossings of:

- Pacific Motorway;
- Pacific Highway.

However, implementation of debris control structures at these locations is not recommended for implementation for the following reasons:

- There are a number of flood liable properties and/or vulnerable facilities located upstream of the Pacific Highway (e.g., Wyong Aged Care Facility, Wyong Christian Community School, properties adjoining Collies Lane). In addition, there is a significant natural narrowing of the floodplain in this area which exacerbates the impact of partial blockage of the river. Therefore, the partial obstruction to flow afforded by debris control structures has the potential to adversely impact on existing flood levels across these properties
- Debris control structures would likely obstruct recreation vehicles such as boats reducing the recreational amenity provided by the river
- A review of 'Blockage of Hydraulic Structures (Engineers Australia, 2015)' indicates that there is only a relatively small potential for blockage of the Pacific Highway and Pacific Motorway structures. Therefore, implementation of debris control structures is not likely to provide a significant reduction in existing flood damages leading to low BCR

Recommendation: Not recommended for implementation.

7.4.7 Tuggerah Lake Entrance Dredging

A number of residents and business owners within the catchment suggested that the Tuggerah Lake entrance at The Entrance could be enlarged which would assist in reducing flood levels across the Tuggerah Lake system as well as the lower Wyong River.

A study was commissioned by the NSW State Government in 2015 to quantify the potential impacts of deepening the entrance channel (through dredging and removal of a part section of the underlying rock shelf) (Cardno, 2015). Entrance training walls and four alternate dredging depths were considered as part of the assessment. The assessment determined that:

- The dredged channel would begin to infill with sand almost immediately resulting in costly ongoing works to maintain.
- There would be minimal reductions in lake levels during most runoff events (typically less than 0.1 metre during events less than the 5% AEP flood). These flood level benefits are only likely to benefit those sections of the Wyong River located downstream of Tacoma.

Overall, the study determined that the potential costs associated with dredging and maintaining the Tuggerah Lake entrance would outweigh the benefits. The potential environmental costs associated with dredging are also significant (refer to discussion in Section7.4.8 of this report). Accordingly, this option was not considered further as part of the current study.

Recommendation: Not recommended for implementation.

7.4.8 Wyong River Dredging

Several community members also noted that the Wyong River shallows significantly as it approaches Tuggerah Lake. This shallowing is likely associated with the reduction in flow velocities along the river as it approaches the lake. As the water slows, any sediment being carried by the river drops out of suspension and is deposited over time across the downstream sections of the river.

Therefore, dredging of the downstream section of the river was investigated as a potential option for improving the flow carrying capacity of the river. The extent of the dredging considered as part of the current study is shown in **Figure H1** in **Map Set H**. The dredging depths shown in **Figure H1** are based on dredging to a minimum depth of -5 mAHD.

Council does have access to a “cutter suction” dredge that is suitable for dredging fine silt and clay. This dredge may be suitable for dredging the river entrance, however, the sediment types would need to be confirmed to determine compatibility.

The potential environmental impacts associated with dredging are significant. The environmental impacts are primarily associated with dredging mobilising sediment (and associated contaminant) which causes turbidity of the water (i.e., reduced water quality) and potentially covers sea-grass (i.e., loss of vegetation and habitat for aquatic life). Any nutrients released during dredging, particularly nitrogen and phosphorus, risk triggering algal blooms which can have adverse impacts on human health.

It will also be necessary to appropriately dispose of the dredged material. This is also an involved process including storage, dewatering, transportation as well as disposal of the material in a land fill. The cost associated with this process is significant. Moreover, existing landfills have a limited capacity, which may ultimately limit the volume of material that can be dredged over the long term.

The up front and ongoing costs of dredging are also likely to be significant. The exact cost of ongoing dredging is difficult to estimate without detailed sediment transportation modelling to gain an understanding of the volume of sediment that is likely to be regularly deposited in the channel. It is estimated that 300,000 m^3 of sediment would need to be initially removed and, for the purposes of providing an indicative cost estimate, that an additional 20% of this volume would need to be removed by the dredge on an annual basis to maintain the dredged channel. These assumptions yielded a total implementation cost over 50 years of over $11 million (refer to **Appendix D** for a detailed cost breakdown). Accordingly, the life cycle cost of this option is significant.

The hydraulic impacts associated with dredging of the river was quantified by updating the channel geometry in the hydraulic model to reflect the channel dredging. The updated TUFLOW model was then used to re-simulate each design flood. Peak floodwater depths and velocities were extracted from the results of the simulations and are presented in **Figures H2** and **H3** for the 20% AEP and 1% AEP flood respectively. The flood level difference maps for the 20% and 1% AEP floods are also provided in **Figures H4** and **H5**.

Figure H4 shows that flood level reductions are predicted during the 20% AEP event. However, the reductions are typically contained within close proximity to the main river channel. **Figure H5** shows more extensive water level reductions during the 1% AEP flood. More specifically, reductions in water level of between 0.05 and 0.20 metres are predicted across both the northern and southern floodplain of the Wyong River downstream of the Pacific Highway. No reductions in water levels are anticipated downstream of South Tacoma as Tuggerah Lake water levels are the dominant flooding mechanism across this section of the river.

The predicted reductions in flood levels is not predicted to alter the number of buildings subject to above floor inundation during the 20% AEP flood. However, 26 fewer buildings are predicted to be inundated above floor level during the 1% AEP event.

Revised damage estimates were also prepared based on the revised simulation results and determined that the dredging would potentially reduce flood damage costs by $5.5 million. This yields a BCR of 0.47. Therefore, although the anticipated damage reductions are significant, the high capital and ongoing costs are likely to outweigh the financial benefits.

The significant capital and ongoing costs coupled with the potential for significant environmental impacts make this option difficult to support.

It should be noted that during floods, high velocity flows have the potential to carry sediment and naturally scour the river channel. A review of the computer model outputs indicates that flow velocities downstream of the Pacific Highway are predicted to exceed 2 m/s as the 1% AEP flood approaches its peak. This velocity is sufficient to carry course sand/fine gravel. Accordingly, there is a high probability that some natural scouring of the channel will occur during large Wyong River floods. Therefore, some of hydraulic benefits identified as part of the dredging assessment will likely be afforded through natural scouring of the river channel. It is noted that flow velocities drop significantly as they approach Tuggerah Lake and much of the scoured material will drop out of suspension in this area. However, peak water levels in this area tend to be dominated by the prevailing Tuggerah Lake water level rather than the Wyong River channel capacity. It is also noted that sediment sourced from the upper catchment may "fill" any scour holes in the lower reaches of the river. However, based on the simulated flow velocities, it is likely that more material will be scoured than deposited along the Wyong River channel between the Pacific Highway and Tacoma.

Table 27 Evaluation Outcomes for Wyong River Dredging

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	++	Water level reductions of across extensive sections of lower Wyong River floodplain
Inundated Buildings	++	26 less buildings inundated above floor level in 1% AEP event
Financial Feasibility	--	Low BCR and high capital and ongoing costs
Community Acceptance	+	General support from the community
Environmental Impacts	--	Significant potential for adverse environmental impacts
Emergency Response	+	Reduced inundation depth/durations across a number of lower floodplain roadways
Technical Feasibility	-N-	No major technical impediments to implementation

Recommendation: High costs and adverse environmental impacts will limit the potential for implementation. Not recommended.

7.5 Drainage Upgrades

7.5.1 Railway Upgrades

The main northern railway line serves as a significant impediment to flow from the Mardi Creek and Wyong River catchments. Therefore, opportunities to increase the drainage capacity through the railway line have been investigated on several occasions. The options previously investigated include the installation of additional culverts at selected locations along the railway alignment right through to replacing the railway line with an elevated viaduct across the full width of the floodplain.

In general, the railway culvert upgrades were found not to provide a significant hydraulic benefit, particularly during larger events. The replacement of the railway embankment with a viaduct was also determined to be prohibitively expensive. Therefore, the previous investigations did not consider the railway drainage upgrades to be feasible options.

The provision of railway drainage upgrades was not explicitly considered as part of the current study with the exception of the additional culvert included as part of the Mardi Creek floodway. The Mardi Creek floodway results tend to confirm the outcomes of the previous assessments (i.e., minor hydraulic benefits for comparatively high capital costs).

As outlined in Section 7.4.2, discussions could be held with Railcorp to gain an understanding of the likelihood of any upgrade works planned for this area in the future, and the opportunity to include works to help alleviate the flooding currently exacerbated by Railcorp infrastructure. If Railcorp can contribute to the drainage upgrade costs it will significantly improve the financial viability of this option.

Recommendation: Not recommended for implementation. However, it is recommended discussions be held with Railcorp to confirm likelihood of upgrade works in the area and the opportunity to include flood mitigation works as part of this.

7.5.2 Local Drainage Studies

It was noted that during consultation with the community that a number of residents advised of poor drainage across some floodplain areas. The most prevalent drainage "problem area" reported by the community was the northern floodplain of the Wyong River around McDonagh Road and Kooindah Waters. In general, the residents stated that the poor drainage was mainly associated with a lack of maintenance of the various drainage channels and culverts. Several residents stated that several culverts were completely blocked by debris, with maintenance of these drains infrequent, if at all in their judgement. The residents recognised that these blockages have a significant impact on the frequent stormwater and overland flooding characteristics in these areas and has placed the cleaning of these structures as a high priority action as part of this risk management plan.

The community also raised issues associated with the cumulative impact that development and fill in the Wyong River floodplain to the east of the railway line has had on the flooding characteristics of the area over time. This includes the concerns relating to the apparent impact larger developments have had on the flooding characteristics to the east of the railways line. Investigation of the former Wyong Shire Council development controls in this area indicate that council were aware of the flooding and stormwater drainage issues in this area and, therefore, limited the amount of fill for each development to an absolute minimum, as per the previous Flood Prone Land Development Policy. Any large developments were not permitted to import fill into the floodplain – all earthworks had to ensure cut and fill within the floodplain were balanced to mitigate the potential for adverse flood impacts.

Nevertheless, evacuation and above floor flooding problems are already evident across the lower Wyong River floodplain. Therefore, even very small changes to current flood levels do have the potential to increase the severity of these flood impacts even further. Accordingly, extreme care must be exercised as part of any future rezoning or major development to ensure there is no loss of floodplain storage. If development is proposed at any location within the lower floodplain (i.e., areas east of the railway line), they will need to be supported by appropriate flood modelling to confirm the cumulative development of these areas will not increase existing flood levels during both frequent and more severe floods.

The focus of the current study is assessing mainstream flooding from major rivers and creeks within the Wyong River catchment. Therefore, the modelling tools developed and used as part of the current study are not sufficiently detailed to provide a detailed assessment of local drainage.

Therefore, it is recommended that a separate, detailed drainage study be completed for these local catchments. The drainage study should include the development of a more detailed hydraulic model of the local catchment, including all major drainage infrastructure (e.g., culverts). The model should be capable of quantifying the extent of the existing drainage problem and assessing potential drainage improvement options.

Recommendations:
1) Undertake a local drainage study for the northern floodplain of the Wyong River between Wyong and Tacoma.
2) Incorporate maintenance of drainage channels and culverts into Council maintenance program

7.5.3 Installation of Flood Gates on Pipes Draining to Wyong River

Council identified the potential to install flood gates on existing pipes that discharge to the Wyong River to prevent "backwater" inundation of low lying areas during Wyong River floods. Most notably the area around Marathon Street and Rockleigh Street, Wyong is typically located around 1 mAHD. However, the area is largely protected from inundation from Wyong River floodwaters by a natural levee that is typically located above 2 mAHD. Nevertheless, there is potential for water to "back up" the pipe system and inundate the area behind the natural levee. Accordingly, the installation of floodgates at the downstream end of these pipes should prevent backwater inundation of the area and afford a higher level of flood immunity.

Unfortunately, as noted in Section 7.5.2, the broad-scale nature of the flood model that was developed for this study meant that local drainage infrastructure, such as stormwater pipes, was not included. Therefore, the hydraulic benefits afforded by the installation of flood gates cannot be represented in the model. Therefore, it is recommended that analysis of this local drainage system and the benefits afforded by the installation of flood gates be completed as part of the local drainage study discussed in Section 7.5.2.

Recommendation: To be investigated as part of the local drainage study

7.6 Recommendations

A summary of the evaluation of each flood modification option is provided in **Table 28**. As shown in **Table 28**, the following options are recommended for further consideration to assist in managing the existing flood risk across the Wyong River floodplain:

- Mardi Creek Detention Basin
- Anzac Road Levee
- Local Drainage Studies (including Wyong River flood gate investigation)

As noted in **Table 28**, further detailed investigations are considered necessary to confirm the potential viability of the South Tacoma Relief Floodway. A modified version of the vegetation clearing may also be viable subject to a detailed flora/fauna assessment to confirm the potential extent of vegetation removal that could be implemented without adverse environmental impacts.

Table 28 Evaluation matrix for Flood Modification Options

Option	Evaluation Criteria / Score#							
	Hydraulic Impacts	Inundated Buildings	Financial Feasibility	Community Acceptance	Environmental Impacts	Emergency Response	Technical Feasibility	Recommended for Further Consideration?
Mardi Creek Detention Basin	++	+	++	+	-	+	-N-	Yes
Anzac Road Levee	+	+	-	+	-	+	-	Yes
Mardi Creek Relief Floodway	+	+	--	++	-N-	-N-	-	Discussions to be held with Railcorp to confirm likelihood of upgrade works in the area and the opportunity to include flood mitigation works
South Tacoma Relief Floodway	+	++	-	++	--	+	-	Recommended for further investigation
Vegetation Removal	+	+	--	++	--	+	-	Could be considered as part of asset management program
Mardi Creek Debris Control Structures	-N-	-N-	-	++	-N-	-	-N-	No
Wyong River Dredging	++	++	--	+	--	+	-N-	No
Local Drainage Studies (including Wyong River flood gate investigation)	Not evaluated as part of current study							Yes

Refer to **Table 20** for evaluation criteria and scoring system

8 PROPERTY MODIFICATION OPTIONS

8.1 Introduction

Property modification options refer to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Modifications to individual properties is typically used to manage existing flood risk while planning measures are employed to manage future flood risk.

Property modification options considered as part of the current study included:

- Voluntary House Purchase
- Voluntary House Raising
- Voluntary Flood Proofing
- Planning Modifications

Further discussion on property modification options that could be potentially implemented to help manage the existing and potential future flood risk is provided below.

8.2 Property Modification Options

8.2.1 Voluntary House Purchase

Voluntary house purchase (VHP) refers to the voluntary purchase of an existing property on a high-risk area of the floodplain. The purchased property is typically demolished and the land is retained as open space or an equivalent land use that is more compatible with the flood risk.

Due to the high capital costs associated with this option, VHP is typically only considered appropriate in floodway / high hazard areas where other flood risk reduction strategies are impractical or uneconomic. Moreover, Government funding is only available for VHP for properties that were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted (Office of Environment & Heritage, 2013a).

The computer flood modelling outputs were interrogated with existing building footprints to identify houses that may be eligible for VHP. More specifically, buildings that fell within the following areas at the peak of the 1% AEP flood were considered potentially eligible for VHP:

- High flood hazard areas; and
- Floodway areas.

It is noted that the 'high hazard' definition in the Office of Environment & Heritage guideline refers to the NSW Government's "Floodplain Development Manual" (2005) hazard categories. The more recent national hazard categories have been adopted as part of the current study (refer Section 3.2.4). In this regard, it was assumed that the national H1, H2 and H3 categories would fall under the 'Low' hazard category in the "Floodplain Development Manual" and the national H4, H5 and H6 categories would fall under the 'high' hazard category in the Manual.

A total of eight houses were identified as being potentially eligible for voluntary purchase. The location of each house is shown in **Figure I1** in **Map Set I**. As shown in **Figure I1**, most of the identified properties are rural residential dwellings located within the Yarramalong Valley. All identified properties are located within high hazard floodway areas at the peak of the 1% AEP event. The depth of above floor flooding is predicted to exceed 0.9 metres and velocities around each dwelling are predicted to exceed 1 m/s at the peak of the 1% AEP flood.

CoreLogic automated property valuations were obtained to gain an estimate of the current market value of each house. This yielded a total voluntary purchase price for the 8 properties of $6.4 million.

Revised flood damage estimates were also prepared by removing the damage contribution provided by these houses. That is, it was assumed that the purchased properties would be demolished and the current occupants relocated to an area outside of the PMF extent. The revised damage calculations yielded a reduction in the net present value of damages of $1.8 million, providing a preliminary BCR of about 0.3.

Although there does not appear to be a significant financial incentive to implement VHP, it should be recognised that the primary goal of VHP is to remove high-risk properties from the floodplain in instances where no other flood or property modification options are viable. In this regard, most VHP programs across NSW provide a BCR less than 1. Therefore, it is still considered worthwhile for Council to pursue VHP as part of a long-term risk reduction strategy across this catchment as well as the broader LGA. It is suggested that Council collate VHP information for all risk management studies and use this information to prioritise potential VHP properties so that the considerable costs associated with implementation of this option are best allocated. Once this prioritised list is prepared, Council could initiate discussions with homeowners to determine their willingness to participate (noting that VHP is <u>voluntary</u>).

If homeowners do not wish to participate in VHP, Council could discuss alternate options for reducing the existing risk. This could include:

- voluntary house raising (discussed in Section 8.2.2);
- "knock down, rebuild" whereby the existing building is demolished and a new dwelling is erected away from the high hazard areas; or
- encourage flood-compatible redevelopment of the existing property (e.g., redevelopment incorporating a PMF refuge).

<u>Recommendation</u>: Voluntary house purchase not considered feasible in the short term. However, Council may like to consider this option as a long-term risk reduction measure.

Table 29 Evaluation Outcomes for Voluntary Purchase

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	Localised changes in flood behaviour may occur in vicinity of purchased properties but broad-scale changes likely to be minimal
Inundated Buildings	+	8 less buildings inundated above floor level during 1% AEP flood
Financial Feasibility	--	High capital cost and low BCR
Community Acceptance	+	General community support
Environmental Impacts	+	Purchased properties could be demolished and returned to open space, increasing visual and environmental amenity
Emergency Response	+	Removal of high risk properties will reduce burden on emergency services
Technical Feasibility	-N-	No significant technical hurdles

8.2.2 Voluntary House Raising

Voluntary house raising (VHR) is a well-established method of reducing the frequency, depth and duration of above floor inundation. VHR can be a suitable measure for reducing the flood damage for individual dwellings or can be used as a compensatory measure where other flood mitigation works are predicted to adversely impact on flood behaviour across individual dwellings. An example of house raising is provided in **Plate 14**.

Plate 14 Examples of houses before (top image), during (middle image) and after (bottom image) house raising (photos courtesy of Fairfield City Council)

VHR is best suited to single-storey, timber or clad walled houses with a pier and beam foundation in areas of low flood hazard where structural mitigation works are impractical or uneconomic. It should also be noted that Government funding is only available for VHR for residential properties that were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted (Office of Environment & Heritage, 2013b).

The computer flood modelling outputs were interrogated in conjunction with building footprints to identify houses that may be eligible for VHR. Specifically, houses that met the following criteria were pursued:

- Subject to frequent above floor inundation. In this regard, properties that were predicted to be inundated above floor level during a 10% AEP event were selected (a VHR scheme based on the 1% AEP was initially considered but was cost-prohibitive).
- Single storey, non-brick houses constructed on a pier and beam foundation; and,
- Low flood hazard area at the peak of the 1% AEP event;

These criteria yielded one house in South Tacoma as being potentially eligible for raising. The location of this house is shown in **Figure I2**.

The cost associated with raising a house will vary depending on the location, size and complexity of the house. However, recent house raising projects completed by Fairfield City Council indicates a typical cost of $82,000 per building. This cost estimate is based on an average floor area of 130 m^2 and raising the house by 2.5 metres. Installation of a car port / garage etc could be accommodated on the lower level, but this is not included in the cost estimate.

However, a review of the identified house indicates that the value of the house itself is likely to be significantly less than the cost to raise the property. Therefore, allocating funds for house raising would likely be overcapitalising. That is, the financial viability of this option is considered to be low. Furthermore, it is questionable as to whether the existing dwelling is structurally suitable for house raising.

Nevertheless, the identified property is predicted to be subject to relatively frequent inundation. Therefore, other opportunities to reduce the potential for frequent inundation of this property are worth pursuing. More specifically, discussions could be held with the property owner to outline the potential high cost of ongoing ownership of the existing property due to flood damages and encourage flood-compatible redevelopment of the existing site. Alternatively, Council may like to explore the purchase of this property as part of any future VHP program (however, as the property is not located within a high hazard flood area, the potential to secure state government funding for the purchase is likely to be limited).

Recommendation: voluntary house raising not considered viable. However, discussions could be held with property owner to encourage flood-compatible redevelopment.

Table 30 Evaluation Outcomes for Voluntary Raising

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	Minimal impacts on flood behaviour anticipated
Inundated Buildings	+	1 less building inundated above floor level during 1% AEP flood
Financial Feasibility	--	Overcapitalisation
Community Acceptance	-N-	50% of the community unsure/neutral
Environmental Impacts	-N-	Negligible impacts
Emergency Response	-	May increase the potential for isolation and/or need for resupply if evacuation is not completed early
Technical Feasibility	-	Additional investigations required to determine if identified property suitable for raising

8.2.3 Voluntary Flood Proofing

For houses within low hazard areas that are subject to regular inundation but are otherwise unsuitable for house raising (e.g., brick, slab-on-ground houses), voluntary flood proofing techniques may be employed to reduce the cost of flooding. Two types of flood proofing are available and are illustrated in **Plate 15**:

- ‘dry’ flood proofing, which aims to prevent the ingress of water into houses;
- ‘wet’ flood proofing, which permits water to enter houses but reduces the damage to the structure of the house through the use of flood resilient materials.

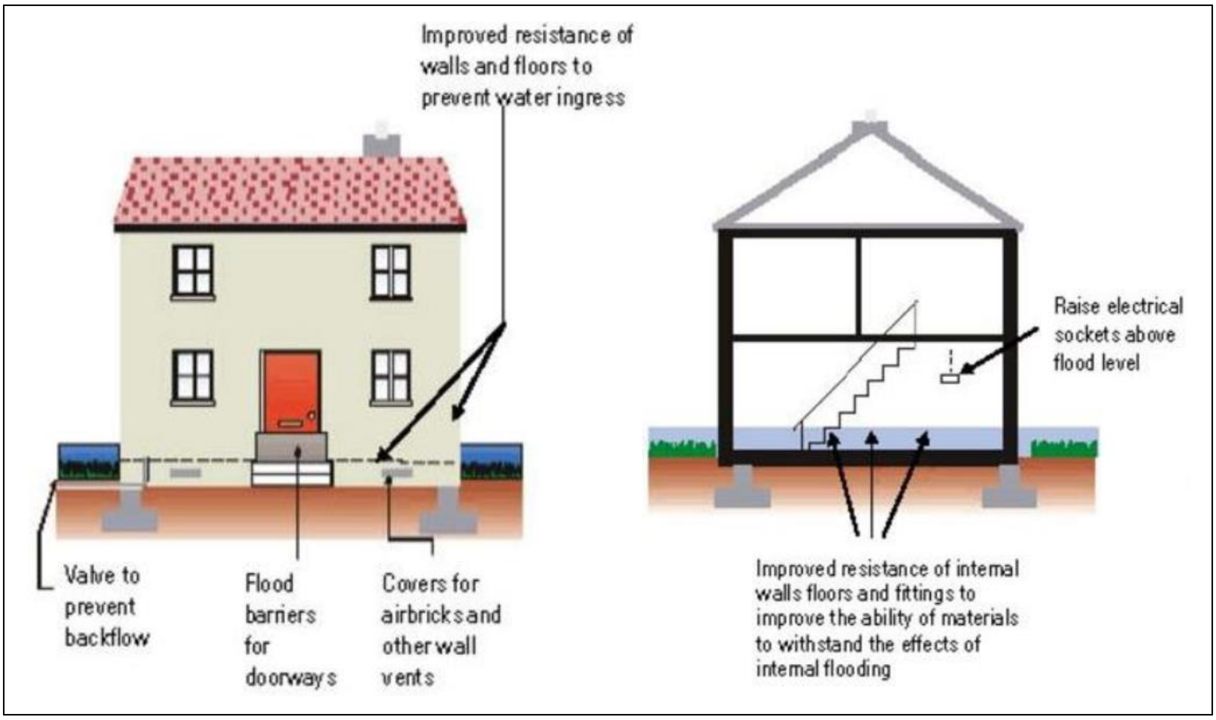


Plate 15 Examples of dry (left image) and wet (right image) flood proofing techniques

‘Dry’ flood proofing aims to reduce inundation damages by completely preventing the ingress of water. In this regard, ‘dry’ flood proofing affords several benefits over ‘wet’ flood proofing as it avoids the potential for damage to building contents, reduces the clean-up efforts after an event and significantly reduces the stress associated with frequent above floor inundation.

Two methods of 'dry' flood proofing are available:

- blocking flooding at some distance from the house footprint through the careful incorporation of elevated features into driveways and/or landscaping; or,
- sealing the building's exterior walls, floors and other entry points.

Care needs to be exercised if employing the first option, as there is potential to displace water. This may cause localised increases in flood levels, thereby reducing the level of protection afforded by this option and/or redirecting flows into neighbouring properties. Moreover, if elevated landscaping features are utilised, drainage from 'behind' the elevated areas must be carefully managed to ensure it does not exacerbate local water depths and elevations behind these topographic features.

The second 'dry' flood proofing option is considered to be more costly and difficult to implement and may only be appropriate for structures that are able to withstand the hydrostatic forces imposed by the external standing water. There is also the potential for failure of the flood proofing scheme if any of the sealing mechanisms fails.

As a result of these risks, 'dry' flood proofing was not pursued any further in this assessment. 'Wet' flood proofing was preferred as it is the most affordable and most straight forward to implement. Examples of options for 'wet' flood proofing include utilising plywood flooring rather than particle board, timber lined wall panelling rather than plasterboard, solid timber or plywood joinery and fittings rather than particle board (e.g. in kitchens), tiles or a sanded and polished floor rather than carpets, and elevated electrical power points and switchboard (HNFMSC, 2006).

The same criteria that were used to identify houses potentially eligible for raising were also used to identify houses potentially eligible for flood proofing. However, flood proofing eligibility was extended to include houses of brick and/or slab-on-ground construction as well as two storey residences.

These criteria identified 7 houses potentially eligible for voluntary flood proofing. The location of the houses is shown in **Figure I3** and includes houses in Tacoma, South Tacoma, Wyong and Alison.

Flood proofing cost estimates have been prepared based on retrofitting structural building components up to a level of 1.0 m above floor. This indicates a typical wet flood proofing cost of $58,000 per building. Accordingly, the total cost to flood proof 7 properties is estimated to be $406,000.

Revised flood damage calculations were prepared to determine the reduction in flood damages costs likely to be afforded by the flood proofing. This was completed by preparing revised flood damage curves that reflected reduced damage to structural building components up to a depth of 1 metre above floor level. It was assumed that contents damage remained unchanged.

The revised damage calculations determined that the flood damage costs would be reduced by $228,000 over 50 years. This provides a BCR of 0.49 indicating the financial costs of implementing this option are greater than the reduction in flood damages.

Most the houses that have been identified for flood proofing are two storey dwellings. The economic analysis also assumes that the lower level of each of the houses incorporates no damage reduction measures, which may not be the case (e.g., all habitable areas with higher value contents may be located on the upper level). Given the frequency with which these properties are predicted to be inundated, it likely means that the respective owners may have already undertaken steps to minimise the potential for flood damage to be incurred. If so, the likely financial benefits of flood proofing may be lower than reported here.

Furthermore, there is an opportunity for Council to target those flood liable properties identified for flood proofing as part of the community education program (discussed in Section 9.2.3) to make the residents more aware of the flood risk to their property and educate them on measures they can take to make their property more flood resilient.

Table 31 Evaluation Outcomes for Voluntary Flood Proofing

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-N-	No change in flood behaviour anticipated
Inundated Buildings	-N-	No change in above floor flooding
Financial Feasibility	--	Low BCR
Community Acceptance	+	52% of community support (5% against)
Environmental Impacts	-N-	
Emergency Response	-N-	
Technical Feasibility	-N-	

Recommendation: Not recommended

8.2.4 Wyong Aged Care Facility Modifications

The Wyong Aged Care Facility requires special consideration as part of this study as it can be isolated during relatively frequent floods and is home to vulnerable residents. Although above floor flooding is not anticipated until the 1% AEP flood, access to/from the facility is predicted to be cut in floods as frequent as the 20% AEP event. If, in a large flood, staff and occupants wait until floodwaters are approaching the floor level, it is likely to be too late to evacuate.

Due to the relatively isolated nature of the facility, the use of traditional structural mitigation measures (e.g., levees) to protect this property was not considered viable.

A private flood emergency response plan has been prepared for the facility that sets out protocols for staff and residents to follow before, during and after a flood. It is considered that early evacuation through application of the emergency response plan is the best option for managing the existing flood risk across this property. But early evacuation may not always succeed. The frail nature of many of the occupants would require substantially more evacuation time than would otherwise be the case, which may not be available. Furthermore, the reported mortality rates associated with evacuating patients with dementia, indicates that evacuation may be detrimental to the wellbeing of some occupants (Brown et al, 2012). Therefore, opportunities for property level modifications were investigated as an additional means of mitigating the flood risk for the aged care facility.

The preferred long-term goal would be to relocate this facility out of the floodplain. This would eliminate the stress/burden on occupants and staff during floods and would also reduce the significant burden placed on emergency services. However, it is acknowledged that this will not assist in reducing the flood risk in the short term.

Voluntary purchase was considered to be prohibitively expensive, raising of the property would not be technically viable and flood proofing will provide little reduction to the existing risk, particularly during large floods. Therefore, traditional property modification approaches are unlikely to be viable for the facility.

It is understood that Riviera Health do have plans to expand the facility. Although intensification of development across this facility is not considered desirable, it may present an opportunity to incorporate an elevated on-site flood refuge. This will ideally provide a structurally sound on-site refuge for residents above the peak level of the PMF that could be utilised if early evacuation is not achievable/viable.

Providing a refuge above the peak level of the PMF would require the floor level to be elevated to at least 7.5 mAHD. The existing site is typically located below 5 mAHD. Therefore, the refuge would need to be elevated >2 metres above the existing terrain. Access to this elevated refuge would need to be available to individuals with restricted mobility and when there are potentially power outages. This may require the use of ramps instead of or in addition to elevators and stairs.

The refuge would need to be designed to withstand the hydrodynamic forces of water as well as potential buoyancy effects and debris loading during the PMF. Peak water depths of more than 2 metres and peak flow velocities of around 1 m/s are predicted at the peak of the PMF around the aged care facility.

It is recommended that Council undertake discussions with Riviera Health if/when expansion of the facility is proposed to determine the feasibility of including an elevated flood refuge. However, as noted elsewhere in this report, evacuation is the preferred mitigation measure to employ for any property. The provision of a refuge would only serve as a backup plan in the event that evacuation cannot be completed in a safe manner.

Recommendation: Council to undertake discussions with Riviera Health to determine the potential for including an elevated flood refuge as part of any future development of the aged care facility

8.3 Planning Modifications

8.3.1 Appropriateness of current LEP 2013 zoning

An assessment was undertaken to establish the compatibility of the Wyong LEP 2013 land use zones with the four flood precincts used by Council (refer Section 4.4.2). As discussed in Section 4.4.2, Council makes use of the “Low” and “High” hazard categories defined in the ‘Floodplain Development Manual’ (NSW Government, 2005) as part of the flood precinct definitions, while the current study has defined hazard based upon the more contemporary H1 – H6 categories presented in the *Australian Disaster Resilience Guideline 7-3 Flood Hazard”* (AIDR, 2017). As part of this assessment, the following definitions were used to convert the H1-H6 categories into an equivalent low/high classification:

- Low Hazard: H1 – H2
- High Hazard: H3 – H6

The results of this assessment are presented in **Plate 16**.

In general, the LEP 2013 land use zones appear to be compatible with the flood hazard precincts.

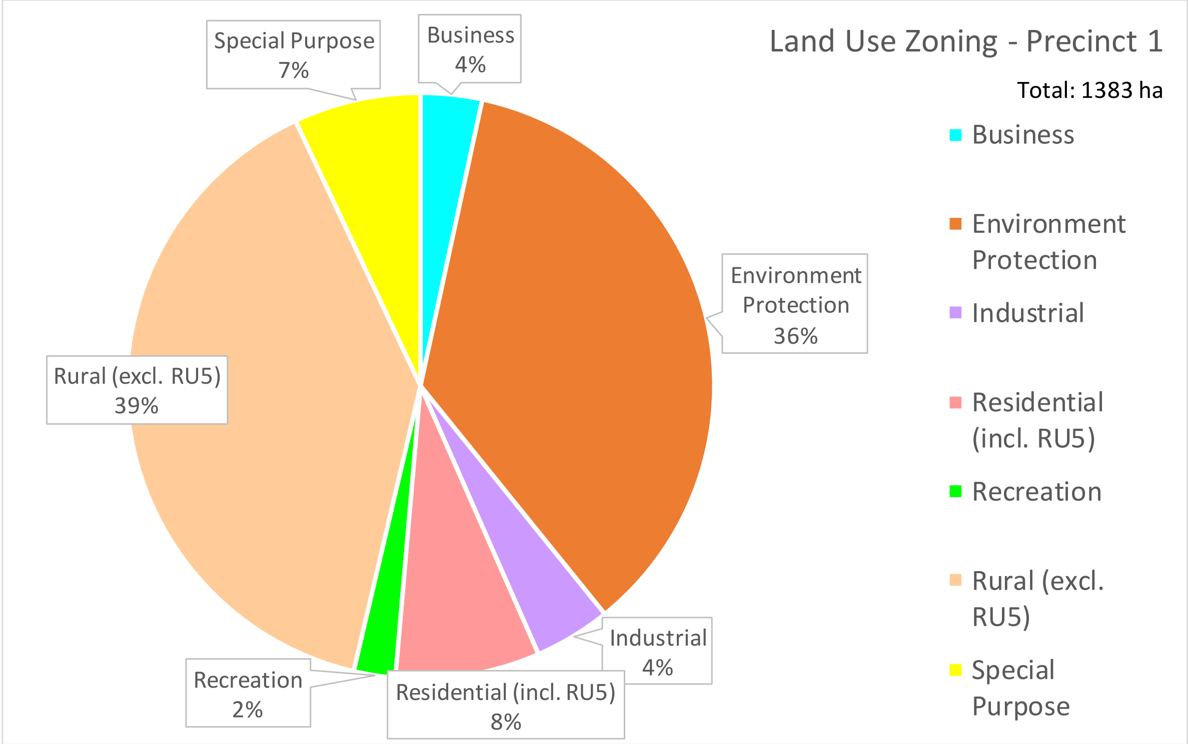
Negligible residential, commercial or industrial development is located in Flood Precinct 4. There is a relatively small area of land zoned for residential use located subject to this high flood hazard. Much of this is in Linga Longa Road in Yarramalong, which is zoned as Rural Village (RU5).

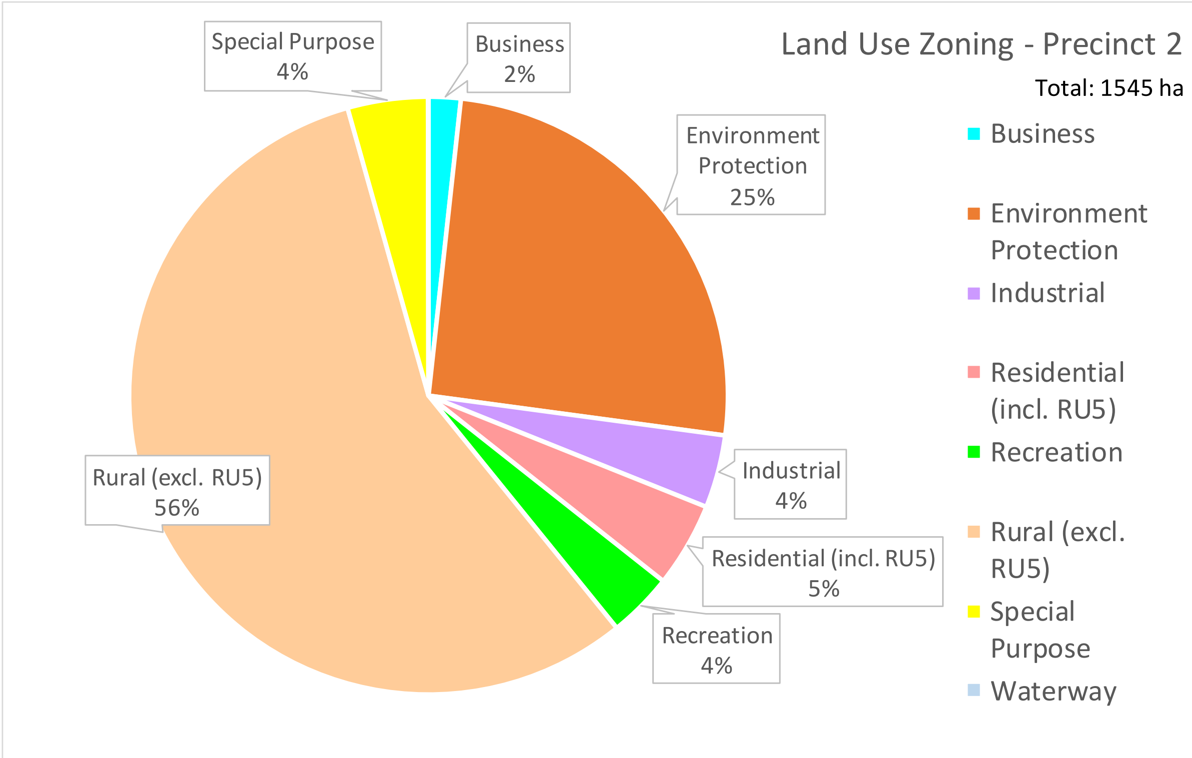
A higher proportion of Flood Precinct 3 is given over to residential uses, including many properties in Tacoma and South Tacoma. Riverside houses in Golding Grove, Wyong, are also located in Precinct 3, zoned as Environmental Management (E3).

Meander Village in Wyong is largely in Precinct 3 but is zoned as Private Recreation (RE2). This zone permits caravan parks with consent. However, Meander Village has evidently evolved from a caravan park into a manufactured home estate marketed at over 50’s residents, which is not desirable for this degree of flood hazard. If the zoning was changed to a zone under which caravan parks are prohibited the existing use rights provisions under the *Environmental Planning & Assessment Act* could apply. If there was a lawful consent for the caravan park it could continue operation but the existing use rights provisions would limit the expansion of the caravan park. The current zoning permits caravan parks so therefore could permit an application to be lodged for expansion or intensification; however, such a proposal will generally not be encouraged/ supported by Council under the current DCP provisions.

Much of the residential area of Wyong east of Leppington Street is located in Flood Precinct 2, as are many of the dwellings in Kooindah Waters resort, which are zoned for Tourist use (SP3).

The Wyong Aged Care Facility is located in Precincts 2, 3 and 4, but evacuation would be difficult due to the early loss of egress. It is zoned as Environmental Management (E3), which does not appear to permit such a sensitive use. Presumably its use pre-dates the current zoning.


Land Use Zoning - Precinct 1
Total: 1383 ha
Special Purpose 7%
Business 4%
Environment Protection 36%
Rural (excl. RU5) 39%
Industrial 4%
Recreation 2%
Residential (incl. RU5) 8%
Business
Environment Protection
Industrial
Residential (incl. RU5)
Recreation
Rural (excl. RU5)
Special Purpose


Land Use Zoning - Precinct 2
Total: 1545 ha
Special Purpose 4%
Business 2%
Environment Protection 25%
Rural (excl. RU5) 56%
Industrial 4%
Residential (incl. RU5) 5%
Recreation 4%
Business
Environment Protection
Industrial
Residential (incl. RU5)
Recreation
Rural (excl. RU5)
Special Purpose
Waterway

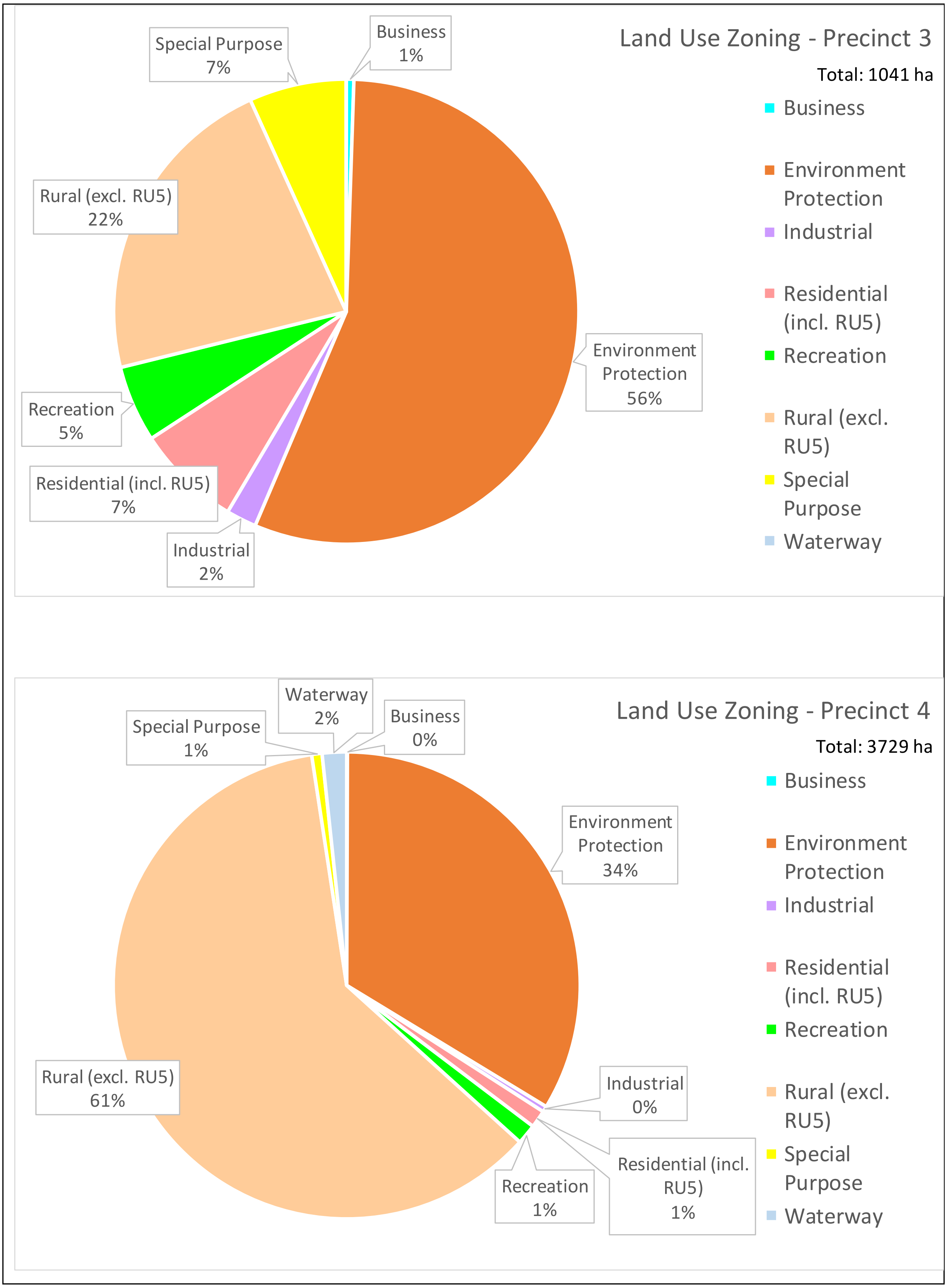


Plate 16 Proportion of flood precincts by LEP land use category

Apart from some of the locations noted above, the LEP zoning appears to be broadly appropriate. That is, there is no obvious need for modification to the current LEP zones. Nevertheless, intensification of land uses below the flood planning level (in particular, those locations highlighted above), should be discouraged.

Recommendations: No modifications to LEP zoning maps considered necessary

8.3.2 Requirement for 'appropriate justification' / 'exceptional circumstances'

As discussed in section 4.3.1, councils must not impose flood-related development controls above the residential flood planning level (i.e., the 1% flood level plus 0.5m freeboard), unless there is 'adequate justification' under S117 Direction No. 4.3 (see Section 4.3.1) or 'exceptional circumstances' under the 2007 Guideline (see Section 4.3.3) It is unclear whether a planning control requiring a residential floor level or a portion of a residential floor level at the level of the PMF (as is desirable for facilitating safer on-site refuge), when applied to dwellings *within* the Flood Planning Area (FPA) as defined by the 1% AEP flood plus 0.5m freeboard, would trigger the requirement for adequate justification/exceptional circumstances. Council will need to seek written clarification from the Department of Planning and Environment as to whether 'exceptional circumstances' are required to effect controls for such a scenario. The desire to apply flood-related development controls to dwellings located between the FPA and the PMF extent certainly *would* trigger this requirement.

An assessment was completed to determine if and where 'exceptional circumstances' may be appropriate for flood-related development controls on residential development on land outside of the FPA. 'Exceptional circumstances' for such areas may be required where there is an unacceptably high flood risk. This was considered by:

1) comparing the extent of the FPA with the PMF,
2) calculating the flood height range between the 1% AEP flood and the PMF,
3) considering whether based on existing housing stock, people could be expected to survive inundation of their houses in a PMF.

In many parts of the study area, the PMF extent is not significantly greater than the FPA – in some places sampled, it is about 60 metres or 10% wider (e.g., Yarramalong Valley). However, this is still sufficiently wide to fully contain a house, which has a flood risk that needs to be considered.

The flood height difference between the 1% flood and the PMF varies across the study area, reaching:

- >4.0m in some parts of the upper Yarramalong Valley
- 3.8m to 2.7m at Wyong between the Pacific Motorway and Pacific Highway
- 3.5m to 2.0m in the 'Mardi rural' area,
- 3.5m to 1.5m around the northern and eastern fringes of Mardi residential area
- 3.2m to 1.4m in the Tuggerah Industrial area (north to south) and
- 3.0m to 1.4m at Wyong east of the Pacific Highway
- 1.5m to 0.4m at Tacoma

- 1.4m to 0.4m at South Tacoma.

Once flood height differences exceed about 2.5m (i.e., >2.0 metres above the FPL) serious consideration must be given to the need for 'exceptional circumstances' due to the high potential risk to life and the potential for structural damage to buildings. As noted in Section 5.4.2, there are many tens of houses in the study area, located beyond the FPA, where early evacuation would be required to manage the risk to life in an extreme flood due to the potential for structural failure of buildings.

If Council wishes to better manage risk to life for future residential developments in areas beyond the FPA but where high hazard conditions are expected during the PMF, it is recommended that it pursue an application for the granting of "exceptional circumstances" permitting Council to include residential development in Clause 7.3(3) of its LEP. The intention of this provision would not be to sterilise development in this area but to ensure new dwellings are designed in a manner such that the risk to life in an extreme flood would be managed satisfactorily either through a rising egress route from the dwelling to high land (without the need to step down into deeper water) or through the provision of a dwelling able to withstand extreme flooding and with some floor space above the PMF to which the occupants could retreat.

Figure I4 in **Map Set I** shows the extent of the area beyond the PMF where the need for 'exceptional circumstances' should be considered. **Figure I4** was prepared by mapping areas beyond the FPA that are exposed to a hazard category greater than H3 during the PMF. The most significant 'exceptional circumstances' area (in terms of extent of area beyond the FPA) is actually contained within the Porters Creek catchment, which falls outside the study area for this project. Nevertheless, there are some areas (most notably Yarramalong Village) where the 'exceptional circumstances' area is sufficiently wide to contain a residential allotment.

Recommendations:
1) Seek written clarification from the Department of Planning and Environment as to whether 'exceptional circumstances' are required to effect controls for PMF refuges in dwellings located on land within the Flood Planning Area.
2) Consider applying for 'exceptional circumstances' to better ensure risk to life is managed satisfactorily in those parts of the floodplain located between the Flood Planning Area and the PMF extent, where PMF hazard is greater than H3.

8.3.3 DCP Revision

A detailed review of the floodplain management chapter of Wyong DCP 2013 was prepared in Section 4.4.2. It is recommended that Council consider the review when next amending the DCP (or when it combines the Wyong DCP with Gosford DCP to form a singular Central Coast DCP chapter for flood risk management). Among the suggested changes are:

- Consider emerging best practice for mapping Flood Planning Constraint Categories;
- Indicate in the prescriptive criteria matrix where development is *unsuitable*;
- Review and update the climate-change related provisions;

- Require houses in Precinct 2 to provide safe access/egress (or an on-site refuge above the PMF, where appropriate); and,
- Prepare different flood risk matrices for different styles of flooding within the LGA (e.g., flash flooding versus riverine versus coastal inundation).

Recommendations: Amend Wyong DCP considering the detailed review presented in Section 4.2.2 of this report.

8.4 Recommendations

The following property modification options have been evaluated as part of the study and are considered viable for further consideration to assist in managing the existing and future flood risk across the Wyong River catchment (refer **Table 32**):

- Pursue opportunities for incorporating PMF refuge at Wyong Aged Care Facility;
- Seek clarification from the Department of Planning and Environment about the need for 'exceptional circumstances' to facilitate on-site refuge above the PMF for dwellings on land below the FPL;
- Consider applying for 'exceptional circumstances' for land above FPL; and,
- DCP amendments.

Table 32 Evaluation matrix for Property Modification Options

Option	Evaluation Criteria / Score#							
	Hydraulic Impacts	Inundated Buildings	Financial Feasibility	Community Acceptance	Environmental Impacts	Technical Feasibility	Emergency Response	Recommended for Further Consideration?
Voluntary House Purchase	**-N-**	**+**	**--**	**+**	**+**	**+**	**-N-**	**Council to undertake discussions with property owners**
Voluntary House Raising	**-N-**	**+**	**--**	**-N-**	**-N-**	**-**	**-**	
Voluntary Flood Proofing	**-N-**	**-N-**	**--**	**+**	**-N-**	**-N-**	**-N-**	**No**
Wyong Aged Care Facility Refuge	Not evaluated as part of study							**Yes**
LEP Amendments	Not evaluated as part of study							**No**
Exceptional Circumstances	Not evaluated as part of study							**Yes**
DCP Amendments	Not evaluated as part of study							**Yes**

Refer to **Table 20** for evaluation criteria and scoring system

9 RESPONSE MODIFICATION OPTIONS

9.1 Introduction

It is generally not economically feasible to treat all flood risk up to and including the PMF through flood modification and property modification measures. Therefore, response modification measures are implemented to manage the residual / continuing flood risk by improving the way in which emergency services and the public respond before, during and after floods. Response modification measures are often the simplest and most cost-effective measures that can be implemented and, therefore, form a critical component of the flood risk management strategy for the catchment.

Response modification options considered as part of the study include:

- Emergency response planning
- Options to improve emergency response during a flood
- Options to aid in post-flood recovery

Further discussion on response modification options that could be potentially implemented is provided below.

9.2 Emergency Response Planning Options

Effective planning for emergency response is a vital way of reducing risks to life and property, particularly for infrequent floods that are not managed through flood or property modification measures. Potential opportunities for improvements to existing emergency response planning are discussed below.

9.2.1 Local Flood Plan Updates

Wyong Shire Local Flood Plan was reviewed in Section 5.1. The review determined that the Plan needs to be updated to align the structure and contents with the new NSW SES Local Flood Plan template, and to incorporate flood intelligence from recent flood studies, floodplain risk management studies, and actual floods. Among the flood intelligence available from the current study is:

- Design flood extents, depths, velocities, hazard and warning times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and
- Evacuation constraints in design floods up to PMF.

Recommendations: Update Wyong Local Flood Plan to align with new SES LFP template and to incorporate new flood intelligence (NSW SES)

9.2.2 Flood Intelligence Card Updates

The Wyong Bridge Flood Intelligence Card needs to be updated to incorporate outputs from the latest design flood modelling as well as potential changes to hydraulic behaviour expected to result from a proposed Pacific Highway upgrade.

If other river level recorders will be used as triggers for various communities such as Yarramalong village, it is also recommended that simple flood intelligence cards be prepared for these using historical and design flood information.

Recommendations:
1) Update Wyong Bridge Flood Intelligence Card to align with new flood modelling and Pacific Highway Bridge upgrade (NSW SES)
2) Prepare new flood intelligence cards for any river level gauges proposed to be used as triggers for communities/users (e.g. Yarramalong gauge) (NSW SES)

9.2.3 Community Education

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'* (Keys, 2002).

Based on learnings from 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 consisting only 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 experiential 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 de-briefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and planning; 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 gains that have been made.

SES Community Education Strategy

The SES developed a *Flood & Coastal Storms Education Strategy* (2011) that aims to build community resilience by improving the capacity of the Central Coast community to better prepare, respond and recover from major floods. The document aims to achieve this by developing an effective community education strategy.

A review of the *Flood & Coastal Storms Education Strategy* was completed as part of the current study. It describes different styles of flooding on the Central Coast, eight objectives, three target groups and stakeholders. Key messages are described to achieve each objective. These include, 'Never enter floodwaters', 'Have a home or business FloodSafe plan', 'Know your evacuation route' and 'Do not rely on being rescued'. Various activities are listed and prioritised to convey the messages, including signage, a Business Breakfast, website, newspaper features, radio spots, a FloodSafe brochure, school newsletters, displays, SES days and street barbeques. How many of these activities have been conducted, and the degree to which they have succeeded in changing attitudes and behaviours such that people are more resilient, is not known, suggesting the need for an audit.

> **Recommendations**: Audit the degree to which the *Flood & Coastal Storms Education Strategy* (2011) has been implemented and the relative success of these strategies (NSW SES)

Education Messages

From the flood risk assessments, the community questionnaire and discussions with stakeholders, a number of key messages emerge for people in the study area:

- 'Never drive, ride, walk or play in floodwaters'. The need to continue broadcasting this message is suggested by the knowledge that motorists in NSW continue to lose their lives when attempting to cross floodwaters, and by the number of roads in the study area that are frequently flooded, especially between Wyong and Yarramalong. Messages could also provide technical information to dissuade drivers from crossing flooded roads, such as the depths at which cars float[4] and emphasise that driving through even shallow water can generate significant waves which will increase the potential for above floor flooding/damage from floodwaters across adjoining areas. Messages could also target the motivations for crossing floodwater, pointing out that it's better to arrive home late than not at all. Messages could also include comments on the impact of waves and wash created by vehicles travelling through floodwaters on buildings, infrastructure and stationary objects in the floodplain.

[4] See http://www.abc.net.au/news/2016-06-18/research-shows-cars-deadly-in-floodwaters/7522798

- ‘One day a bigger, faster flood will happen than what anyone has ever seen. Council has modelled what these floods might be like. Learn whether your house/business could be flooded in an extreme flood. Identify whether it’s safe for you to stay or whether you need to evacuate before flooding. Plan ahead to keep your family/staff safe’. A message such as this is important because of the high proportion of respondents to the questionnaire who indicated they would remain at home rather than evacuate (Section 2.5). While such a response might have worked for the relatively small historical floods people have observed, it could lead to disaster in an extreme flood (Section 5.4.2).
- ‘Evacuation needs to occur before roads are submerged by floodwaters’. There is an obvious reluctance for people to evacuate from the imminent threat of flooding if they cannot see the floodwater themselves. However, in this catchment, many access roads become inundated by floodwaters long before floodwaters reach residential or commercial properties, subsequently isolating these properties and necessitating residents to drive through floodwaters if they choose to evacuate later. Therefore, the education messages really need to emphasise that early evacuation from these areas is the only safe evacuation option. This message also needs to acknowledge the residents concern to leave their property and valuables behind, so as part of the development and update of the education and evacuation strategies from these areas, safety of property needs to be catered for by the authorities (SES/police etc) and conveyed to the residents.

Recommendations: Develop educational messages targeting dangerous behaviours (NSW SES)

Property Level Flood Information

A starting point for improving people’s readiness for floods is to help them better understand how they could be directly affected by floods. Knowing how their house or business could be directly affected by floods is more likely to cut through the scepticism that can grow when communities are not flooded for some years, than more generic advice.

Advancements in flood modelling software and associated spatial datasets has significantly enhanced the quantity and quality of information from flood studies and floodplain risk management studies available at the property level. Council already makes Flood Precinct mapping extents available via the Wyong Council On-line Mapping System. Therefore, the existing information provided on Council’s online mapping page could be expanded to convey additional flood hazard information including design flood depths, hydraulic hazard, information describing when and where access to individual properties will be cut as well as special risk factors such as the location of “low flood islands”. But additional resources would be required to explain what this information means and how it could be used to assist in the preparation of property level flood response plans. In addition, to help residents and business owners interpret the meaning of floods in real-time, design and historical flood levels at river gauges in the study area could be made available.

If Council’s existing mapping website cannot accommodate this information, it could be included in a separate flood information portal website (refer to discussion in the following section). However, as reported by one community member, there is some uncertainty within the community about where to source flood information (including flood warnings).

Therefore, it is considered desirable to avoid distributing flood information across multiple sites to help ensure this uncertainty is avoided (i.e., hold all flood information on a single website).

The high level of detail available from the Emergency Response Planning Classification tool also makes it possible to prepare customised flood information flyers, fridge magnets etc for individual properties. These flyers/magnets can be printed by specialist printers using mail merge techniques to provide property level information for all potentially flood liable properties. Alternatively, the flyers/magnets can be generated via a website and individual property owners can print their own. Information that could be potentially included on a customised flyer/magnet may include:

- A river gauge diagram (for the closest river gauge) showing the peaks of past floods and information on the gauge level typically coinciding with any cut of the evacuation route for the property.
- The closest evacuation centre, approximate driving distance and even the best route. This could even be presented as a map.
- Identification of any special risk factors such as being in an area that may get surrounded by floodwaters or an area at risk of flash flooding.

Software, such as WaterRIDE™, can also automate the preparation of documentation summarising key flood parameters at the property scale including graphics depicting inundation extents. An example of property level flood information generated by WaterRIDE™ is shown in **Plate 17**.

It is noted that at the time this report was being prepared, Council is developing a Flood Information Tool (FIT). This tool could be an alternate way in which the property level flood information could be disseminated. However, the tool was not sufficiently advanced to be reviewed as part of the current study.

Pending the outcomes of the FIT project, Council may be interested in undertaking a pilot project across a small section of the catchment (e.g., Yarramalong village) to determine the effectiveness of providing this type of property level flood information. It is suggested that the pilot project employ multiple communication techniques (e.g., letters, fridge magnets, online portal) and include a brief survey to seek feedback on which option(s) the community prefers. If feedback from this pilot project is positive, opportunities to extend the project to include all potentially flood liable properties or, as a minimum, high risk properties, could be explored.

Recommendations:

1) 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 (Council; NSW SES)

2) Consider undertaking a pilot project involving the distribution of property level flood information to a small section of the catchment (Council)

A City Council Flood Certificate

31/08/2016

My Company
My Street
My Town

Attn: My Name

Dear Sir/Madam,

Property:	**LOT 21 : DP 123456**
Address:	**123 Main Street, Any town**

The information supplied in this certificate represents the most current flooding information held by Council at the time the certificate was created.

The current flood information adopted by Council includes the Town Creek Flood Model Study, September 2013, and the Upper Valley Flood Study Review and Model Upgrade, December 2010.

The following flood information relates to this property:

	20 Year ARI Flood	100 Year ARI Flood
Max. Water Level (m AHD)	23.86	24.35
Min. Water Level (m AHD)	23.81	24.29
Max. Water Depth (m)	2.26	2.75
Min. Water Depth (m)	0.63	1.12
Max. Velocity (m/s)	3.94	5.70
Min. Velocity (m/s)	0.03	0.04
Max. Hazard (H1 to H6)	H6	H6
Min. Hazard (H1 to H6)	H3	H3

ARI = average return interval (a 100yr ARI flood has a 1% chance of occurring in any given year)
Level = elevation of the flood surface above Australian Height Datum (AHD)
Depth is based on 2013 LiDAR aerial survey data
Velocity = speed of the flowing flood water
Hazard= potential for floodwaters to affect vehicles, wading by an adult, damage to a house, damage to industrial buildings
The maximums relate to the highest value around the perimeter of the property parcel

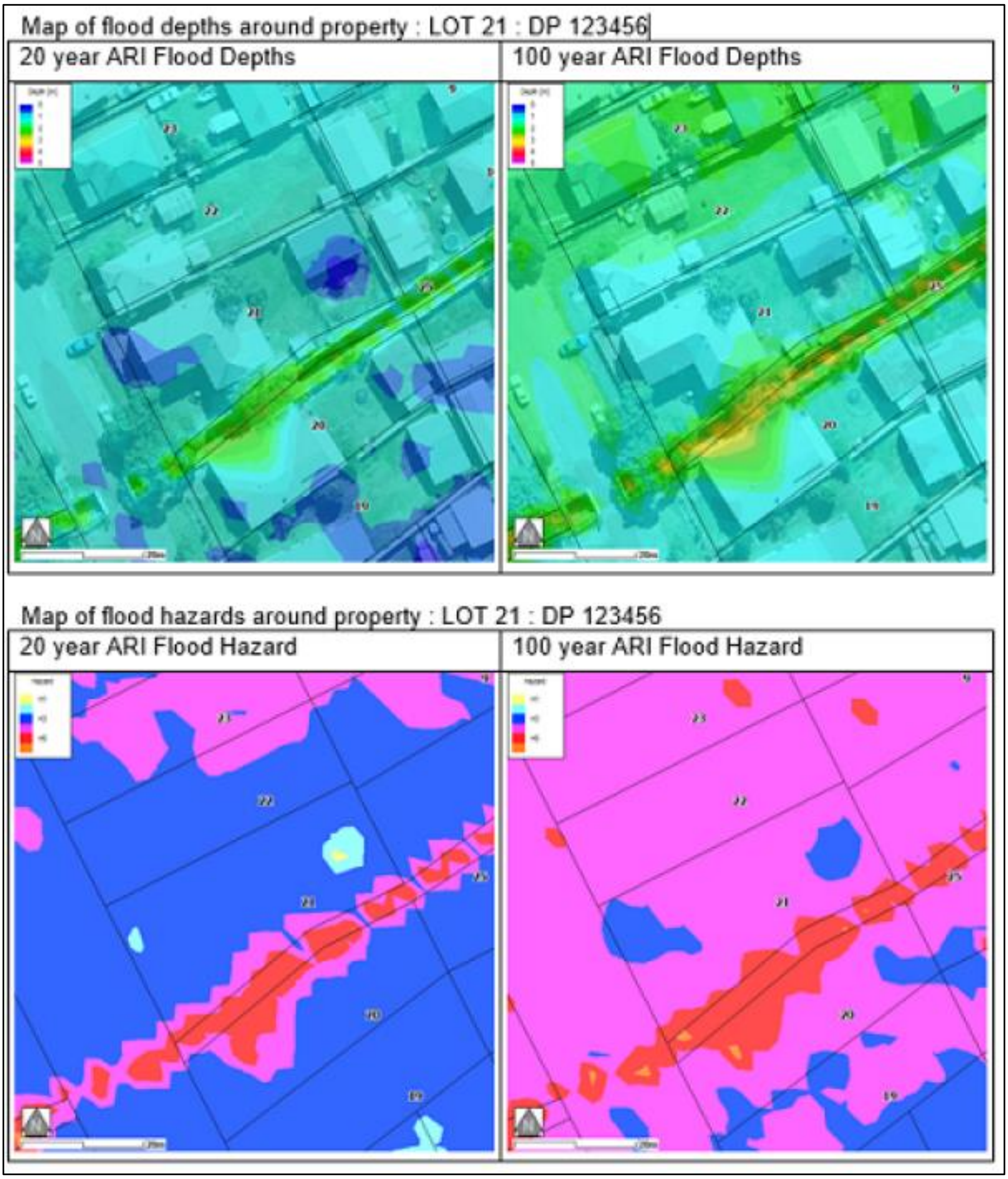


Plate 17 Example of property level flood information (images provided courtesy of Advisian)

Flood Information Portal

As discussed, the development of a flood information portal is likely to be an effective means of emergency response planning by facilitating the widespread distribution of flooding information to emergency services as well as the public. This could be facilitated by expanding Council's existing online mapping site or through the development of a separate website dedicated specifically to flooding across the Wyong River catchment.

A flood information portal would aim to provide the following:

- Information that will allow property owners to understand their existing flood risk which can "feed" into the preparation of a flood plan
- Real time flood information that can be accessed during floods (e.g., flood warnings, current & projected water levels at gauges).

An advantage of websites is their ability to be a living document incorporating current information sources such as flood mapping, BoM flood warnings, live information on nearby river and rain gauges and the latest advice from relevant organisations such as the SES and RMS. Therefore, assuming the website is maintained, it can serve as a central repository for a range of contemporary flood information.

Some of the potential capabilities of flood portals in order of increasing complexity are:

- 'Pull' style (on demand user requested) distribution of generic and regionalised flood information flyers;
- 'Pull' style re-broadcasting of relevant information such as flood warnings and SES alerts;
- 'Push' (based on prior opt-in or subscription) of information based on email / SMS subscription lists;
- Generation of customised flood information flyers for individual properties;
- Showing 'live' river and rainfall gauge information in the context of past floods and peak rainfall events. This can also include live identification of flooded roads and identification of alternative flood evacuation routes for any point in the catchment; and,
- Integration with rainfall forecasting systems and real time flood modelling to predict the extents and timing of the current flood and generate required warnings.

Recommendations: Undertake a flood information portal pilot study to develop basic web site. Functionality could be expanded as funding becomes available (Council)

9.2.4 Emergency Response Plans

Flood Plans for Major Facilities

There would be benefit in NSW SES and Council encouraging and helping key floodplain exposures to prepare or update their own flood emergency response plans, taking advantage of the superior flood behaviour information generated from the current study. Among the higher priorities for flood plans are:

- Wyong Aged Care Facility, McPherson Road, Mardi (see also Cardno, 2015);
- Wyong Christian Community School, Alison Road, Wyong;
- C3 Church, Gavenlock Road, Tuggerah;
- Meander Village, Boyce Avenue, Wyong.

Other facilities that may benefit from the development of flood plans are described in Section 3.2.8.

In addition, it is recommended that Council notify major infrastructure providers, such as Ausgrid, advising of the revised study and the potential to provide revised flood information for their assets. This will ideally assist in providing each asset owners with an improved understanding of the flood exposure of their assets and explore opportunities for improving the level of service afforded by these important facilities during times of flood.

<u>Recommendations</u>: Assist the following facilities to prepare or update their own flood emergency response plans incorporating new flood intelligence (NSW SES, Council):

1) Wyong Aged Care Facility, McPherson Road, Mardi (see also Cardno, 2015);
2) Wyong Christian Community School, Alison Road, Wyong;
3) C3 Church, Gavenlock Road, Tuggerah;
4) Meander Village, Boyce Avenue, Wyong.

Council should also approach key infrastructure providers with revised flood intelligence information (Council)

Home Flood Plan Preparation / Updates

It is unlikely that many private dwellings within the floodplain have formal flood emergency response plans. This requires innovative approaches to persuade residents to plan ahead for floods. It is considered that the most effective method, albeit a labour-intensive method, will be via direct outreach from the NSW SES to particular communities and residents. The SES could, with Council's assistance, host flood planning mornings or evenings in various communities, including in Yarramalong village, Wyong Creek, Wyong (western side), Wyong (eastern side), Tacoma, Mardi (rural), Mardi (urban) and South Tacoma. Council could staff the meetings with laptops enabling the inspection of flood risks at property scales (booking times might be required to ensure adequate resources are made available), and SES personnel could then help homeowners translate that information into effective home emergency plans. Prior to these public information sessions, there would need to be an acceptance from official stakeholders that on-site refuge may be acceptable and even preferred at some sites (and is generally preferred by residents, especially those caring for animals), rather than a general insistence upon evacuation.

Evacuation planning for these residential areas need to consider other issues that may impact on a person's ability or willingness to evacuate, such as animals and valuables, and include them in the evacuation plan. Past practices during flood events indicate residents are often hesitant to leave pets behind, or are scared of potential looting should they evacuate, and so choose to stay rather than evacuate when requested to do so. Inclusion of these considerations in a home flood plan prior to a flood is a good way to ease the concern a resident may have when they are forced to make decisions in difficult circumstances in future as well as make them aware that particular authorities have formal roles to fulfil these concerns during such an event.

Recommendations: Host meetings in various communities to promote the preparation of Home Emergency Plans (NSW SES; Council)

Business Flood Plan Preparation / Updates

Businesses across flood liable sections of the catchment would benefit from flood plans. The plans set out protocols to follow by the business before, during and after a flood to help mitigate damages and the potential for risk to life at the property level. The preparation and implementation of such plans is an important risk management option across particularly flood liable sections of the catchment (e.g., Tuggerah industrial area).

Although flood plans may have already been prepared for some businesses, they need to be reviewed and updated regularly to ensure all staff remain fully aware of the requirements of the plan and to ensure the plan takes advantage of the latest available information. As for private flood plans, Council should be able to provide significant information describing the flood risk at the property scale based on the outputs from this study including the potential frequency and depth of inundation as well which roadways will be cut and the likely duration of any isolation. If updates are completed to the flood warning system (refer Section 9.2), this information should also be reflected in updated flood plans.

In the first instance, an audit could be conducted to confirm if each business across the Tuggerah industrial area has developed a business flood plan. There may be opportunities for the Wyong Regional Chamber of Commerce to assist in this regard. The SES has developed a Business FloodSafe Toolkit to assist with the preparation of Business FloodSafe plans. These can be completed either online or as a hardcopy (see http://www.floodsafe.com.au/what-floodsafe-means-for-you/business).

Following the audit, an SES Business Breakfast could be hosted to promote the development or updating of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process. (Note, this was one of the activities proposed in the *Flood & Coastal Storm Education Strategy* (refer discussion in Section 9.2.3), which has yet to be carried out). A prize could be offered as an incentive to complete the plans. A follow up audit/breakfast could then be completed at a later date (say, 6 months later) to ensure that the FloodSafe plans have been developed/updated.

Council could also consider regulation to promote the development of a business flood plans when businesses change ownership / use (see Section 8.3.3).

Recommendations: Conduct an audit and host a Business FloodSafe Breakfast to promote the preparation of Business FloodSafe Plans (NSW SES; Council)

9.3 Options to Improve Emergency Response During a Flood

9.3.1 Flood Warning System

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. An effective flood warning system requires integration of a number of components (Australian Government, 2009):

- monitoring of rainfall and river flows that may lead to flooding;
- prediction of flood severity and the time of onset of particular levels of flooding;
- interpretation of the prediction to determine the likely flood impacts on the community;
- construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken;
- dissemination of warning messages;
- response to the warnings by the agencies involved and community members; and,
- review of the warning system after flood events.

Where effective flood warnings are provided, risk to life and property can be significantly reduced. Studies have shown that flood warning systems generally have high benefit-cost ratios if sufficient warning time is provided and if the population at risk is aware of the threat and prepared to respond appropriately.

The Bureau of Meteorology issues a number of products that provide warning of floods, including Severe Weather Warnings for torrential rain and/or flash flooding, and Flood Watches that typically provide 24 to 48 hours' notice that flooding is possible based upon current catchment conditions and forecast rainfall.

The Wyong River is also serviced by a quantitative flood warning system. As indicated in the NSW State Flood Sub Plan, the Bureau of Meteorology issues height-time predictions for the Wyong River at Wyong Bridge as well as for Tuggerah Lake (see **Table 33**). The aim of this system is to provide six hours' warning of minor flooding (2.7m) at the Wyong Bridge gauge.

Table 33 Flood Warning Gauges

Bureau number	AWRC number	Forecast location	Station owner	Gauge type	Flood classification (mAHD)			Prediction type	Target warning lead time		70% of peak forecasts within	Local Flood Advices provided by SES
					Minor	Moderate	Major		Time (hrs)	Trigger height (m)		
561025	211002	Wyong	Local Council	Auto	2.7	3.8	4.0	Quantitative	6 hrs	>2.7m	+/- 0.3m	
561001	211418	Tuggerah Lake – Long Jetty	MHL	Auto	0.9	1.8	2.2	Quantitative	6 hrs	>0.9m	+/- 0.3m	

Sources: NSW State Flood Sub Plan March 2015, Volume 3 Flood Planning Arrangements and Gauge Warning Network; Bureau of Meteorology 2013, Service Level Specification for Flood Forecasting and Warning Services for New South Wales Version 2.

However, the analysis of effective warning times in **Table 15** showed that the formal flood warning system may not provide sufficient time to evacuate before roads are cut for some floods across much of the floodplain, including the Yarramalong Valley, Dooralong Valley, Wyong west of the Pacific Highway, South Tacoma and the “Mardi rural” sector. In addition, flooding in the upper catchment and from Mardi Creek would be considered “flash” flooding with minimal opportunities to issue flood warnings.

There is a need to enhance the flood warning system, because in an extreme flood, early evacuation would be vital for reducing the risk to life (Section 5.4.2). The community has also indicated its strong support for improved flood warning systems, with 87% of respondents to the questionnaire in favour.

The opportunity to enhance the flood warning system was considered for each of the phases of the total flood warning system. The Bureau of Meteorology’s new Flash Flood Advisory Resource (FLARE) was used as a resource for this analysis. FLARE includes a method of assessing risk. A 1% AEP flood (‘unlikely’ likelihood) would cause damage to multiple residential and commercial properties (‘high’ consequence), which translates to a ‘medium’ risk. FLARE suggests that a medium risk requires an ‘advanced’ flash flood warning system. Elements of such a system are depicted in **Table 34**. (These components may not all be required since Wyong River is already serviced by a flood warning system. However, it helps to clarify potential areas for investment).

Monitoring and Prediction

The Wyong River catchment is well serviced by both rain gauges and water level recorders, which are used for the Bureau’s formal flood prediction system. Readings for most of these gauges are posted in near real-time upon websites (see **Table 35**, **Table 36** and **Figure A18**). This density of the hydrological monitoring network suggests that no additional gauges are required. But there is potential to make real-time information more readily accessible, perhaps through a flood portal, that brings together *all* available real-time data, or through the automatic dissemination of warnings (at the very least to the emergency services, but preferably to any community subscribers too) when pre-determined water level or rainfall triggers are reached.

Interpretation

The flood modelling carried out for this study provides a robust basis for linking triggers to impacts on the ground. Design flood levels at nearby river gauges could be provided to the community, along with design flood depths at their houses/businesses, to aid their own interpretation of possible impacts. Historical levels could also be included, where available, to provide some real word context.

Message Construction

The SES could pre-prepare warning messages suitable for specific locations in the valley, such as Yarramalong village (for which a trigger could be based on Yarramalong river gauge) and South Tacoma (for which early evacuation may be required). Ready-Set-Go phases may, however, differ, for different locations, households and vulnerabilities – some actions will be required even upon issuance of a Flood Watch, since insufficient time could be available if actions are delayed until a river level trigger is reached.

Table 34 Components of an advanced flash flood warning system

Total Flood Warning System element	Advanced Flash Flood Warning System components
Monitoring and Prediction	• Severe weather warnings • Severe Thunderstorm Warnings • Flood Watches • Access to real-time information from weather radar. • Real-time information from rain gauges installed in the flash flood area. • Rainfall triggers (depth/duration e.g. 30mm in an hour) set to warn of onset of flooding. • Real-time information from river gauges installed in the flash flood locality. • READY (monitor), SET (prepare), GO (act) based on Bureau warnings, observed rainfall triggers and observed river level triggers respectively.
Interpretation	• Some flood studies and flood modelling/mapping may have been carried out. • Interpretation from historical data and SES flood intelligence to link triggers to impact on the ground.
Message Construction	• Standard Bureau messages for weather warnings and flood watches. • Predefined flash flood warning messages for READY, SET, GO phases.
Communication	• Bureau warnings and information available on the web, and broadcast by the media. • Direct and automatic dissemination of warnings to the affected community e.g. via SMS
Response	• Generally proactive community and SES response underpinned by local recurrent public flood awareness and education program. • Good community awareness of flooding and personal actions required; some community members have personal flood plans prepared. • A Municipal Flood Emergency Plan (MFEP) or response plan exists but has gaps or requires updating.
Review	• Review performance of the system (including each individual element) after each significant flash flood event. • Regular and scheduled reviews of the readiness and maintenance of system components such as gauges, communications, public education and planning.

Source: FLARE (Bureau of Meteorology)

Table 35 Automatic Rain Gauges in or near Wyong River Catchment

Name	Number	AWRC number	Owner	Latitude	Longitude	Real Time Data?		
						BoM	MHL	NoW
Yarramalong at Bumble Hill Road	561137		MHL	-33.225	151.270		☑	
Whitemans Ridge at Watagan's Forest Drive	561026		MHL	-33.203	151.322	☑	☑	
Sterland at Red Hill Forest Road			MHL	-33.289	151.307		☑	
Kulnura at George Downs Drive	561078		MHL	-33.232	151.216		☑	
Mardi Dam at Old Maitland Road	561082		MHL	-33.297	151.400		☑	
Kulnura (Jeavons)	61382		BoM	-33.1681	151.2181	☑		
Gears (Wyong River)	61383	211911	BoM	-33.2528	151.316	☑		
Wyong (Olney Forest)	61385		BoM	-33.0776	151.3417	☑		
Mangrove Mountain AWS	61375		BoM	-33.2894	151.2107	☑		
Jilliby (Jilliby Creek)	61380	211010	BoM	-33.2486	151.39	☑		☑
Wyong R D/S Bridge	561025		BoM	-33.29	151.4236	☑		
Kangy Angy (Ourimbah Creek)	61384	211990	BoM	-33.3319	151.3833	☑		

Table 36 Automatic Water Level Recorders in or near Wyong River Catchment

Name	Number	AAWRC number	Owner	Latitude	Longitude	Real Time Data?		
						BoM	MHL	NoW
Wyong River at Yarramalong	561031	211014	NSW Office of Water	-33.2169	151.2761	☑		☑
Wyong River at Gears	061383	211911	Council	-33.2528	151.316	☑		
Wyong River at Gracemere	561038	211009	NSW Office of Water	-33.2692	151.3614	☑		☑
Jilliby Creek at Jilliby	061380	211010	NSW Office of Water	-33.2442	151.3921	☑		☑
Wyong River at Upstream Wyong Weir	561066	211417	MHL	-33.277	151.406	☑	☑	
Wyong River at Wyong Fishway		211017	NSW Office of Water	-33.27781	151.4064			☑
Wyong River U/S Bridge	061386	211992	Council	-33.2903	151.4242	☑		
Wyong River D/S Bridge	561025	211002	Council	-33.29	151.4236	☑		
Tuggerah Lake at Toukley	561000	211401	MHL	-33.263	151.524	☑	☑	

Note: water level recorders are arranged upstream to downstream; some latitudes and longitudes do not plot precisely where expected

Communication

Communication of flood warnings is vital. At the current time, people's ability to look up a web portal, or to directly receive landline or mobile phone warnings could be compromised by electricity outages (not uncommon during severe weather) and limited mobile phone reception, especially for the Yarramalong and part sections of the Dooralong Valleys (see **Plate 18**). For example, during the 2007 flood, electrical outages for up to four days were experienced and many mobile phone towers did not operate during this period.

It is understood that Telstra is working to improve mobile phone coverage across the upper catchment areas, including 3G / 4G mobile coverage for the following locations:

- Yarramalong (anticipated completion 2017);
- Wyong Creek (anticipated completion 2018);
- Dooralong (anticipated completion 2017);
- Lemon Tree (anticipated completion 2017);

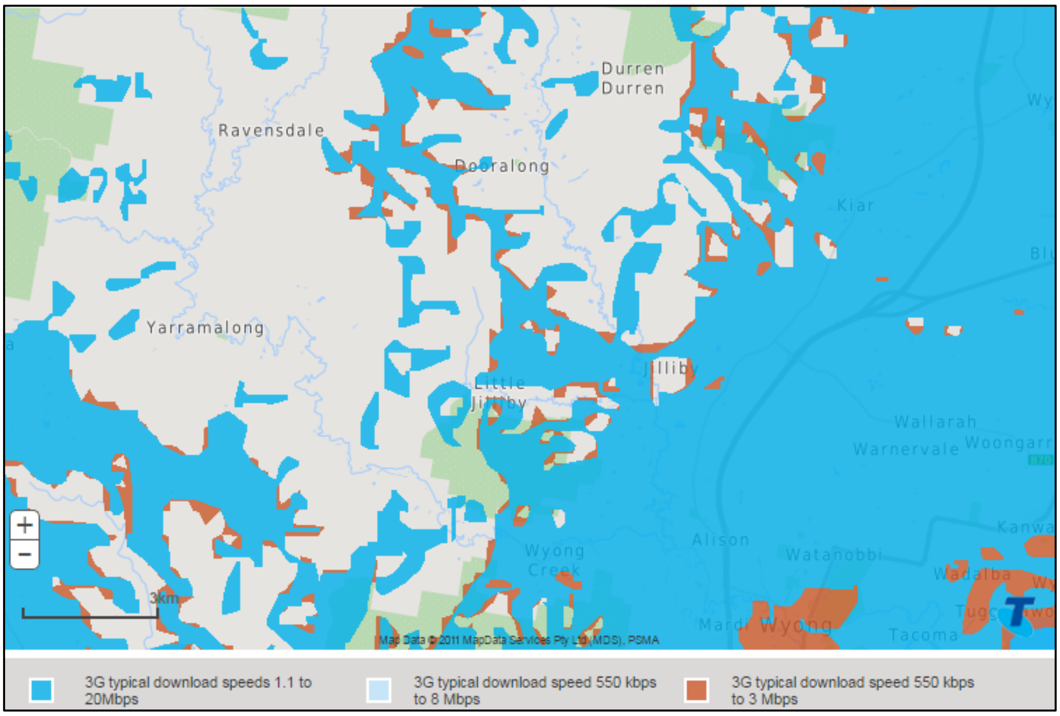


Plate 18 Mobile phone coverage across Yarramalong and Dooralong Valleys.
Source: http://mobilemaps.net.au/ (as at 23 Dec 2016)

Expansion of mobile coverage across these upper catchment areas will make flood warning communication systems more resilient for those with mobile phones. Nevertheless, power outages can still occur meaning opportunities to charge phones may be reduced. Therefore, USB type 'power banks" may be necessary to supplement traditional power supplies during extended periods of inundation and power outages. This could be recommended as part of the community education strategy (refer Section 9.2.4).

It is also recommended that infrastructure (most notably telecommunications) providers are contacted and are made aware of the important role their infrastructure provides during natural disasters, such as floods. These communications could also make recommendations for ways in which the level of service afforded could be improved. For example, mobile phone towers could be supported by backup power supplies to ensure mobile phone coverage is maintained even when the main power grid is down.

Opportunities could also be explored in the future for disseminating flood information via a mobile phone application (i.e., an "app"). The app could provide real time flood information, including roads that are cut by floodwaters (which could be populated by emergency services or the broader community) and could suggest alternate evacuation routes.

Response

While the SES has a Local Flood Plan and a well-resourced unit (see Section 5.3), the reality is that many residents and workers in the Wyong River floodplain will need to respond proactively to reduce the risk to life and property during a flood emergency, without assistance from the SES or other emergency services. As well as striving for more direct warning communication modes, various educational initiatives are proposed in Section 9.2.3 to promote proactive responses.

Review

It is important to review the flood warning system following each flood to determine its effectiveness and look at opportunities to improve the system. It is not clear whether reviews of the flood warning system are routinely carried out after an event and/or for system maintenance.

Further Considerations

Council is currently investigating the capacity and adequacy of its existing rainfall and water level gauge network. The results of this investigation and installation or upgrading of any existing gauges will assist in the enhancement of its flood gauged network and automatic reporting of rainfall and water levels to emergency management authorities e.g. BoM and SES. This, in turn, will also make it possible to enhance its existing or investigate a new Flood Warning System for the Wyong River and its tributaries as well as many other catchments throughout the Central Coast.

As such, Council should work with the emergency management authorities on determining the suitability of the existing infrastructure (and updating where required) for their use in a local flood warning system.

Recommendations:

1) Make real-time information more readily accessible (e.g. through a flood portal) (Council)

2) Help floodplain residents interpret real-time information by providing design flood heights for gauges as well as design flood depths at their properties (Council & SES)

3) Pre-prepare flood bulletin messages for distinct communities (SES)

4) Establish river level triggers for various gauges that issue phone messages or SMS directly to subscribers (SES)

5) Improve mobile phone coverage in Yarramalong and Dooralong Valleys (Telstra)

6) Confirm reviews of the system are completed following each flood (BoM)

7) Improve the current flood warning system or investigate a new system to cover the flood risks of the whole Wyong River floodplain as identified in this study

9.3.2 Upgrade of Existing Evacuation Routes

Since the year 2000, 178 people have lost their lives in Australia as a result of flooding. The majority of these deaths are associated with motorists attempting to drive across flooded bridges, culverts, causeways or roads in their local area. Although flood deaths have been steadily declining since the 1960s, motor vehicle related deaths in floodwaters are rising (Haynes et al, 2016).

Access to a number of communities within the Wyong River catchment is provided via a single roadway. This includes South Tacoma as well as much of the Yarramalong Valley. Upgrading of evacuation routes would aim to reduce the frequency of roadway inundation and/or prevent vehicles driving through floodwaters.

Installation of Barriers on Flood Liable Roadways

Research indicates that many people ignore traditional warning and road closure signs (Haynes & Gissing, 2016). Therefore, this option would involve the installation of formalised barriers/gates that would prevent vehicles from driving through floodwaters at known roadway overtopping locations.

An example of a barrier that may be suitable for such an application is shown in **Plate 19**.

Plate 19 Examples of automatic flood barrier system (photo courtesy of David Bagnall)

The barrier shown in **Plate 19** includes the following features:

- Closes automatically once water depths at the barrier exceed a threshold level
- Inbuilt telemetry system notifies emergency services of road closure
- Flashing lights (i.e., effective at night)
- Floatation devices on boom arm allows arm to rise and fall with floodwaters.

Although more expensive than manual barriers, the installation of automatic barriers is preferred as it is not reliant on emergency personnel. Therefore, it will close as soon as water depths exceed a dangerous threshold and will free personnel for other emergency response requirements.

The primary disadvantages associated with the flood barriers include:

- Automatic flood barriers will require regular maintenance to ensure they remain operational which adds to the life cycle cost of the option.
- They do not reduce the frequency or depth of inundation. Therefore, residents requiring access along one of these low-lying roadways will continue to be isolated relatively frequently.
- If motorists try to drive past a closing flood barrier there is potential for the car to become trapped between the closed flood barriers.
- Once a flood barrier is closed, no access beyond the barrier is possible. This will limit the possibility of access/evacuation/resupply, even for larger vehicles that would otherwise be able to traverse the floodwaters (although an emergency override could be potentially implemented for access by emergency vehicles).

An analysis of potential installation locations was completed by reviewing the flood modelling results to identify major roadway locations that are subject to frequent and dangerous inundation. In this regard, all major roads that get overtopped to a depth of at least 0.5 metres during the 20% AEP flood were selected. **Figure J1** in **Map Set J** shows each of the critical locations. A total of 19 locations were identified, with most occurring across the Yarramalong Valley.

In most cases, two flood barriers would be required at each location to prevent access from both sides of the roadway low point. However, where there are a number of roadway low points in series (e.g., lower section of Yarramalong Road), a flood barrier at the very start and end of the series of low points would likely suffice. In order to protect each of the critical roadway overtopping points, it is anticipated that 36 flood barriers would be required. **Figure J2** shows the potential location of each flood barrier.

The flood barriers shown in **Plate 19** cost approximately $20,000 (including installation but excluding ongoing maintenance costs). Therefore, the installation of 36 flood barriers is expected to involve a capital investment of $720,000. If capital funding is not available for this full amount, progressive installation of the flood barriers could occur (starting with the most vulnerable/busiest locations first) as funding becomes available.

The primary advantage of the installation of flood barriers is to reduce the potential for loss of life. Therefore, although the cost of this option is significant, it may be considered worthwhile if even a single life is saved in the future.

It is also noted that several of the identified roadway overtopping locations are located in close proximity to a stream gauge. Therefore, using information generated as part of the study, it may be possible to correlate gauges heights with when roadway will be overtopped. This will enable emergency services to understand when roads are likely to be overtopped based upon real-time stream gauge information.

It is recommended that a trial of the flood barriers be undertaken at a selection of critical locations. If this trial is successful and appropriate funding is available, the installation of flood barriers in other locations could be progressively implemented. Based on the predicted depths of inundation during the 1% AEP event as well as anticipated traffic loads, it is suggested that the flood barriers should be trialled at the following locations:

- Bradleys Creek crossing of Yarramalong Road;
- Yarramalong Road (near Kidmans Lane)

Recommendation: Install flood barriers at a selection of critical location on a trial basis. If trial is deemed successful, look to install flood barriers across remaining critical locations.

Installation of Flood Depth Indicators

Flood depth indicators could be installed at known roadway overtopping points (refer **Figure J1**). The depth indicators show the depth of water across the roadway, thereby helping to inform the community about whether the roadway may be safe to cross in a vehicle. However, without any accompanying information to describe the potential dangers associated with crossing flooded roads, the potential success of flood depth indicators can be limited. Furthermore, emergency services advocate not driving through any floodwater regardless of depth as the integrity of the road surface beneath the water cannot be guaranteed. Therefore, there is potential for installation of depth indicators to increase the number of vehicles driving through water which may increase the flood risk.

Therefore, if this option is pursued it should be supplemented with appropriate signage not to drive through floodwaters and/or other education material. In recent flood events in NSW, the SES has been increasingly creative and persistent in broadcasting this message through its social media platforms, even including video interviews with drivers who have turned around when confronted by flooded roads – demonstrating good behaviours.

Figure J1 in **Map Set J** shows roadways subject to frequent inundation including those where flood depth indicators are already installed (based upon Google Street View which dates from 2007 in some locations). As shown in **Figure J1**, only 4 of the 19 critical locations already have flood depth indicators installed. Therefore, there is potential to install flood depth indicators at the remaining 15 locations.

Although the installation of flood depth indicators is not recommended due to the issues associated with driving through floodwaters, they are a relatively 'cheap' option (the cost of a typical indicator is about $400 including installation). Therefore, they may be considered in areas subject to frequent inundation where other more robust options (e.g., installation of flood barriers) are not feasible.

It may also be possible to "link" most of the critical roadway overtopping locations to a nearby water level recorder (refer **Figure J1**). This would allow the gauge height at which each roadway will likely be overtopped to be identified. This would allow road closure estimates to be linked back to key gauge heights and this information could be subsequently disseminated to emergency services and the broader community. The density of current water level recorders is considered to be sufficient across most problematic road overtopping locations to facilitate such an activity. As discussed in Section 9.2.2, it is recommended that the road overtopping information presented in this report be used to update flood intelligence cards for key gauges in the catchment. It is suggested that this will include gauge heights at which specific roadways are overtopped.

Recommendation: Could be considered at locations that do not have an existing flood depth indicator and where flood gates are not feasible. However, should be supplemented with appropriate education material.

South Tacoma

Access to South Tacoma is provided via a single roadway that is cut at a low level, early during a flood (see Section 5.4.2). It is not practicable to elevate the low-point because this is located under a bridge and so would reduce the clearance height for vehicles. A potential alternative route through Pioneer Dairy is available (see **Plate 12**), which offers additional effective warning time under some scenarios. However, at the current time it is not suitable for use as a flood evacuation route because it is unsealed and the load capacity of bridges along the route is not known. Development of the Tuggerah Regional Sporting and Recreation Complex and the Pioneer Dairy site could also threaten the use of this route. The sensitive environment in the area could also restrict the extent of any evacuation upgrade works. Therefore, any potential for upgrade of this particular evacuation route will need to be prefixed by appropriate environmental investigations.

The following recommendations are made regarding the alternate evacuation route:

Recommendations:

1) Investigate the feasibility of upgrading the flood evacuation route track between South Tacoma and Lake Road through Pioneer Dairy to provide wet-weather access with due regard given to environmental conservation of the area

2) Assess relative level, utility, safety and load capacity of existing bridge crossing over Tuggerah Creek near Pioneer Dairy

3) Formalise permissions for evacuation traffic and emergency services' vehicles to use the route during flood emergencies

4) Ensure that the proposed development of the Tuggerah Regional Sporting and Recreation Complex preserves a capacity for evacuation traffic from South Tacoma to pass through the site from its northern boundary (aligned with the existing track) to Lake Road

5) Ensure that any future development of the Pioneer Dairy property preserves a capacity for evacuation traffic from South Tacoma to pass through the site from South Tacoma Road to the proposed Tuggerah Regional Sporting and Recreation Complex. This may take the form of an easement or restriction on use over the land.

Council also enquired about the potential to install a helipad at South Tacoma that would permit evacuation via helicopter should vehicular evacuation not be possible. On potential location of a helipad is at 6 Kingsland Close, South Tacoma. This site is currently home to a sewer pumping station; however, this facility is to be decommissioned in the future. Once decommissioned, the pumping station could be removed, and the area could be filled by around 1.5 metres to ensure the pad is located above the PMF. Further investigations are required to confirm potential environmental impacts (a number of trees would need to be removed) and whether minimum clearance requirements could be met.

If a helipad is not considered to be viable, opportunities could still be explored for providing a PMF refuge in this area. If the area is sufficiently sized, it may allow residents to temporarily seek refuge above the PMF and await boat pickup/rescue.

Recommendation: Council to consider potential to construct helipad or PMF refuge near Kingsland Close, South Tacoma once pumping station is decommissioned.

Road Raising in Yarramalong and Dooralong Valleys

The Yarramalong Valley comprises a significant proportion of the overall Wyong River catchment. Access to/from the valley is provided via a single, major roadway (Yarramalong Road). As noted in Sections 3.2.7 and 9.3.2, Yarramalong Road is cut at a number of locations during relatively frequent floods (refer **Figure J1**). Therefore, properties within the Yarramalong Valley can be isolated during relatively frequent floods.

Potential upgrades to Yarramalong Road would aim to reduce the frequency and severity of inundation by elevating particularly low lying sections of roadways. The primary advantage of this option over other options, such as installation of flood barriers and flood depth indicators, is that it would reduce the frequency of roadway overtopping and, therefore, the potential frequency of people driving through floodwaters. It would also afford additional evacuation time during larger floods.

As shown in **Figure J1**, Yarramalong Road is overtopped at 9 different locations during the 20% AEP events to depths of over 0.5 metres and a further 8 locations are inundated to depths of more than 0.3 metres. Therefore, the upgrades that would be necessary to elevate Yarramalong Road above the 20% AEP flood would be significant. It is estimated that upgrades of this magnitude would cost in the order of $17 million to implement, which is likely to be cost prohibitive.

Therefore, the financial viability of this option is considered to be limited unless upgrades of the roadway are planned and elevating the roadway can be accommodated as part of the upgrades.

Recommendation: Not considered to be financially viable unless it can be incorporated as part of a planned upgrade of the road

Open and Maintain Rural Fire Trails

As discussed, access to much of the Yarramalong and Dooralong Valleys is via a limited number of low lying roadways. The majority of these roadways are located in close proximity to major waterways and are subject to relatively frequent inundation. Although many residents are accustomed to being isolated for several days by floodwaters, this isolation may pose problems if emergency services require access for, say, a medical emergency.

Much of the upper catchment is flanked by state forest (e.g., Ourimbah State Forest) that includes a network of fire trails. The fire trails are generally elevated and may provide an alternate means of accessing the upper catchment areas during floods. Most notably, a trial may be available linking Yarramalong village to various lower catchment roadways including Old Maitland Road via Bumble Hill Road, Forest Road and Red Hill Road.

In general, the fire trails are not sealed and are only suitable for trail bikes and four wheel drives in dry weather conditions. Therefore, it is unlikely that access to the upper catchment areas can be accommodated along the existing fire trails for all vehicle types. Nevertheless, the trails may be appropriate for some emergency response vehicles.

It is suggested that discussions with the Forestry Corporation of NSW (and potentially the rural fire service) be undertaken to confirm the suitability of using the fire trails during times of flood to provide, as a minimum, emergency vehicle access. If these discussions prove fruitful, an audit of the fire trails should be completed to confirm their suitability for conveying emergency vehicles. Based on the outcomes of the audit, cost estimates could be prepared for remediation works (if necessary) to determine if this option is still financially feasible. Arrangements may also need to be made for the provision of keys to emergency response personnel to allow access through any gated trails. A plan for the maintenance will also need to be established to ensure the trials remain trafficable in the future.

Recommendation: Council to discuss opportunities to open fire trails with the Forestry Corporation of NSW to provide access during times of flood. Assuming discussions are fruitful, undertake an audit of fire trails and develop a plan to remediate and maintain trails for future use across upper and potentially lower catchment areas

Proposed RMS Pacific Motorway and Pacific Highway Upgrades

During the study, discussions were held with Roads & Maritime Services (RMS) to discuss proposed upgrades to the Pacific Motorway and Pacific Highway. Both roadways serve as major transportation and, potentially, evacuation routes during Wyong River floods. Moreover, any modifications to bridge and culvert crossings that are completed as part of the upgrades have the potential to alter existing flood behaviour.

The Pacific Motorway upgrade will involve widening the existing roadway between the Tuggerah and Doyalson interchanges to provide three lanes in each direction of travel. The upgrade will involve widening the motorway into the median area. Therefore, the "footprint" of the motorway will not change as part of the upgrade. No substantial changes are proposed to the existing roadway profile of culvert/bridge crossing. Therefore, the Pacific Motorway upgrade is expected to have a negligible impact on existing flood behaviour or evacuation potential.

The Pacific Highway upgrade will include:

- Provision of two lanes for each direction of travel between Johnson Road, Tuggerah and Cutler Drive, Wyong
- Construction of two new bridge crossings of the Wyong River (and demolition of the existing bridge)
- Modifications to South Tacoma Road and Panonia Road where they pass beneath the new bridges

RMS completed an independent flood impact assessment as part of the design of the upgraded highway to quantify the potential impact of the proposed works. As part of the design, they looked at opportunities to reduce afflux through the bridge opening by increasing the waterway area beneath the bridge and aligning bridge piers. Computer flood modelling completed as part of the work indicated that the revised bridge arrangement is predicted to produce a small reduction in peak 1% AEP water levels upstream of the highway (in the order of 30mm). Therefore, the proposed highway upgrade is predicted to produce a very small reduction in flood risk upstream of the highway.

During the PMF, flood level reductions of about 120mm are predicted upstream of the proposed bridges. The flood level reductions are predicted to extend approximately 9 km upstream of the proposed bridges. Downstream of the proposed bridges, flood level increases of up to 150 mm are predicted across a large area of Wyong and Tacoma. However, the reported flood impacts (e.g., above floor flooding, available evacuation time) during the PMF are predicted to remain relatively unchanged during the PMF.

The new bridges will be elevated above the peak 1% AEP flood level, which provides a greater level of flood immunity relative to the existing bridge. However, the highway drops back down near the McPherson Road intersection which is predicted to be cut during a 5% AEP event. Therefore, although the proposed upgrade will increase the flood immunity of the Wyong River bridge crossing, the immunity of the overall highway will remain unchanged as a result of the upgrade.

It is expected that the elevation of South Tacoma Road and Panonia Road will remain essentially unchanged. Therefore, the proposed upgrade is unlikely to afford any significant changes to evacuation potential along either roadway.

Recommendation: No further investigations considered necessary.

9.4 Options to Aid in Post-Flood Recovery

9.4.1 Recovery Planning

The Wyong Shire Local Flood Plan (LFP) sets out the responsibilities of various agencies in post-flood recovery. Recovery, as outlined in the LFP, largely rests with the SES with assistance from other agencies, as required.

It is suggested that additional, specific items could be included in the LFP to further assist emergency services and the community to expedite post-flood recovery, including:

- Council to ensure vital facilities such as water and sewer are restored/operational
- Council to aid in removing waste and debris as part of clean-up activities
- Appropriate agencies to ensure vital utilities such as power and gas are restored/operational
- Appropriate agencies to offer welfare assistance and counselling services
- Various agencies to record post-flood information to assist in future updates/calibration of flood models and flood studies.

Recommendation: SES look to update Local Flood Plan to reflect additional flood recovery responsibilities for various agencies

9.4.2 Flood Insurance

Flood insurance is now available for residential, commercial and industrial buildings as part of most home and contents insurance policies. Flood insurance can also be taken out on public infrastructure and buildings.

Although flood insurance does not reduce the potential for flood damage nor reduce the residual flood risk, it can help in post-flood recovery by providing financial assistance to offset flood damage costs.

The cost of flood insurance varies significantly, based on a range of factors, including:

- The likelihood of flooding
- Expected depth of flooding across insured building (refer **Plate 20**)
- The size and the floor level of the house
- The material used to build the house

Therefore, buildings with a high likelihood of flooding and/or high flood damage potential will face higher insurance premiums. The cost of insurance must be borne by the building owners. Therefore, those properties that are at higher risk of flooding and would arguably benefit the most from flood insurance will face the highest premiums. In such instances, property owners may not be able to afford such premiums.

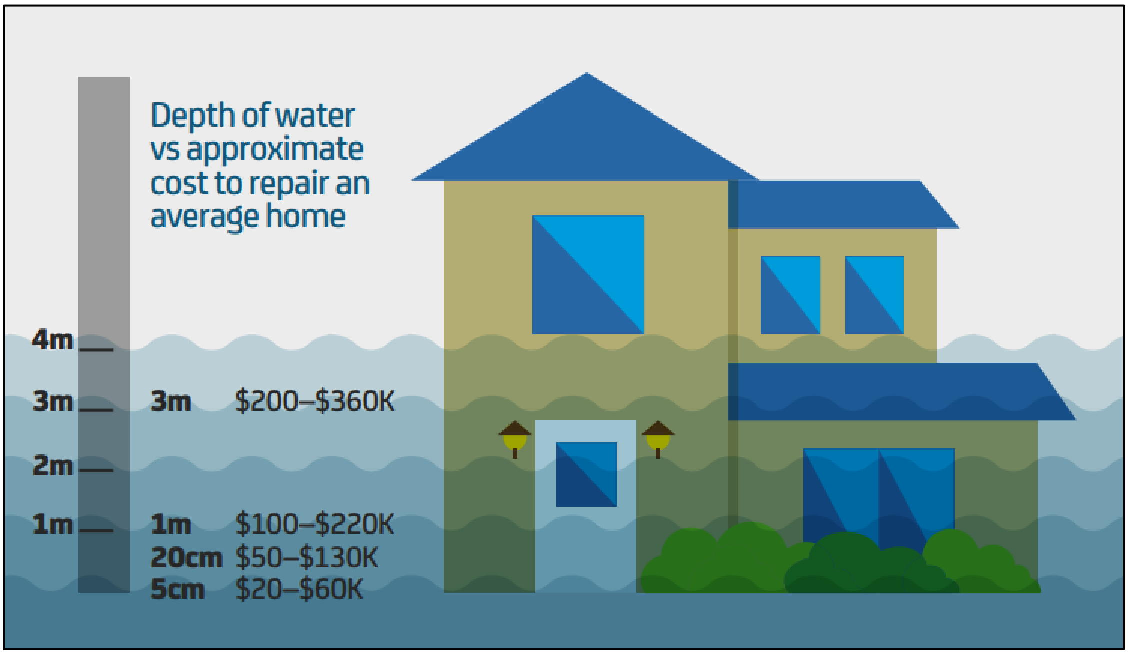


Plate 20 **Examples of repair costs versus depth of above floor inundation used by insurance companies to estimate premiums (NRMA, 2015)**

Nevertheless, flood insurance should be considered by property owners in high risk areas, where a single large flood may result in an unaffordable loss (through damage to contents or the loss of the building itself - refer **Plate 20**). Council could assist property owners as part of this process by providing property level flood information (refer Section 9.2.4), so property owners can understand their flood risk and the potential financial implications of a significant flood. Based on this, the property owners can make an informed decision on the need to acquire flood insurance. Assuming flood insurance is desired by the property owners, the property level flood information can also be used to assist in negotiating premiums with insurance companies.

Recommendations:
1) Individual property owners should consider flood insurance.
2) Council to assist property owners by providing property specific flood information.

9.4.3 Disaster Relief

Disaster relief provides financial assistance following the declaration of a natural disaster. A disaster declaration is initiated by the State Government and, depending on the nature and extent of the disaster, may be supplemented by the Federal Government (subject to a natural disaster declaration by the attorney-General's Department).

Local government areas that are declared natural disaster zones are eligible for the Natural Disaster Assistance Scheme, including:

- Disaster assistance for Individuals
- Primary producers (loans & transport subsidies)
- Small businesses

- Assistance for Councils
- Trustees of parks and reserves
- Sporting clubs
- Churches and voluntary non-profit organisations

However, such disaster assistance may not be available to all individuals or organisations. For example, relief grants for individuals will typically only be available for those with limited financial resources and no insurance. Furthermore, funding may only partly offset the total damage costs.

Therefore, disaster relief may only provide financial support for some individuals and groups during large floods that are declared a natural disaster. Like flood insurance, disaster relief funding does not reduce the potential for flood damage or the residual flood risk.

Recommendation: No actions necessary

10 Draft Floodplain Risk Management Plan

10.1 Introduction

The draft Floodplain Risk Management Plan sets out options that can be implemented in the short, medium and long term to manage the flood risk across the Wyong River catchment. It also outlines responsibilities for the implementation of each option along with cost estimates and funding opportunities.

10.2 Recommended Options

The options that are recommended for implementation as part of the draft Wyong River Catchment Floodplain Risk Management Plan are summarised in **Table 37** and are also shown in **Figure K1** in **Map Set K**. The options have been selected from a range of potential flood modification, property modification and response modifications measures based upon their impact on flood hydraulics and existing properties, capital and ongoing costs as well as any potential social and environmental impacts. The outcomes of the detailed assessment are discussed in more detail in Chapters 7, 8 and 9 of this report.

10.3 Plan Implementation

10.3.1 Prioritisation / Timing

The recommended options have been prioritised according to how easily each option could be implemented and the anticipated benefits afforded by each option (i.e., options that are relatively straight forward to implement and have a significant benefit would be assigned a high priority). A timeframe has also been estimated that reflects the likely time to implement each option based upon available resources (i.e., financial and human resources) as well as the need to undertake additional investigations and/or community consultation.

In general, it is anticipated that the majority of the options would be implemented progressively over a 5-year time frame. However, this will be dependent on the budgetary commitments of Council and availability of funding from other sources.

10.3.2 Costs and Funding

The total capital cost to implement the Plan is expected to be about $2.1 million. The most significant costs are associated with implementation of automatic flood barriers (~$800,000 capital cost plus ongoing maintenance costs) and the Mardi Creek detention basin (~$440,000 capital cost plus ongoing maintenance costs).

Removal of vegetation and preparation of a maintenance plan for creeks and culverts across the lower floodplain is also worth pursuing. However, the cost of this option is likely to be significant (capital cost >$1 million) and will need to be coordinated with the various floodplain landowners.

The South Tacoma floodway is also predicted to afford some significant hydraulic benefits. However, more detailed investigations are required to confirm the feasibility of this option and the associated implementation costs.

In addition to the capital costs, some options will incur ongoing maintenance costs. As noted in **Table 37**, many of the options will require an investment in time from various agencies including Central Coast Council, the State Emergency Service and the Bureau of Meteorology in addition to monetary contributions.

Funding for implementation of the plan could be obtained from the following sources:

- Central Coast Council's capital and operating budgets
- NSW State Government's Floodplain Management Grants (through OEH)
- Section 94 contributions
- Commonwealth Government's Natural Disaster Resilience Program
- Volunteer labour from community groups

It is expected that most options will be eligible for funding through the NSW State Government's Floodplain Management Grants on a 2:1 basis (State Government : Council). This can include additional investigations, design activities as well as construction. However, funding under this program cannot be guaranteed as funding must be distributed to competing projects across the state. Furthermore, the NSW Government's Floodplain Management Grants are primarily available to manage risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties. It should also be noted that ongoing costs will generally be the responsibility of Council.

10.3.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually reviewed and updated over time to ensure that it evolves with the catchment and takes advantage of any improvements in flood knowledge, such as new flood studies, historic floods or information on climate change.

As noted in **Table 37**, most options are scheduled for implementation within a 5-year time frame. Therefore, as a minimum, it is recommended that the Plan be revisited after 5 years.

Table 37 Draft Wyong River Catchment Floodplain Risk Management Plan

Option		Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
Flood Modification Options								
Mardi Creek Detention Basin	FM1	7.2.3	Council	$440k	$60k	Medium	4 years	
Anzac Road Levee	FM2	7.3.3	Council	$120k	$30k	Medium	2 years	
Vegetation removal	FM3	7.4.4	Various asset owners	~$1.7 million	$350k	Medium	3 years	Incorporate removal of unnecessary floodplain vegetation as part of annual management program for asset owners.

Option		Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
Railway Drainage Upgrades	FM4	7.4.2	Council & Railcorp	$1.5 million	$10k (maintenance)	Low	>5 years	Council to initiate discussions with RailCorp to confirm likelihood of railway upgrades and opportunities to include flood mitigation works as part of this
Local Drainage Study for northern floodplain of the lower Wyong River	FM5	7.5.2	Council	$50k	$0k	High	2 years	Wyong River flood gate investigation could be included as part of this drainage study. Also, incorporate maintenance of floodplain drainage channels and culverts into Council maintenance program.

Option		Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
<u>Property Modification Options</u>								
Look at opportunities for incorporating PMF refuge at Wyong Aged Care Facility	PM1	8.2.4	Riviera Health & Council	Not determined as part of study		Medium	<5 years	Dependent on Riviera Health's development plans
Clarify the need for Exceptional Circumstances to promote safer on-site refuge for dwellings located on land below the FPL	PM2	8.3.2	Council	Council time	$0k	High	1 year	
Consider applying for Exceptional Circumstances	PM3	8.3.2	Council	Council time	$0k	High	1 year	
DCP Amendments	PM4	8.3.3	Council	Council time	$0k	High	1 year	
Voluntary house purchase	PM5	8.2.1	Council	To be confirmed	To be confirmed	Low	>10 years	Council to undertake discussions with property owners to discuss options for reducing the current flood risk
Voluntary house raising	PM6	8.2.2	Council	To be confirmed	To be confirmed	Low	5 years	

<table>
<tr><th colspan="4">Option</th><th>Report Section</th><th>Implementation Responsibility</th><th>Capital Cost</th><th>Ongoing Cost</th><th>Priority</th><th>Timing</th><th>Comments</th></tr>
<tr><td colspan="11"><u>Response Modification Options</u></td></tr>
<tr><td colspan="3">Wyong Local Flood Plan Updates</td><td>RM1</td><td>9.2.1 & 9.4.1</td><td>SES</td><td>SES time</td><td>$0k</td><td>High</td><td>1 year</td><td></td></tr>
<tr><td colspan="3">Flood Intelligence Card Updates</td><td>RM2</td><td>9.2.2</td><td>SES</td><td>SES time</td><td>$0k</td><td>High</td><td>1 year</td><td></td></tr>
<tr><td rowspan="4">Flood Plan Preparation / Updates</td><td rowspan="4">Key floodplain exposures</td><td>Wyong Aged Care Facility</td><td>RM3</td><td rowspan="4">9.2.4</td><td>Riviera Health & Council</td><td>Council & Riviera Health time</td><td>Minimal</td><td rowspan="4">High</td><td rowspan="4"><2 years</td><td></td></tr>
<tr><td>Wyong Christian Community School</td><td>RM4</td><td>Wyong Christian Community School & Council</td><td>Council & Wyong Christian Community School time</td><td>Minimal</td><td></td></tr>
<tr><td>C3 Church</td><td>RM5</td><td>C3 Church & Council</td><td>Council & C3 Church time</td><td>Minimal</td><td></td></tr>
<tr><td>Meander Village</td><td>RM6</td><td>Meander Village & Council</td><td>Council & Meander Village time</td><td>Minimal</td><td></td></tr>
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Option			Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
	Host meetings in various communities to promote the preparation of Home Emergency Plans	RM7	9.2.4	Council	Council time + venue hire ($3k assuming 3 meetings completed)	~$3k every 5 years	Medium	<2 years	Should be repeated periodically (e.g., every 5 years) to cater for potential turnovers.
	Conduct an audit and host a Business FloodSafe Breakfast	RM8	9.2.4	Council, SES & Chamber of Commerce	Council, SES and Chamber of Commerce time + venue hire ($1k)	~$1k every 5 years	High	1 year	
Flood warning system upgrades	Make real-time information more readily accessible	RM9	9.3.1	Council & BoM	Council & BoM time	Minimal	Medium	3 years	Could be augmented as part of flood portal project
	Help floodplain residents interpret real-time information	RM10		Council	Council time	Minimal	Medium	2 years	Can be incorporated into other community education components
	Pre-prepare flood bulletin messages for distinct communities	RM11		SES	SES time	Minimal	Medium	2 years	

Option			Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
	Establish river level triggers for various gauges that issue phone messages or SMS directly to subscribers	RM12		SES	SES time	$0	High	3 year	
	Improve mobile phone coverage in Yarramalong and Dooralong Valleys	RM13		Telstra	Not determined as part of study.		High	2 years	Currently on Telstra's work plan for implementation by 2018
	Confirm reviews of the system are completed following each flood	RM14		BoM & SES	Variable	Variable	Medium	Ongoing	Costs will vary depending on the frequency of floods
	Improve the current flood warning system or investigate a new system to cover the flood risks of the whole Wyong River floodplain as identified in this study	RM15		Council	Council, SES and BOM time	Not determined as part of study	High	2 years	Costs will vary depending on the outcome of the investigations currently underway (by others).

Option			Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
Community Education	Audit Flood & Coastal Storms Education Strategy	RM16	9.2.3	SES	SES time	Minimal	Medium	1 year	Costs are dependent on the outcomes of the audit
	Develop educational messages targeting dangerous behaviours	RM17	9.2.3	SES	SES time	Minimal	Medium	1 year	
	Undertake a flood information portal website pilot study	RM18	9.2.3	Council	$30k	$2k pa for hosting, maintenance and ongoing upgrades	Medium	1 year + ongoing updates	Property level flood information and flood portal pilot study could be completed together
	Make property level flood information available	RM19	9.2.3	Council	$10k for pilot project. $15k for balance of catchment	$5k every 5 years for mail outs	Medium	1 year + ongoing updates	
	Continue to develop social media platforms for flood safe messaging	RM20	9.2.3	SES	SES time	Minimal	High	2 years	

Option			Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
Pioneer dairy flood evacuation evaluation and upgrade	Upgrade the flood evacuation route track between South Tacoma and Lake Road through Pioneer Dairy to provide wet-weather access	RM21	9.3.2	Council	~$150k	Minimal	Medium	5 years	Total cost of the Pioneer Dairy flood evacuation evaluation and upgrade will be dependent on the outcomes of the review of the existing bridge capacity. Any bridge upgrades may increase the cost considerably. This option is also highly dependent on discussions with land owners for access for both construction and during flood events when required.
	Assess relative level, safety and load capacity of existing bridge crossing over Tuggerah Creek near Pioneer Dairy	RM22		Council	$20k	$0K	Medium	2 years	
	Formalise permissions for evacuation traffic and emergency services' vehicles to use the route during flood emergencies	RM23		Council	Minimal	$0K	High	2 years	
	Ensure that the proposed Tuggerah Regional Sporting and Recreation Complex preserves a capacity for evacuation traffic from South Tacoma to pass through the site from its northern boundary to Lake Road	RM24		Council	Minimal	$0K	High	<1 year	
	Ensure that any future development of the Pioneer Dairy property preserves a capacity for evacuation traffic from South Tacoma to pass through the site from	RM25		Council & Developers	Minimal	Minimal	Medium	unknown	

Option		Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
South Tacoma Road to Lake Road.								
Install flood barriers	RM26	9.3.2	Council	$100k for pilot project. $700k for balance of catchment	Variable maintenance costs depending on number of barriers installed	Low	2 years for pilot project 10 years for full catchment	
South Tacoma Helipad / PMF refuge	RM27	9.3.2	Council	Not determined as part of study.		Low	3 years	Additional investigations to determine feasibility of installing a helipad or elevated PMF refuge at South Tacoma
Open fire trails for access to upper catchment during times of flood	RM28	9.3.2	Council & Forestry Corporation of NSW	Not determined as part of study.		Low	5 years	Total cost to upgrade and maintain fire trials is dependent on the current state of trails. Therefore, an audit of the trials should be completed to confirm the implementation cost

Option			Report Section	Implementation Responsibility	Capital Cost	Ongoing Cost	Priority	Timing	Comments
Flood Insurance	Individual property owners should consider flood insurance	RM29	9.4.2	Property owners	Varies depending on property in question		Low	< 2 years	Individual property owners should consider flood insurance
Flood Insurance	Council to assist property owners by providing property specific flood information	RM30	9.4.2	Council	Council time	Council time	Low	As required	
Notification of updated flood information to key infrastructure providers		RM31	9.2.4	Council	Council time	Council time	High	<1 year	Provide updated flood information to improve the level of service afforded by key infrastructure during floods

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12 Glossary

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. Eg, 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 events 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.
Building Code of Australia (BCA)	A uniform set of technical provisions for the design and construction of buildings and other structures throughout Australia.
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 Local Governments 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 OEH, as having the function to determine an application.

Deemed to satisfy (DTS) Prescriptive provisions to satisfy the performance requirements of a particular objective of a guideline or code.

defined flood event (DFE) The design flood event selected for the management of flood hazard to new development, based on an understanding of flood behaviour and the associated likelihood and consequences of flooding, and the social, economic, environmental and cultural consequences of flooding of different severities. Used with a freeboard to determined the flood planning level.

Development is defined in Part 4 of the Environmental Planning and Assessment Act (*EP&A Act*).

infill development: refers to 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).

ESD 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 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.
emergency response precinct (ERP)	Classification for each development within the floodplain based on flood emergency response categories that consider the full range of flood behaviour and its impacts upon access to communities or precincts to inform emergency response management. Based upon the probable maximum (PMF) or similar extreme flood event.
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	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 and 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 hazard area (FHA)	The area (whether or not mapped) encompassing land lower than the flood hazard level.
flood hazard level (FHL)	The flood level used to determine the height of floors in a building that represents the defined flood level plus the freeboard. area (whether or not mapped).
flood liable land	is synonymous with flood prone land, i.e., land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (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 SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls.
flood planning levels (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.
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	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
flood readiness	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. <u>existing flood risk</u>**:** the risk a community is exposed to as a result of its location on the floodplain. <u>future flood risk</u>: the risk a community may be exposed to as a result of new development on the floodplain. <u>continuing flood risk</u>: 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 flow, or a significant increase in flood levels.

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.

hazard — a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community.

Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (*2005*).

historical flood — a flood which has actually occurred.

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 — 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. 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 0.3m (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 flowpaths 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 flood 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 annual exceedance probability*).
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 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.
TUFLOW	is a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.

velocity	the speed or rate of motion (*distance per unit of time, e.g., metres per second*) in a specific direction at which the flood waters are moving.
Voluntary House Purchase (VHP)	A floodplain management option that would entail the voluntary sale of a property located in the high hazard area part of the floodplain to eliminate future flood risk to the owners and/or occupiers of that property.
Voluntary House Raising (VHR)	A floodplain management option that would entail the voluntary raising of the floor level of a dwelling to reduce or remove it from potential flood waters and future flood damages.
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.
XP-RAFTS	is a non-linear runoff routing software. It incorporates subcatchment information such as area, slope, roughness and percentage impervious and is used to simulate the transformation of historic or design rainfall into runoff (i.e., discharge hydrographs).

APPENDIX A

TUFLOW MODEL UPDATES

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A1. TUFLOW MODEL UPDATES AND VERIFICATION

1.1 Introduction

Design flood behaviour within the Wyong River catchment is currently defined using a XP-RAFTS hydrologic model and a TUFLOW hydraulic model that was developed as part of the "Wyong River Catchment Flood Study" (BMT WBM, 2014). TUFLOW is a fully dynamic, 1D/2D finite difference software developed by BMT WBM (2012). It is used extensively across Australia to assist in defining flood behaviour and was considered to be a suitable software for modelling the potential for local catchment and tidal inundation as part of the current study.

However, since the adoption of the Wyong River Flood Study by Wyong Shire Council, some enhancements to the model were desired to be included within the modelling for the current Floodplain Risk Management Study. Additionally, review by Catchment Simulation Solutions at the inception of the study identified some additional updates that could be included.

To ensure a reliable description of flooding within the Wyong River catchment for use within the Floodplain Risk Management Study, modifications were undertaken to the original TUFLOW model to incorporate the identified enhancements and modifications. A summary of the updates that were completed are outlined in the following sections.

1.2 Hydrologic Model Updates

1.2.1 Additional Discretisation of Sub catchments

An XP-RAFTS hydrologic model is used to generate inflow hydrographs for the various subcatchments that make up the Wyong River Catchment. The original XP-RAFTS model was broken down into 138 subcatchments at a fairly coarse scale. It was desired to extend the upstream modelled extent of the TUFLOW hydraulic model to include additional area, however the original coarse scale was not considered sufficiently detailed for the reliable application of flow at these desired locations.

As such, the XP-RAFTS model required modification to quantify design flows at these discreet locations. This required the breakdown of the original 138 subcatchments into a number of smaller subcatchments, introducing an additional 21 subcatchments. This breakdown was aided by the CatchmentSIM software to define the extent and locations of the additional subcatchments and calculate catchment areas and slopes for the additional and modified subcatchments.

The newly defined subcatchments were then incorporated within the XP-RAFTS model, and flow hydrographs generated. These hydrographs were then applied within the TUFLOW hydraulic model at the desired locations.

1.3 Hydraulic Model Updates

1.3.1 Model Extent

As described in Section 1.2.1, the extension of the hydraulic model area was desired. This required the new flow hydrographs generated within XP-RAFTS to be applied to the desired locations within the hydraulic model. The TUFLOW model extent was extended to these desired locations to include the additional model area.

1.3.2 Model Topography

Elevations within the original TUFLOW hydraulic model were assigned to each grid cell within the 2-dimensional domain based on LiDAR information that was collected across the lower catchment in 2007, and the upper and middle catchment in 2011.

As the LiDAR data was collected in 2007 (lower catchment) and 2011 (middle and upper catchment), the terrain description provided by the LiDAR is representative of topographic conditions at that time. That is, any topographic modifications completed after LiDAR collection will not be reflected in the model. A review of historic aerial photography (i.e., 2007 versus 2014) indicates there has been some development within the Mardi area of the catchment, and some minor re-development in other areas of the catchment.

As a result, it was considered appropriate to gain and utilise the latest available LiDAR information to provide a consistent description of contemporary topographic conditions across the Wyong river Catchment. LiDAR collected in 2014 on behalf of Land and Property Information, NSW was identified as appropriate for this. This LiDAR dataset was collected across the entire catchment and was obtained for use within the TUFLOW model.

1.3.3 Materials Definition

The original TUFLOW model utilised material polygons to represent the various land use types within the catchment. These polygons were generated at a coarse scale suitable for large scale implication to flood behaviour. As the hydraulic model within the Floodplain Risk Management Study will need to be used to quantify impacts of various floodplain management options, a more detailed definition of land use, and the associated Manning's 'n' roughness was required.

A remote sensing classification technique is documented in a paper titled "Using LiDAR Survey for Land Use Classification" (Ryan, 2013). The classification algorithm assist with the identification of different land uses across the study based on analysis of non-ground points (e.g., buildings, trees) and the laser return intensities gained with collection of LiDAR data. This technique was considered appropriate to define the land use type across the catchment at a suitable level of detail for this study. The 2014 LiDAR data was used as the basis of the process, and provided consistency between the topography and the land use definition.

The following land use classifications were defined as part of utilising the remote sensing technique:

- Buildings
- Trees
- Grass
- Roads
- Water

A sample output from the remote sensing for a section of Wyong is provided in **Plate 1**. As shown in **Plate 1**, the remote sensing output provides a detailed description of the spatial variation in land uses / materials.

1.3.4 Manning's 'n' Roughness

The remote sensing output was used as the basis for assigning Manning's "n" roughness coefficients to each TUFLOW grid cell. The adopted materials types and the corresponding Manning's 'n' values are summarised in **Table 1**. In all cases, the adopted Manning's "n" values were consistent with those adopted in the "Wyong River Flood Study" (BMT WBM, 2014).

Table 1 TUFLOW Manning's 'n' Roughness Values

Material Description	Manning's 'n'
Buildings	1.000
Trees	0.200
Grass	0.040
Roads incl. Road easements	0.030
Water (River, Estuarine, Middle Channel, Lower Channel)	0.030, 0.020, 0.040, 0.060

1.3.5 Structure Blockage

Blockage was assessed as a sensitivity parameter for a number of structures as part of the "Wyong River Flood Study" (BMT WBM, 2014). Structures selected for sensitivity tests were based on an assessment of the likelihood to become blocked and the likely scale of impact in the event of becoming blocked on the overall catchment flood behaviour. As such, no blockage was considered during design model simulations, and a large number of structures were not assessed for localised impacts of blockage.

Assessment was undertaken to calculate blockage factors for all structures within the Wyong River catchment hydraulic model as per blockage guidelines contained in the Australian Rainfall & Runoff document titled 'Blockage of Hydraulic Structures (Engineers Australia, 2015)'. This guideline requires an assessment of potential debris type, debris availability, debris mobility and debris transportability at each structure location. This assessment was completed using the materials definition information described in Section 1.3.3 as well as the LiDAR information described in Section 1.3.2. This assessment was thought to provide catchment wide consistency in modelling approach, and ensure localised impacts on flood behaviour due to structure blockage was considered as part of the model design simulations.

Plate 1 Example of remote sensing output (bottom image) and aerial image (top image) for a section of Wyong

1.4 Hydraulic Model Validation

In order to ensure the TUFLOW model updates were providing a reliable representation of flood behaviour, the updated model was validated. The validation was completed by comparing peak design flood levels generated by the updated model against peak design flood levels documented in the "Wyong River Flood Study" (BMT WBM, 2014).

1.4.1 Design Flood Validation

Validation of the updated TUFLOW model was completed by comparing peak 20% AEP and peak 1%AEP water levels from the updated TUFLOW model against peak design water levels extracted from the original TUFLOW model developed for the "Wyong River Flood Study" (BMT WBM, 2014).

In this regard, the updated TUFLOW model was used to simulate the critical range of durations for the 20% AEP and 1% AEP events. Peak water levels were extracted from the results of the modelling at a variety of locations across the study area and were compared against peak water levels extracted from the original TUFLOW model. The peak water level comparisons are also provided in **Table 2**.

The comparison provided in **Table 2** shows that the updated TUFLOW model provides comparable peak 20% AEP and 1% AEP floods levels relative to the original TUFLOW model across most of the study area. The average difference between the original and updated peak flood levels is 0.003 metres for the 20% AEP event and 0.034 metres for the 1% AEP event.

Some more significant flood level differences occur at some isolated locations (e.g., Downstream of Cedar Brush Creek) and are typically associated with differences in the topographic definition provided by the newly gathered LiDAR data relative to the original 2007/2011 gathered LiDAR. For example, the terrain representation in the original TUFLOW model in the vicinity of Cedar Brush Creek is typically 0.19 metres above the terrain representation provided in the updated model, and can be due to a number of factors, some as simple as varying vegetation cover between collection dates, or localised earthworks by landholders.

It is considered that the updated TUFLOW model is providing realistic flood levels and that these, on average, match closely with those obtained in the original TUFLOW model, with some larger variations in the vicinity of 0.2m in isolated locations. The outcomes of the validation indicate that the updated TUFLOW model provides a suitable tool for quantifying the existing flood problem, as well as the potential impacts of including flood mitigation works across the Wyong River catchment.

Table 2 Results of TUFLOW Design Flood Validation

Location		Peak Design Flood Level *(mAHD)*					
		20% AEP			1% AEP		
		Original Model #	Updated Model *	Difference *(m)*	Original Model #	Updated Model *	Difference *(m)*
Mardi Creek	South arm, upstream of M1	15.20	15.27	0.07	16.00	16.94	0.94
	North arm, upstream of M1	12.78	12.90	0.12	13.12	13.23	0.11
	North Arm, upstream of Woodbury Pk Dr	8.03	8.03	0	8.27	8.2	-0.07
	Upstream of Pacific Hwy	4.56	4.42	-0.14	4.86	4.69	-0.17
Wyong River	Upstream of Railway	1.98	2.01	0.03	3.95	4.07	0.12
	Downstream of Railway	1.92	1.95	0.03	3.95	4.07	0.12
	Upstream of M1 Motorway	5.43	5.54	0.11	6.5	6.5	0
	Wyong Nursing Home	2.00	2.03	0.03	4.31	4.39	0.08
	Downstream of Bryants Ck	11.85	12.00	0.15	13.06	13.2	0.14
	Downstream Chandlers Ck	14.87	14.87	0	15.95	15.92	-0.03
	Downstream of Jilliby Jilliby Ck	8.09	8.11	0.02	9.78	9.76	-0.02
	Downstream of Bunnik Ck and Wyong River	27.76	27.64	-0.12	29.52	29.36	-0.16
	Downstream Cedar Brush Ck	29.22	29.08	-0.14	30.75	30.56	-0.19
	Adjacent to Tacoma/South Tacoma	1.48	1.49	0.01	2.29	2.29	0
	Adjacent to Yarramalong	24.25	24.36	0.11	26.16	26.31	0.15
	Adjacent to Ravensdale	33.90	33.92	0.02	34.93	34.9	-0.03
	Downstream of Tuggerah Creek	1.71	1.72	0.01	2.98	3.00	0.02
Tuggerah	Tuggerah Straight	2.70	2.53	-0.17	4.25	4.24	-0.01
	Upstream of Lake Rd/Bryant Dr	4.53	4.26	-0.27	4.59	4.61	0.02
Jilliby Jilliby Creek	Downstream of Little Jilliby Jilliby Ck	12.56	12.56	0	13.33	13.33	0
	Downstream of Mandalong Rd	24.35	24.35	0	24.71	24.72	0.01

Location		Peak Design Flood Level *(mAHD)*					
		20% AEP			1% AEP		
		Original Model #	**Updated Model ***	**Difference *(m)***	**Original Model #**	**Updated Model ***	**Difference *(m)***
	Downstream of 3 valley confluence	29.17	29.11	-0.06	29.62	29.5	-0.12
Lemon Tree	Downstream of Dooralong Rd	35.60	35.85	0.25	36.4	36.27	-0.13
	Average:			0.003			0.034

NOTE: # "Original Model" refers to peak design flood levels extracted from the results of the TUFLOW model developed for the "Wyong River Flood Study" (BMT WBM, 2014)
* "Updated Model" refers to the updated version of the TUFLOW model discussed in Section 1.2 that was prepared for the current study.

A2. REFERENCES

1. BMT WBM (2014). Wyong River Flood Study. Prepared for Wyong Shire Council.

APPENDIX B

ROADWAY INUNDATION CHARACTERISTICS

MAJOR ROADWAY INUNDATION CHARACTERISTICS FOR WYONG RIVER CATCHMENT

20% AEP Flood

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
Brush Creek Rd		5.5	27.5	1.6
Brush Creek Rd		8.0	8.5	0.6
Brush Creek Rd		9.0	30.5	1.4
Brush Creek Rd		12.5	18.0	1.1
Brush Creek Rd	Near Yarramalong Rd	13.0	16.5	1.1
Dooralong Rd	Near Phil Tunks Rd	5.5	34.5	3.5
Dooralong Rd		20.5	5.5	0.6
Dooralong Rd	Near Phil Tunks Rd	20.5	6.5	0.7
Dooralong Rd	Near Yambo Forest Rd	21.0	4.5	0.5
Gavenlock Rd	Near Johnson Rd	38.5	1.5	0.5
Jilliby Rd	Near Watagan Forest Dr	27.0	13.0	0.9
Jilliby Rd		32.5	7.5	0.7
McPherson Rd	Near Old Maitland Rd	34.5	5.5	2.1
Old Maitland Rd		33.5	6.5	1.4
Ravensdale Rd		5.5	34.5	3.5
Ravensdale Rd		6.5	33.5	3.3
Ravensdale Rd	Near Yarramalong Rd	12.0	18.5	1.1
Ravensdale Rd		12.5	17.0	1.0
Red Hill Forest Rd	Near Yarramalong Rd	32.0	2.0	0.3
South Tacoma Rd		32.5	7.5	0.8
South Tacoma Rd		34.5	5.5	0.4
Yarramalong Rd		10.5	29.5	1.5
Yarramalong Rd		12.5	27.5	3.3
Yarramalong Rd		13.5	26.5	2.4
Yarramalong Rd		14.0	26.0	2.3
Yarramalong Rd		14.5	24.0	2.1
Yarramalong Rd		19.0	21.0	3.5
Yarramalong Rd		22.5	7.0	0.8
Yarramalong Rd		22.5	15.0	2.5
Yarramalong Rd		22.5	15.5	2.2
Yarramalong Rd		23.0	5.0	0.6
Yarramalong Rd		23.0	14.0	1.7
Yarramalong Rd		26.5	13.5	2.0
Yarramalong Rd		29.0	11.0	2.1
Yarramalong Rd		31.0	9.0	1.2
Yarramalong Rd		31.0	9.0	1.2
Yarramalong Rd		33.0	7.0	0.6
	Near Ravensdale Rd	6.5	33.5	3.4
	Near Wolseley Ave	20.0	20.0	0.3
	Between Yarramalong Rd and Lauffs La	29.0	11.0	1.7
	Near Panonia Rd	33.0	7.0	0.8
	Near Gavenlock Rd	38.5	1.5	0.5
	Between Gavenlock Rd and Mcpherson Rd	38.5	1.5	0.5
	Near South Tacoma Rd	39.0	1.0	0.3

MAJOR ROADWAY INUNDATION CHARACTERISTICS FOR WYONG RIVER CATCHMENT

5% AEP Flood

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
Alison Rd	Near Cape Rd	30.0	10.0	0.7
Anzac Rd	Between Gavenlock Rd and Pacific Highway (NthBnd)	6.0	34.0	0.8
Brush Creek Rd		5.0	31.0	1.9
Brush Creek Rd		6.0	15.5	1.1
Brush Creek Rd		7.5	32.5	2.0
Brush Creek Rd	Near Yarramalong Rd	8.0	25.5	1.8
Brush Creek Rd		8.0	27.0	1.8
Brush Creek Rd		20.5	2.0	0.3
Dooralong Rd	Near Phil Tunks Rd	4.5	35.5	3.9
Dooralong Rd	Near Whitemans La	8.0	7.5	0.4
Dooralong Rd	Near Yambo Forest Rd	8.0	12.0	0.8
Dooralong Rd		8.0	13.0	0.9
Dooralong Rd	Near Phil Tunks Rd	8.0	14.5	1.0
Dooralong Rd		21.0	4.5	0.4
Gavenlock Rd	Near Mildon Rd	6.5	0.5	0.3
Gavenlock Rd	Near Mildon Rd	6.5	2.0	0.3
Gavenlock Rd	Near Johnson Rd	30.0	10.0	1.9
Jilliby Rd	Near Mandalong Rd	19.5	3.5	0.3
Jilliby Rd		21.5	18.5	0.6
Jilliby Rd	Near Watagan Forest Dr	25.5	14.5	2.0
Jilliby Rd		26.0	14.0	1.9
Jilliby Rd		28.0	7.5	1.0
Mcdonagh Rd	Near Wolseley Ave	31.0	9.0	1.0
Mcdonagh Rd		31.5	8.5	0.9
Mcpherson Rd	Near Old Maitland Rd	28.5	11.5	3.5
Old Maitland Rd		25.0	15.0	2.5
Pacific Highway		31.5	2.5	0.4
Panonia Rd		31.5	4.0	0.4
Pollock Ave		32.5	7.5	0.6
Ravensdale Rd		5.0	35.0	4.0
Ravensdale Rd		6.0	34.0	3.7
Ravensdale Rd		9.5	25.0	1.5
Ravensdale Rd	Near Yarramalong Rd	9.5	26.0	1.5
Red Hill Forest Rd	Near Yarramalong Rd	27.0	9.5	0.8
South Tacoma Rd		23.5	16.5	2.0
South Tacoma Rd		24.0	16.0	0.8
South Tacoma Rd		28.5	11.5	0.7
South Tacoma Rd		29.0	11.0	0.7
South Tacoma Rd		31.5	3.5	0.5
Wolseley Ave		30.5	9.5	0.6
Wyong Rd (WstBnd)		5.5	34.5	0.6
Yarramalong Rd		8.5	31.5	2.4
Yarramalong Rd		9.5	30.5	4.3
Yarramalong Rd		10.5	15.5	1.7
Yarramalong Rd		10.5	29.5	3.2
Yarramalong Rd		10.5	29.5	3.3
Yarramalong Rd		10.5	29.5	3.4
Yarramalong Rd		11.0	27.0	2.8
Yarramalong Rd		12.0	11.0	1.5
Yarramalong Rd		13.5	26.5	4.5
Yarramalong Rd		15.0	25.0	3.1
Yarramalong Rd		15.0	25.0	2.9
Yarramalong Rd		16.0	24.0	3.1
Yarramalong Rd		18.0	22.0	2.8
Yarramalong Rd		21.0	19.0	1.7
Yarramalong Rd		21.0	19.0	1.7
Yarramalong Rd		27.0	7.5	0.7
Yarramalong Rd		28.0	12.0	1.5
	Near Ravensdale Rd	5.5	34.5	3.8
	Between Yarramalong Rd and Lauffs La	18.5	21.5	2.4
	Near Wolseley Ave	20.5	19.5	0.7
	Near Yarramalong Rd	22.5	6.0	0.9

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
	Near Panonia Rd	28.0	12.0	2.0
	Near South Tacoma Rd	28.5	11.5	0.8
	Near Gavenlock Rd	28.5	11.5	2.0
	Between Yarramalong Rd and Old Maitland Rd	29.5	2.0	0.3
	Near South Tacoma Rd	29.5	10.5	1.9
		30.0	10.0	1.7
	Between Gavenlock Rd and Mcpherson Rd	30.0	10.0	1.9
	Near Wolseley Ave	30.5	9.5	0.5

MAJOR ROADWAY INUNDATION CHARACTERISTICS FOR WYONG RIVER CATCHMENT

1% AEP Flood

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
Alison Rd	Near Cape Rd	20.0	16.5	1.4
Anzac Rd	Between Gavenlock Rd and Pacific Highway (NthBnd)	5.0	35.0	1.0
Boyce Ave	Between Mcdonagh Rd and Panonia Rd	27.5	12.5	0.8
Boyce Ave		28.5	11.5	1.0
Boyce Ave	Near Pollock Ave	28.5	11.5	0.9
Brush Creek Rd		4.5	34.0	2.2
Brush Creek Rd		5.5	21.5	1.5
Brush Creek Rd		6.5	33.5	2.7
Brush Creek Rd		7.0	9.0	0.8
Brush Creek Rd	Near Yarramalong Rd	7.0	31.0	2.6
Brush Creek Rd		7.0	32.0	2.6
Dooralong Rd	Near Phil Tunks Rd	3.5	36.5	4.3
Dooralong Rd	Near Whitemans La	6.5	13.5	0.5
Dooralong Rd	Near Yambo Forest Rd	7.0	17.5	1.0
Dooralong Rd		7.0	18.5	1.1
Dooralong Rd	Near Phil Tunks Rd	7.0	20.0	1.2
Dooralong Rd		9.0	6.0	0.7
Dooralong Rd	Near Hitchcocks La	18.5	4.0	0.3
Gavenlock Rd		5.5	5.5	0.4
Gavenlock Rd	Near Mildon Rd	5.5	15.0	0.7
Gavenlock Rd	Near Mildon Rd	6.0	15.0	0.8
Gavenlock Rd	Near Johnson Rd	19.5	20.5	2.8
Gavenlock Rd	Near Johnson Rd	27.5	12.5	1.2
Gavenlock Rd		28.0	12.0	1.3
Gavenlock Rd		28.0	12.0	1.2
Gavenlock Rd		28.5	9.0	0.8
Jilliby Rd	Near Mandalong Rd	6.5	8.0	0.4
Jilliby Rd		8.5	31.5	0.7
Jilliby Rd	Near Watagan Forest Dr	13.0	27.0	2.7
Jilliby Rd		14.0	26.0	2.6
Jilliby Rd		17.5	14.5	1.7
Jilliby Rd	Near Little Jilliby Rd	20.5	4.0	0.3
Jilliby Rd		21.5	6.0	0.5
Jilliby Rd	Between Little Jilliby Rd and Watagan Forest Dr	25.0	6.0	1.1
Mcdonagh Rd	Near Wolseley Ave	22.5	17.5	1.5
Mcdonagh Rd		23.5	16.5	1.4
Mcpherson Rd	Near Old Maitland Rd	17.5	22.5	4.1
Old Maitland Rd		14.0	26.0	3.2
Pacific Highway	Near Pacific Highway (NthBnd)	27.0	13.0	1.3
Pacific Highway (NthBnd)	Near Pacific Highway (SthBnd)	6.0	16.0	0.4
Pacific Highway (NthBnd)	Between Pacific Highway (SthBnd) and South Tacoma R	27.5	11.5	1.0
Pacific Highway (SthBnd)	Near South Tacoma Rd	27.5	11.0	0.9
Panonia Rd		27.0	13.0	1.0
Panonia Rd		27.5	12.5	0.8
Panonia Rd		27.5	12.5	1.2
Panonia Rd		28.0	12.0	0.6
Panonia Rd		28.0	12.0	0.7
Pollock Ave		27.5	12.5	1.0
Pollock Ave		29.5	10.5	0.4
Ravensdale Rd		4.0	36.0	4.5
Ravensdale Rd		5.0	35.0	4.3
Ravensdale Rd	Near Yarramalong Rd	7.5	23.0	2.1
Ravensdale Rd		7.5	31.0	2.0
Red Hill Forest Rd	Near Yarramalong Rd	15.5	20.5	1.3
South Tacoma Rd		17.0	23.0	2.6
South Tacoma Rd		19.0	21.0	1.2
South Tacoma Rd		20.5	19.5	1.1
South Tacoma Rd		21.5	18.5	1.1
South Tacoma Rd		27.0	13.0	1.4
Wolseley Ave		22.5	17.5	1.0
Wyong Rd (WstBnd)		4.5	35.5	0.6
Yarramalong Rd		6.5	31.0	4.0

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
Yarramalong Rd		7.5	32.5	3.2
Yarramalong Rd		8.0	21.0	2.3
Yarramalong Rd		8.0	23.5	2.5
Yarramalong Rd		8.0	32.0	5.3
Yarramalong Rd		8.0	32.0	4.3
Yarramalong Rd		8.5	31.5	4.1
Yarramalong Rd		8.5	31.5	5.4
Yarramalong Rd		8.5	31.5	4.2
Yarramalong Rd		9.0	31.0	3.7
Yarramalong Rd		10.0	30.0	3.7
Yarramalong Rd		12.0	28.0	3.8
Yarramalong Rd		13.5	26.5	3.5
Yarramalong Rd		15.0	25.0	2.2
Yarramalong Rd		15.0	25.0	2.2
Yarramalong Rd		16.0	15.5	1.1
Yarramalong Rd		16.5	23.5	1.9
Yarramalong Rd		21.5	4.5	0.6
Yarramalong Rd		22.0	3.0	0.5
	Near Ravensdale Rd	5.0	35.0	4.4
	Between Yarramalong Rd and Lauffs La	6.5	28.0	2.9
	Near Wolseley Ave	9.5	30.5	1.1
	Near Yarramalong Rd	10.5	13.0	1.8
	Near Panonia Rd	18.0	22.0	3.1
	Near Gavenlock Rd	19.0	21.0	2.9
	Near South Tacoma Rd	19.5	20.5	2.7
	Between Gavenlock Rd and Mcpherson Rd	19.5	20.5	2.8
		20.0	19.5	2.5
	Near South Tacoma Rd	21.0	19.0	1.2
	Near Wolseley Ave	24.0	16.0	0.9
	Between Yarramalong Rd and Old Maitland Rd	25.5	9.0	0.8
	Between Panonia Rd and Warner Ave	27.0	12.5	0.8
	Near Panonia Rd	27.5	12.5	0.9
	Between Boyce Ave and Panonia Rd	27.5	12.5	0.9
	Near Brathwate Rd	28.5	11.5	0.6
	Near Mildon Rd	29.0	7.0	0.6

MAJOR ROADWAY INUNDATION CHARACTERISTICS FOR WYONG RIVER CATCHMENT

Probable Maximum Flood

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
Alison Rd	Near Cape Rd	5.0	35.0	5.0
Anzac Rd	Between Gavenlock Rd and Pacific Highway (NthBnd)	0.5	39.5	2.4
Boyce Ave		6.5	33.5	2.6
Boyce Ave	Near Pollock Ave	6.5	33.5	2.5
Boyce Ave	Near Pollock Ave	7.0	31.0	1.6
Boyce Ave	Between Mcdonagh Rd and Panonia Rd	6.0	34.0	2.5
Brathwate Rd	Near Jensen Rd	7.5	32.5	1.8
Brush Creek Rd		0.5	33.0	5.7
Brush Creek Rd	Near Yarramalong Rd	1.5	33.0	6.8
Brush Creek Rd		1.5	33.5	6.8
Brush Creek Rd		1.5	36.5	6.9
Brush Creek Rd		1.0	26.0	4.7
Brush Creek Rd		1.0	28.0	5.4
Dooralong Rd	Near Phil Tunks Rd	0.5	39.5	7.8
Dooralong Rd	Near Yambo Forest Rd	1.5	27.5	3.0
Dooralong Rd	Near Yambo Forest Rd	2.0	22.0	1.6
Dooralong Rd	Near Hitchcocks La	1.5	19.0	1.5
Dooralong Rd	Between Whitemans La and Jilliby Rd	1.0	9.0	0.6
Dooralong Rd	Near Whitemans La	1.5	8.0	1.6
Dooralong Rd	Near Hitchcocks La	1.0	2.5	0.8
Dooralong Rd		1.5	27.0	2.5
Dooralong Rd		2.5	2.0	0.7
Dooralong Rd	Near Phil Tunks Rd	1.5	28.5	3.2
Dooralong Rd		1.5	28.0	3.1
Gavenlock Rd	Near Johnson Rd	4.5	35.5	6.0
Gavenlock Rd	Near Johnson Rd	1.5	38.5	4.1
Gavenlock Rd		1.0	37.5	2.3
Gavenlock Rd	Near Mildon Rd	1.0	39.0	2.9
Gavenlock Rd	Near Mildon Rd	1.0	39.0	3.0
Gavenlock Rd		1.5	38.5	3.6
Gavenlock Rd		1.5	38.5	3.6
Gavenlock Rd		2.0	38.0	3.4
Jilliby Rd		3.0	37.0	4.8
Jilliby Rd	Near Mandalong Rd	3.0	2.0	0.9
Jilliby Rd		3.0	27.0	2.0
Jilliby Rd		3.0	20.0	1.4
Jilliby Rd		1.5	38.5	1.1
Jilliby Rd	Between Little Jilliby Rd and Watagan Forest Dr	1.5	31.5	3.3
Jilliby Rd	Near Watagan Forest Dr	2.5	37.5	5.0
Jilliby Rd		4.0	33.5	3.9
Jilliby Rd	Near Little Jilliby Rd	2.0	25.0	0.8
Mcdonagh Rd	Near Wolseley Ave	6.5	33.5	3.0
Mcdonagh Rd		6.5	33.5	3.0
Mcpherson Rd	Near Old Maitland Rd	3.0	37.0	6.5
Old Maitland Rd		2.0	38.0	5.5
Old Maitland Rd		1.0	1.5	0.4
Pacific Highway	Near Pacific Highway (NthBnd)	2.5	37.5	3.9
Pacific Highway		19.5	8.5	0.7
Pacific Highway	Near Pacific Hwy	7.0	23.0	1.9
Pacific Highway (NthBnd)	Between Wyong Rd and Pacific Highway (SthBnd)	1.0	32.0	1.5
Pacific Highway (NthBnd)	Near Pacific Highway (SthBnd)	1.0	37.0	2.0
Pacific Highway (NthBnd)	Between Pacific Highway (SthBnd) and South Tacoma R	2.0	38.0	3.1
Pacific Highway (SthBnd)	Near Wyong Rd	1.5	29.5	1.3
Pacific Highway (SthBnd)		1.5	36.0	1.9
Pacific Highway (SthBnd)	Near South Tacoma Rd	2.0	38.0	3.0
Pacific Hwy	Near Sparks Rd	19.0	21.0	2.1
PACIFIC MOTORWAY		17.5	15.0	1.7
PACIFIC MOTORWAY		21.5	4.5	0.4
PACIFIC MOTORWAY		18.0	14.5	1.7
PACIFIC MOTORWAY		18.5	13.0	1.5
PACIFIC MOTORWAY		22.0	5.0	0.6
PACIFIC MOTORWAY		6.0	25.0	1.7

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
PACIFIC MOTORWAY		6.0	24.0	1.6
PACIFIC MOTORWAY		6.0	22.0	1.5
PACIFIC MOTORWAY		6.0	24.0	1.5
PACIFIC MOTORWAY		5.5	25.5	1.5
PACIFIC MOTORWAY		6.0	25.0	1.4
PACIFIC MOTORWAY		21.5	2.5	0.3
PACIFIC MOTORWAY		18.5	9.5	0.7
PACIFIC MOTORWAY		18.0	14.0	1.6
PACIFIC MOTORWAY		18.0	14.5	1.7
PACIFIC MOTORWAY		17.5	15.0	1.7
PACIFIC MOTORWAY		18.0	14.5	1.7
Panonia Rd		6.0	34.0	2.4
Panonia Rd		6.0	34.0	2.9
Panonia Rd		6.0	34.0	2.7
Panonia Rd		6.0	34.0	2.7
Panonia Rd		5.5	34.5	2.5
Pollock Ave		4.0	36.0	2.6
Pollock Ave		7.0	33.0	2.1
Ravensdale Rd		0.5	36.5	7.6
Ravensdale Rd		0.5	37.5	7.8
Ravensdale Rd	Near Yarramalong Rd	1.0	31.0	6.2
Ravensdale Rd		1.0	34.0	5.0
Red Hill Forest Rd	Near Yarramalong Rd	3.0	35.5	3.3
South Tacoma Rd		2.5	37.5	5.3
South Tacoma Rd		6.0	34.0	1.7
South Tacoma Rd		6.5	33.5	1.6
South Tacoma Rd		2.5	37.5	4.2
South Tacoma Rd		6.0	34.0	1.7
Wolseley Ave		6.0	34.0	2.4
Wyong Rd (EstBnd)	Near Wyong Rd (WstBnd)	1.0	4.0	0.7
Wyong Rd (EstBnd)	Near Wyong Rd (WstBnd)	16.5	16.0	0.9
Wyong Rd (EstBnd)	Near Wyong Rd (WstBnd)	1.0	2.0	0.7
Wyong Rd (WstBnd)		9.0	31.0	1.3
Wyong Rd (WstBnd)		1.0	39.0	0.9
Wyong Rd (WstBnd)	Near Wyong Road	1.0	2.0	0.6
Yarramalong Rd		1.5	38.5	7.4
Yarramalong Rd		1.5	37.5	7.5
Yarramalong Rd		1.5	38.5	9.1
Yarramalong Rd		3.5	2.0	0.7
Yarramalong Rd		3.5	6.5	1.0
Yarramalong Rd		2.0	35.5	7.0
Yarramalong Rd		1.0	39.0	9.0
Yarramalong Rd		4.5	20.5	1.8
Yarramalong Rd		1.5	38.5	6.3
Yarramalong Rd		1.5	38.5	5.9
Yarramalong Rd		4.0	36.0	3.8
Yarramalong Rd		1.0	39.0	7.0
Yarramalong Rd		1.0	39.0	6.8
Yarramalong Rd		1.5	38.5	7.5
Yarramalong Rd		1.0	39.0	7.6
Yarramalong Rd		2.5	26.0	4.2
Yarramalong Rd		2.5	26.0	4.5
Yarramalong Rd		2.0	30.0	6.6
Yarramalong Rd		2.0	31.0	6.8
Yarramalong Rd		3.0	34.0	3.2
Yarramalong Rd		3.0	37.0	4.2
Yarramalong Rd		3.0	37.0	4.2
	Near South Tacoma Rd	2.5	37.5	5.7
	Near Yarramalong Rd	3.5	2.0	0.6
	Between Panonia Rd and Warner Ave	5.5	34.5	2.2
		7.0	23.0	1.9
	Near Panonia Rd	5.0	35.0	6.4
	Near Wolseley Ave	6.0	34.0	1.9
	Near Wolseley Ave	2.5	37.5	2.1
	Near Brathwate Rd	7.0	33.0	1.6
	Near Yarramalong Rd	2.5	29.0	5.1

Road Name	Cross Road	Time of First Inundation (hours)	Duration of Inundation (hours)	Maximum Depth of Inundation (metres)
	Near Yarramalong Rd	4.5	21.5	1.9
	Between Yarramalong Rd and Lauffs La	1.5	38.5	4.7
	Between Yarramalong Rd and Old Maitland Rd	4.5	31.0	2.9
	Near Mildon Rd	1.0	38.5	2.8
		5.0	35.0	5.5
	Near Gavenlock Rd	3.5	35.5	6.2
	Between Gavenlock Rd and Mcpherson Rd	4.5	35.5	6.0
		7.0	23.0	1.9
	Near Panonia Rd	6.0	34.0	2.5
	Near Panonia Rd	6.5	30.5	1.5
	Near Boyce Ave	19.5	10.0	0.5
		20.0	20.0	0.8
	Between Boyce Ave and Panonia Rd	6.0	34.0	2.6
	Near Ravensdale Rd	0.5	39.5	7.7

APPENDIX C

FLOOD DAMAGE CALCULATIONS

Catchment Simulation Solutions

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C1 Flood Damage Calculations

1.1 Introduction

In an effort to quantify the financial impact that flooding has on residents and business owners within the Wyong River catchment, the number of properties subject to over floor flooding and the flood damage cost that would likely be incurred during the full range of modelled design floods was calculated. The approach that was adopted to estimate the flood damage costs is presented below.

1.2 Property Database

A property database was developed as part of the study to enable damage calculations to be prepared across residential, commercial and industrial properties. The database was developed in GIS and included the details of all habitable buildings located within the PMF extent.

The following information was included as fields within the database for each building:

- Property type (i.e., residential, commercial or industrial);
- Building floor level;
- Building floor area (gained through automated GIS interrogation);
- Residential building type (i.e., two story, single level high set, single level low set or apartments);
- Number of apartments on each level of residential apartments blocks
- Commercial property contents value (low, medium or high value);

In general, the information listed above was populated using a “drive by” survey. In instances where buildings were not visible from the street, a best estimate of the building properties was made based on information gleaned from surrounding buildings.

1.3 Building Floor Levels

As outlined above, it is necessary to have information describing the floor height / level of every building within the PMF extent. The floor levels were defined using either surveyed floor level information (where available) or were estimated using a “drive by” survey. The surveyed floor levels were generally extracted from detailed floor level survey conducted by Chase Burke in February 2007 and cover the majority of the buildings within the 1%AEP flood extent downstream of the Pacific Motorway.

Where surveyed floor levels were not available, the floor levels were estimated using the following "drive by" survey process:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground;
2. The ground level at the point where the floor height was estimated was extracted from the available LiDAR data;
3. The floor level was subsequently estimated by adding the floor height (calculated in step 1) to the ground elevation (calculated in step 2).

1.4 Types of Damage Costs

The damage costs associated with inundation can be broken down into a number of categories, as shown in **Plate 1**. However, broadly speaking, damage costs fall under two major categories;

- tangible damages; and
- intangible damages.

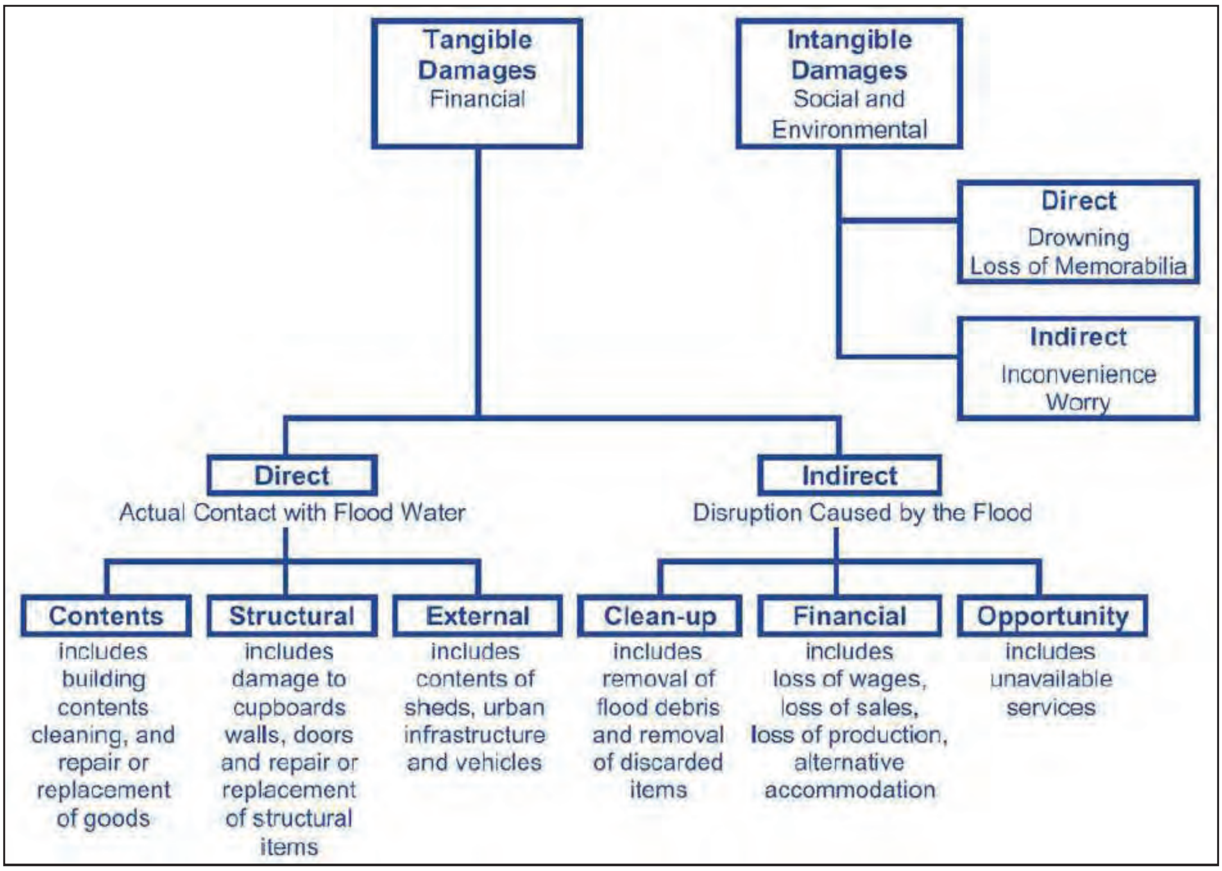


Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by waters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents.

Indirect flood damage costs are costs incurred outside of the specific inundation event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

Due to the difficulty associated with assigning a monetary values to intangible damages, only tangible damages were considered as part of this study. Further information on how tangible damages costs were estimated is presented in the following sections.

1.5 Flood Damage Calculations

1.5.1 Residential Properties

The NSW Office of Environment and Heritage (OEH) has prepared a spreadsheet that provides a standardised approach for deriving depth-damage curves for residential properties (version 3.00, October 2007). The spreadsheet requires a range of parameters to be defined to enable a meaningful damage estimate to be derived. The default parameters that were adopted for the current study are provided on the following page.

It was noted that the resulting depth-damage curves incorporate a damage allowance for 'negative' depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, sheds, belongings stored below the building floor). The damage curves for 'single storey low set' and 'two storey' properties commence at -0.3 metres, which was considered to be appropriate for the catchment and is in line with that adopted in the 'Porters Creek Floodplain Risk Management Study' (Cardno, 2011).

The default 'single storey high set' damage curves commence at -5 metres. This considered to be too far below the floor level given the relatively flat topography across the majority of the residential sections of the study area. In order to verify this, single storey high set building floor levels within the PMF extent were compared against the minimum ground elevation within each cadastral lot (i.e., the minimum elevation within each cadastral lot at which inundation will first occur and, therefore, where damage is likely to commence). This determined that the median difference between the building floor level and minimum ground level within the corresponding lot was 1.1 metres. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced only when the flood water was at a level less than 1.1 metres below the floor level.

Building floor areas for each residential building in the catchment were calculated using GIS. The building floor area serves as one of the residential damage curve inputs. The floor area for residential buildings within the catchment was reviewed and it was determined that the median floor area was 185 m^2. Accordingly, this area was adopted for the flood damage curves

The resulting residential depth-damage curves are included on the following page. The residential depth-damage curves include allowances for both direct and indirect cost components.

It is noted that there are apartment buildings located within the catchment. Apartments have the potential to contribute significantly to the flood damage costs. Therefore, the

Residential Flood Damage Input Paramaters

DIRECT COST INPUTS

Flood Damage Parameter	Recommended Range	Adopted Value	Source
Regional Cost Variation Factor		1	From Rawlinsons
Post late 2001 adjustments	AWE as factor compared to late 2001	2.23	From ABS (http://www.abs.gov.au/ausstats/abs@.nsf/mf/6302.0)AWE in November 2014 is $1539.40
Post Flood Inflation Factor	1.0 to 1.5	1	From OEH Residential Damage Curve Spreadsheet v 3.00, Metro City
Typical Duration of Immersion		24	From Emergency Response Classification Results
Building Damage Repair Limitation Factor	0.85 (short duration) to 1.00 (long duration)	0.85	From OEH Residential Damage Curve Spreadsheet v 3.00
Typical House Size		185	From GIS analysis of housing polygons
Average Contents Relevant To Site		$87,572	2009-10 contents value for Smithfield from ABS (http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10Dec+2011#Contents5) = $61,000. Adjusted to 2015 dollars = $67,370 and then adjusted to 2001 dollars = $29,548 for input into OEH spreadsheet
Contents Damage Repair Limitation Factor	0.75 (short duration) to 0.90 (long duration)	0.75	From OEH Residential Damage Curve Spreadsheet v 3.00
Level of Flood Awareness	Low default unless otherwise justifiable	Low	From OEH Residential Damage Curve Spreadsheet v 3.00
Effective Warning Time		0	Reduction factors due to warning applied independantly based on building location in catchment
Typical Table/Bench Height (TTBH)	0.9m is typical height. If typical is 2 storey, use 2.6m	0.9	From OEH Residential Damage Curve Spreadsheet v 3.00
External Damage	$6,700 recommended	$6,700	From OEH Residential Damage Curve Spreadsheet v 3.00
Up to Second Floor Level, less than		2.6m	From OEH Residential Damage Curve Spreadsheet v 3.00
From Second Storey up, greater than		2.6m	From OEH Residential Damage Curve Spreadsheet v 3.00
Up to Second Floor Level, less than (% single storey slab on ground)		70%	From OEH Residential Damage Curve Spreadsheet v 3.00
From Second Storey up, greater than (% single storey slab on ground)		110%	From OEH Residential Damage Curve Spreadsheet v 3.00

INDIRECT COST INPUTS

Flood Damage Parameter	Recommended Range	Adopted Value	Source
Clean Up Costs	$4,000 recommended	$4,000	From OEH Residential Damage Curve Spreadsheet v 3.00
Likely Time in Alternate Accommodation		1 week	Assuming it takes 1 week to clean up and re-establish habitability of house
Additional accommodation costs/Loss of Rent	$220 recommended without justification	$450/week	Average weekly rent in Wyong locality (Factored up using CPI from 2011 census data)

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT						
Version 3.00 October 2007						
PROJECT Wyong	**DETAILS** Residential Buildings Flood Damages Assessment			**DATE** 1/06/2016	**JOB No.**	

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*				
Post late 2001 adjustments	2.23	*Changes in AWE see AWE Stats Worksheet*				
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*		
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*				
	Regional City			*Regional Town*		
	Houses Affected		*Factor*	*Houses Affected*		*Factor*
Small scale impact	*<*	*50*	*1.00*	*<*	*10*	*1.00*
Medium scale impacts in Regional City		*100*	*1.20*		*30*	*1.30*
Large scale impacts in Regional City	*>*	*150*	*1.40*	*>*	*50*	*1.50*
Typical Duration of Immersion	24	hours				
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*		*long duration*
		Suggested range		*0.85*	*to*	*1.00*
Typical House Size	185	m^2		*240 m^2 is Base*		
Building Size Adjustment	0.8					
Total Building Adjustment Factor	**1.46**					

CONTENTS

Average Contents Relevant to Site	$ 87,572		*Base for 240 m^2 house*		*$ 60,000*	
Post late 2001 adjustments	2.23	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*		*short duration*		*long duration*
Sub-Total Adjustment Factor	1.67	*Suggested range*		*0.75*	*to*	*0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	0	hour				
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor				
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**1.67**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.67**					

Most recent advice from Victorian Rapid Assessment Method					
Low level of awareness is expected norm (long term average) any deviation needs to be justified.					
Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS

Post late 2001 adjustments	2.23	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	1	weeks
Additional accommodation costs /Loss of Rent	$ 450	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves		AFD = Above Floor Depth					
Single Storey Slab/Low Set	13164	+	4871		x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m			
Validity Limits	AFD	less than or equal to			6	m	
Single Storey High Set	16586	+	7454		x	AFD	
Structure with GST	AFD	greater than	-1.1	m			
Validity Limits	AFD	less than or equal to			6	m	
Contents	20000	+	20000		x	AFD	
Contents with GST	AFD	greater than			0		
Validity Limits	AFD	less than or equal to			2		

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT			
Version 3.00 October 2007			
PROJECT	**DETAILS**	**DATE**	**JOB No.**
Wyong	Apartment Buildings Flood Damages Assessment	1/06/2016	

BUILDINGS							
Regional Cost Variation Factor	1.00	*From Rawlinsons*					
Post late 2001 adjustments	2.23	*Changes in AWE see AWE Stats Worksheet*					
Post Flood Inflation Factor	1.00	*1.0*	*to*	*1.5*			
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					
	Regional City			*Regional Town*			
	Houses Affected		*Factor*	*Houses Affected*			*Factor*
Small scale impact	*<*	*50*	*1.00*	*<*	*10*		*1.00*
Medium scale impacts in Regional City		*100*	*1.20*		*30*		*1.30*
Large scale impacts in Regional City	*>*	*150*	*1.40*	*>*	*50*		*1.50*
Typical Duration of Immersion	6	hours					
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*			*long duration*
		Suggested range		*0.85*	*to*		*1.00*
Typical House Size	120	m^2	*240 m^2 is Base*				
Building Size Adjustment	0.5						
Total Building Adjustment Factor	**0.95**						

CONTENTS						
Average Contents Relevant to Site	$ 56,803	*Base for 240 m^2 house*		*$ 60,000*		
Post late 2001 adjustments	2.23	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*			*long duration*
Sub-Total Adjustment Factor	1.67	*Suggested range*	*0.75*	*to*		*0.90*
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	0	hour				
Interpolated DRF adjustment (Awareness/Time)	1.00	IDRF = Interpolated Damage Reduction Factor				
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**1.67**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.67**					

Most recent advice from Victorian Rapid Assessment Method					
Low level of awareness is expected norm (long term average) any deviation needs to be justified.					
Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*0*		
Site Specific iterations	*1.00*	*0.89*	*1.00*		

ADDITIONAL FACTORS		
Post late 2001 adjustments	2.23	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	1	weeks
Additional accommodation costs /Loss of Rent	$ 450	*$220 per week recommended without justification*

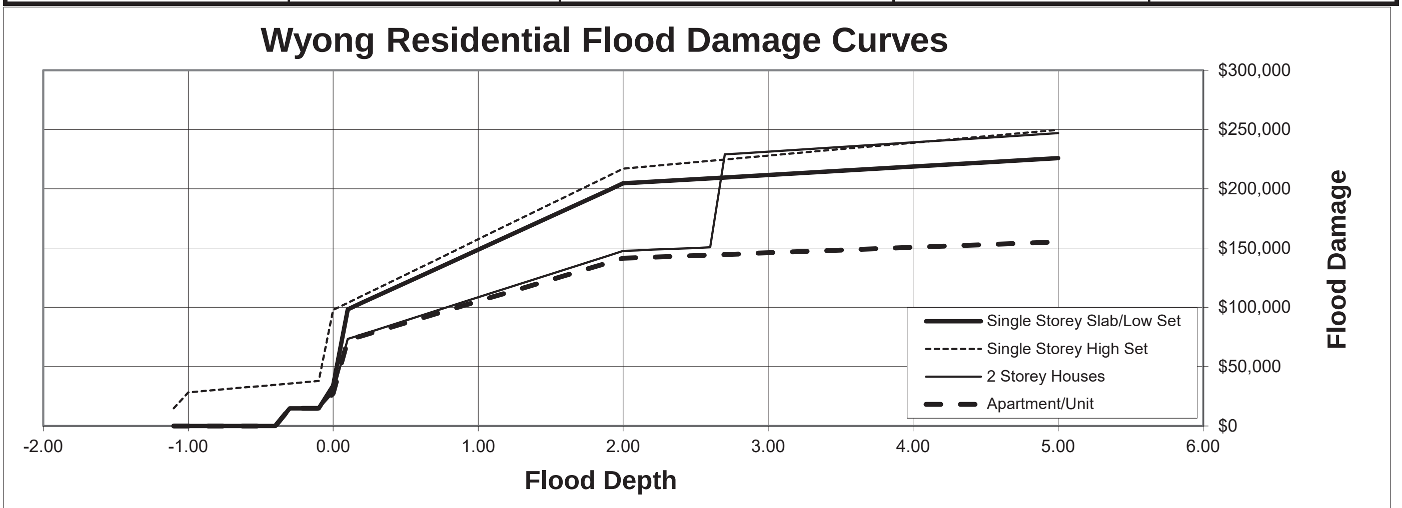
TWO STOREY HOUSE BUILDING & CONTENTS FACTORS				
Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves		AFD = Above Floor Depth				
Single Storey Slab/Low Set	13164	+	4871		x	AFD in metres
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to			6	m
Single Storey High Set	16586	+	7454		x	AFD
Structure with GST	AFD	greater than	-1.1	m		
Validity Limits	AFD	less than or equal to			6	m
Contents	20000	+	20000		x	AFD
Contents with GST	AFD	greater than			0	
Validity Limits	AFD	less than or equal to			2	

Floodplain Specific Damage Curves for Individual Residences

Steps in Curve 0.1 m

	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses	Apartment/Unit
Type	1	2	3	4
AFD from Modelling	Damage	Damage	Damage	Damage
-5.00	$0	$0	$0	$0
-1.10	$14,925	$0	$0	$0
-1.00	$28,254	$0	$0	$0
-0.90	$29,341	$0	$0	$0
-0.80	$30,429	$0	$0	$0
-0.70	$31,517	$0	$0	$0
-0.60	$32,605	$0	$0	$0
-0.50	$33,693	$0	$0	$0
-0.40	$34,781	$0	$0	$0
-0.30	$35,869	$14,925	$14,925	$14,925
-0.20	$36,957	$14,925	$14,925	$14,925
-0.10	$38,044	$14,925	$14,925	$14,925
0.00	$97,813	$34,138	$28,374	$27,387
0.10	$103,778	$98,407	$73,362	$72,558
0.20	$109,743	$103,994	$77,273	$76,182
0.30	$115,708	$109,582	$81,185	$79,807
0.40	$121,672	$115,170	$85,096	$83,431
0.50	$127,637	$120,758	$89,008	$87,056
0.60	$133,602	$126,345	$92,919	$90,680
0.70	$139,566	$131,933	$96,831	$94,305
0.80	$145,531	$137,521	$100,742	$97,929
0.90	$151,496	$143,109	$104,653	$101,554
1.00	$157,461	$148,696	$108,565	$105,178
1.10	$163,425	$154,284	$112,476	$108,803
1.20	$169,390	$159,872	$116,388	$112,427
1.30	$175,355	$165,460	$120,299	$116,052
1.40	$181,319	$171,047	$124,211	$119,676
1.50	$187,284	$176,635	$128,122	$123,301
1.60	$193,249	$182,223	$132,033	$126,925
1.70	$199,214	$187,811	$135,945	$130,550
1.80	$205,178	$193,398	$139,856	$134,174
1.90	$211,143	$198,986	$143,768	$137,799
2.00	$217,108	$204,574	$147,679	$141,423
2.10	$218,196	$205,285	$148,177	$141,884
2.20	$219,284	$205,996	$148,674	$142,345
2.30	$220,371	$206,706	$149,172	$142,807
2.40	$221,459	$207,417	$149,670	$143,268
2.50	$222,547	$208,128	$150,167	$143,729
2.60	$223,635	$208,839	$150,665	$144,190
2.70	$224,723	$209,550	$229,013	$144,651
2.80	$225,811	$210,261	$229,795	$145,112
2.90	$226,899	$210,972	$230,577	$145,573
3.00	$227,987	$211,683	$231,359	$146,034
3.10	$229,074	$212,394	$232,141	$146,496
3.20	$230,162	$213,105	$232,923	$146,957
3.30	$231,250	$213,816	$233,705	$147,418
3.40	$232,338	$214,526	$234,487	$147,879
3.50	$233,426	$215,237	$235,269	$148,340
4.00	$238,865	$218,792	$239,179	$150,646
4.50	$244,305	$222,346	$243,089	$152,951
5.00	$249,744	$225,901	$246,999	$155,257



number of apartments located on the lowest habitable level of each apartment building was estimates and the total building floor area divided by this number to establish a representative average floor area for apartments within the study area. This was found to be 120 m^2, and this was used to develop separate depth-damage curves for apartment blocks using the same procedure as for traditional residential buildings.

1.5.2 Commercial/Industrial Properties

Unlike residential flood damage calculations, there are no standard curves available for estimating commercial and industrial flood damages in NSW. Commercial property types include offices and shops, and industrial properties include facilities such as warehouses and automotive repairs.

As part of the 'Lower Wyong River Floodplain Risk Management Study' (Paterson Consulting, 2010), damage curves were compiled from data collected following the Nyngan and Inverell floods during the 1990s, as well as data gained from interviews of 41 businesses in Gloucester. The collation of these data sources enabled damage curves to be generated for commercial/industrial properties and could be applied to commercial/industrial properties within the Wyong River Catchment.

However, as part of the 'Lower Wyong River Floodplain Risk Management Study', information gained from the interviews of 18 properties located in the Tuggerah Straight Industrial Area in 1996 allowed the generic damage information compiled above to be supplemented with data specific to the study area. This allowed the development of a custom set of damage curves for the commercial and industrial businesses within this area. It was considered appropriate to use these curves for the current study in the absence of a standard set of damage curves.

However, the Tuggerah Straight depth-damage curves were updated to 2016 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the catchment.

In order to apply the damage curves, it was necessary to categorise each commercial/industrial property according to the value of the contents (i.e., normal and high damage potential). This is intended to reflect the fact that the damage incurred across commercial/industrial properties is likely to be directly related to the value of its contents. **Table 1** and **Table 2** provide a summary of common commercial and industrial property types and the associated contents value that each would fall under.

The adopted commercial depth-damage curves are presented on the following page.

No specific allowance is included in the commercial/industrial damage curves for indirect losses, such as clean-up costs and loss of income while clean-up occurs. Therefore, indirect damage costs were estimated as 50% of the direct flood damages, and this was added to the base damage curves.

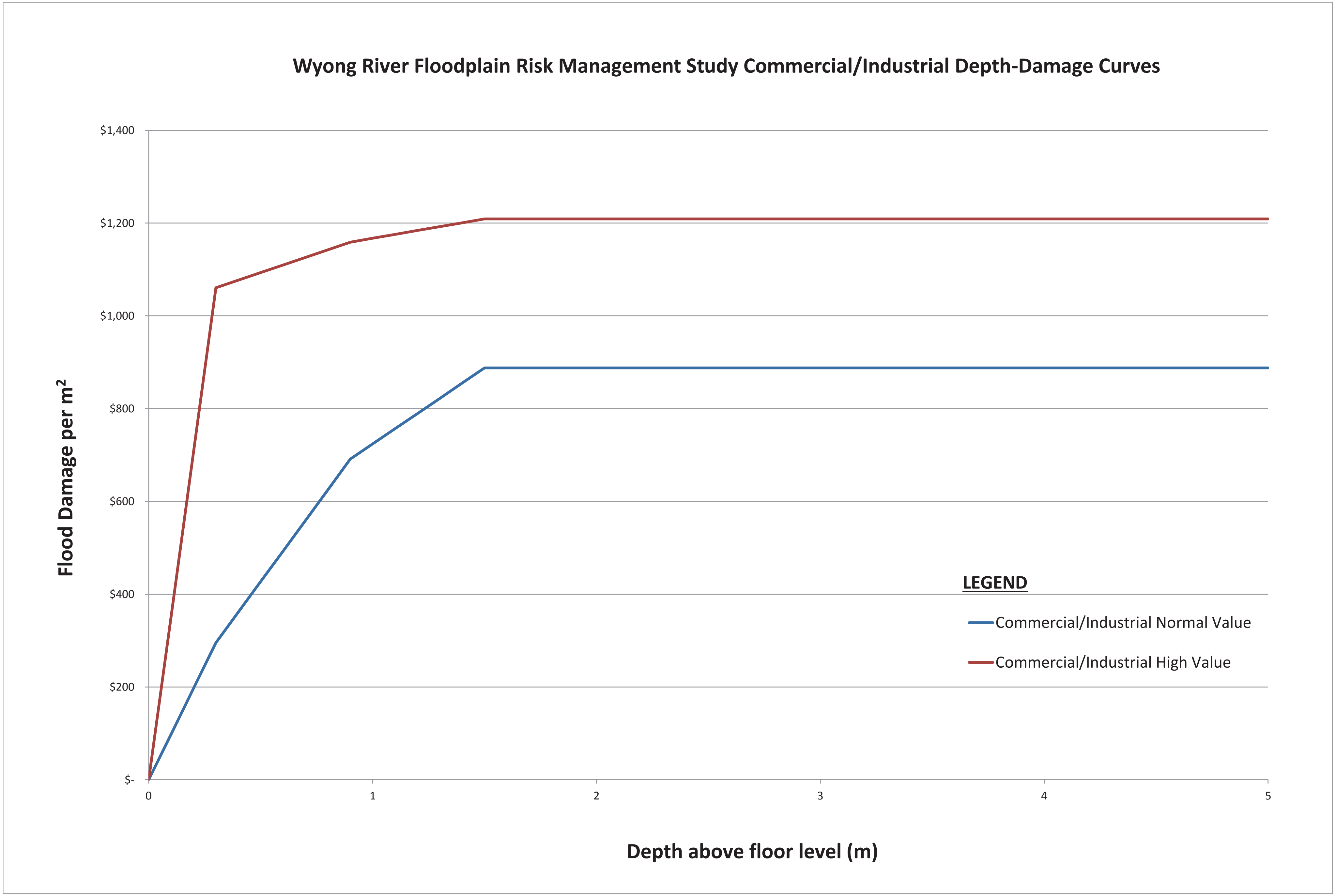

Wyong River Floodplain Risk Management Study Commercial/Industrial Depth-Damage Curves
$1,400
$1,200
$1,000
$800
$600
$400
$200
$-
Flood Damage per m²
0
1
2
3
4
5
Depth above floor level (m)
LEGEND
Commercial/Industrial Normal Value
Commercial/Industrial High Value

Table 1 Content Value Categories for Commercial Property Types

Normal Value Contents	High Value Contents
Food stores	Electrical shops
Grocers	Chemists
Corner stores / mixed business	Shoe Shops
Take away food	Clothing stores
Hairdressers	Bottle shops
Banks	Bookshops
Dry cleaners	Newsagents
Professions (e.g., solicitors)	Sporting goods
Small hardware	Furniture
Small retail	DVD rental
Offices	Kitchenware
Public halls	Restaurants
Post office	Schools
Churches	

Table 2 Content Value Categories for Industrial Property Types

Normal Value Contents	High Value Contents
Equipment hire	Smash repairs
Food distribution	Panel beating
Leather & upholstery	Car yard sales
Carpet warehouses	Vehicle showrooms
Agricultural equipment	Service stations
Storage	
Vacant factories	
Automotive repairs	
Paving & landscaping	
Sale yards	
Council & Governments depots	

1.5.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. Infrastructure damage has been estimated at 15% of the total direct residential, commercial and industrial damages.

1.5.4 Potential versus Actual Damages

The residential, commercial and industrial damage calculations outlined above assume that no actions are taken by residents and business owners to reduce the potential damage. However, if some warning is provided of the impending inundation event, there may be sufficient time for residents and business owners to undertake actions to reduce the potential damage costs incurred during a flood. For example, residents/business owners could potentially 'sandbag' properties to prevent the ingress of floodwaters, relocate vehicles to high ground and/or elevate electrical devices above the anticipated peak flood level. As a result, actual flood damages will typically be lower than the potential calculated flood damages.

Only very limited data has been collected in Australia to assist in quantifying how flood warnings can reduce potential flood damages. Information presented by Water Studies (1992) infers that direct residential property damages can be reduced by up to 50% with some effective warning time (although no specific information is provided on the minimum warning time required to achieve this).

More extensive research in flood damage reductions associated with effective flood warning has been completed across Europe. This research notes that the flood damage reduction potential is not only dependent on the amount of warning time provided, but also how effectively this warning information is disseminated, the reliability of the warning information, the proportion of households that are proactive with the warning information and how well these households respond to the warning information (Parker, 1991). The Flood Hazard Research Centre (FHRC) also published the following table which relates the potential flood damages avoided (PFA) with respect to variations in depth of flooding and flood warning time for short duration floods (Penning-Rowsell et al, 2013).

Table 8.3: Calculation of Potential Flood Damages Avoided (PFA) for a short duration flood (<12 hour) for residential property

Depth of Flooding (m)	Total Potential Damage £	Total Potential Household Inventory Damage £	Flood warning lead times							
			Up to 2hours		2-4 hours		6 hours		8 hours	
			PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage
1.2	33,040	20,423	8,359	25.3	11,795	35.7	12,786	38.7	13,447	40.7
0.9	31,265	20,237	8,254	26.4	11,756	37.6	12,694	40.6	13,319	42.6
0.6	29,268	19,051	7,463	25.5	10,888	37.2	11,766	40.2	12,351	42.2
0.3	26,105	18,046	7,832	30.0	10,990	42.1	11,774	45.1	12,296	47.1
0.1	13,507	9,977	3,309	24.5	4,430	32.8	4,835	35.8	5,105	37.8

It indicates that reductions in direct flood damages of around 25% are typical with up to 2 hours warning time increasing to reductions of over 40% with 8 hours warning time. The FHRC also noted that reductions in potential flood damages above 50% are unlikely as only 40-50% of potentially damageable items can be relocated/moved.

The Wyong River Catchment has an active flood warning system comprising rainfall and river height gauges that feed into the Bureau of Meteorology's 'ALERT' flood warning system. However, as detailed in Section 5.4.2, the expected warning time before roadways are cut is generally insufficient to provide an effective warning to residents/business owners to prepare for the onset of a major flood (in most cases, there is a negative warning time). As such, it was considered inappropriate to apply any flood damage reduction factors within the Wyong River catchment.

1.6 Summary of Inundation Costs

1.6.1 Damage Costs

Flood damages were calculated using flood level estimates extracted from the TUFLOW hydraulic model with building floor level information to determine the depth of above floor flooding during each design flood at each residential, commercial and industrial property within the catchment. A summary of the number of properties subject to above floor flooding is summarised in **Table 3**.

Table 3 Number of Properties Subject to Over Floor Flooding

Flood Event	Residential	Commercial/ Industrial	Total Number
20% AEP	3	0	3
10% AEP	14	5	19
5% AEP	131	28	159
2% AEP	293	58	351
1% AEP	416	92	508
0.5% AEP	500	134	634
PMF	1358	370	1728

The above floor flooding depths were also combined with the appropriate depth-damage curves to estimate the damage cost incurred at each property during each design flood. The number of properties that are predicted to incur damage during each design flood are summarised in **Table 4**.

The individual property damage estimates were subsequently summed with infrastructure damage cost estimates to calculate the total flood damages for each design event, which is summarised in **Table 5**.

Table 4 Number of Properties Incurring Flood Damages

Flood Event	Residential	Commercial/ Industrial	Total Number
20% AEP	27	0	27
10% AEP	104	5	109
5% AEP	285	28	313
2% AEP	498	58	556
1% AEP	640	92	732
0.5% AEP	740	135	875
PMF	1428	370	1798

Table 5 Total Flood Damage Cost Estimates

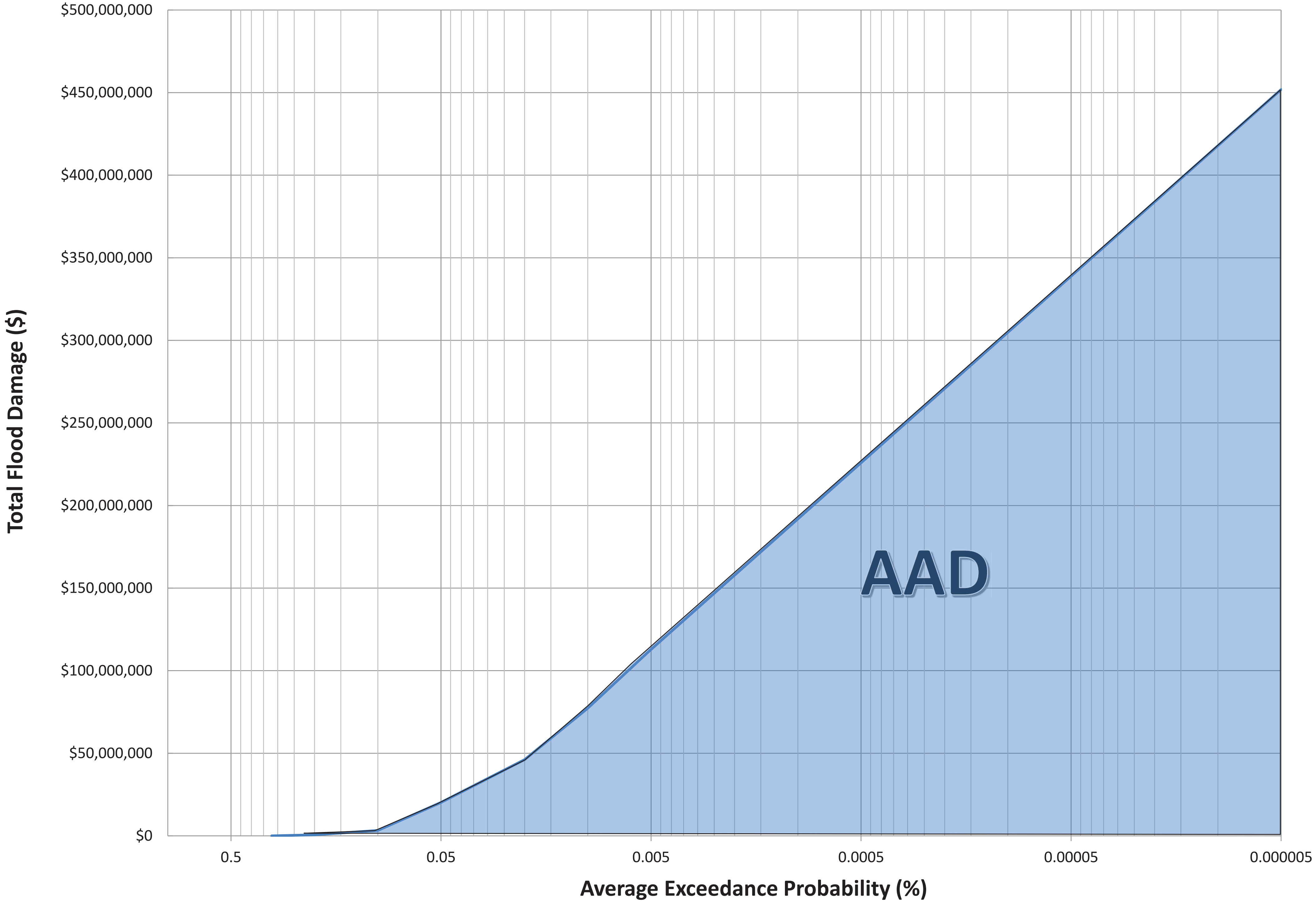
Flood Event	Flood Damages ($ millions)			
	Residential	Commercial/ Industrial	Infrastructure	Total Damages
20% AEP	0.62	0.00	0.09	0.71
10% AEP	2.82	0.44	0.49	3.75
5% AEP	14.28	5.91	3.03	23.22
2% AEP	31.83	14.26	6.91	53.01
1% AEP	48.66	28.61	11.59	88.86
0.5% AEP	60.45	52.42	16.93	129.79
PMF	212.51	239.31	67.77	519.60

1.6.2 Average Annual Damages

The total flood damages for each flood event was subsequently used to estimate the Average Annual Damage (AAD) cost for the Wyong River catchment. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe. The AAD for the study area for existing conditions was calculated as $4.31 million.

1.7 Limitations of Damage Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared. However, the estimates are exactly that – estimates. Actual damage costs during future floods may vary.



NOTE: PMF probability is taken as $5x10^{-6}$ as per GSDM for a catchment > $100km^2$

C1 REFERENCES

1. Cardno (2011). *Porters Creek Floodplain Risk Management Study*. Prepared for Wyong Shire Council

2. Paterson Consulting (2010). *Lower Wyong River Floodplain Risk Management Study*. Prepared for Wyong Shire Council

3. Water Studies (1992). *Forbes Flood Damage Study, August 1990 Flood*. Report for NSW Department of Water Resources.

4. Parker, D. J. (1991). *An Evaluation of Flood Forecasting, Warning and Response Systems in the European Union*. Water Resources Management, 10, 279-302.

5. Penning-Rowsell, E., Priest, S., Parker, D., Morris, J., Tunstall, S., Viavattene, C., Chatterton, J. & Owen, D., D. J. (2013). *Flood and Coastal Erosion Risk Management: A manual for Economic Appraisal*.

APPENDIX D

PRELIMINARY COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Mardi Detention Basin

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$27,550**
	1.01	Site Establishment (allowance only)	Lump sum	1	4,000	$4,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	700	16.50	$11,550
	1.06	Mardi Dam Operational Plan modification (max operational capacity 90%, remainder for flood mitigation)	Lump sum	1	4,000	$4,000
2		**EARTHWORKS**				**$188,636**
	2.01	Excavation/backfilling for Trash Rack installation and fixing	m3	10	61.90	$619
	2.02	Excavation and Filling of Basin Wall/Access Road - level and consolidated (General Filling) Council supplied and carted to site	m3	5869	19.00	$111,511
	2.03	Access Roadway with Basecourse (crushed blue metal, 100mm thick, rolled, compacted) and 2 coats prime and sprayed bitumen sealing	m2	3732	20.50	$76,506
3		**TRASH RACK AND PIPES**				**$16,832**
	3.01	Concrete headwall for outlet culvert (suit 0.45m culvert (1xUS, 1xDS), with additional excavation at toe)	each	2	486	$972
	3.02	Trash Rack supply and installed upstream of basin outlet	each	1	13,000	$13,000
	3.03	Concrete (class 2) culvert through new basin wall - 0.45m diameter	m	13	220	$2,860
4		**LANDSCAPING**				**$704**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	2200	0.32	$704
5		**OPERATION AND MAINTENANCE**				**$18,956**
	5.01	Trash Rack Maintenance (inpections/cleaning x 2 times per year x 50 years) **(NPV @ 7%)**	Item	1	16,561	$16,561
	5.02	Trash Rack Component Replacement at year 25 **(NPV @ 7%)**	Item	1	2,395	$2,395
					SUBTOTAL	**$252,678**
6		**ENGINEERING DESIGN**				**$63,170**
	6.01	Preparation of engineering design plans (10%)				$63,170
7		**PROJECT MANAGEMENT**				**$63,170**
	7.01	Supervision, Project Management etc (20%)				$63,170
8		**OTHER CONTINGENCIES**				**$63,170**
	8.01	General (20%)				$63,170
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$440,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Anzac Road Levee

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$13,821**
	1.01	Site Establishment (allowance only)	Lump sum	1	4,000	$4,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	10	16.50	$165
	1.06	Erosion and Sediment control - Floating Silt Curtain at site and along Mardi Creek	m	24	69.00	$1,656
2		**EARTHWORKS FOR LEVEE, GPT AND FLOOD GATES**				**$14,530**
	2.01	Excavation/backfilling for GPT sump	m3	120	61.90	$7,428
	2.02	Excavation/clearing/preparation of levee base	m3	24	61.90	$1,486
	2.03	Fill for Levee Wall (including placement & compaction)	m3	54	104.00	$5,616
3		**FLOOD GATES PIPES and GPT**				**$50,304**
	3.01	Flood Gate (Supply and Commission) - to suit 1.2m diameter outlet	each	2	15,000	$30,000
	3.02	GPT supply and installed at Anzac Rd outlet (Sump GPT type incl. Concrete base/Access Rd and Grate)	each	1	18,000	$18,000
	3.03	Concrete (class 2) culverts through new levee - 1.2m diameter	m	2	960	$2,304
4		**LANDSCAPING**				**$350**
	4.01	Turf, laid, rolled & watered for 2 weeks immediately around earthworks	m2	40	8.75	$350
5		**OPERATION AND MAINTENANCE**				**$27,609**
	5.01	Flood Gate Maintenance (inpections/cleaning x 4 times per year x 50 years) **(NPV @ 7%)**	Item	1	22,081	$22,081
	5.02	Flood Gate Component Replacement at year 25 **(NPV @ 7%)**	Item	1	5,527	$5,527
					SUBTOTAL	**$106,613**
6		**ENGINEERING DESIGN**				**$10,661**
	6.01	Preparation of engineering design plans (10%)				$10,661
7		**PROJECT MANAGEMENT**				**$10,661**
	7.01	Supervision, Project Management etc (10%)				$10,661
8		**OTHER CONTINGENCIES**				**$21,323**
	8.01	General (20%)				$21,323
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$150,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Mardi Relief Culverts

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$24,650**
	1.01	Site Establishment (allowance only)	Lump sum	1	4,000	$4,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	100	16.50	$1,650
	1.06	Geotechnical investigations of railway embankment/surrounds	Lump sum	1	11,000	$11,000
2		**EARTHWORKS FOR CULVERT INSTALLATION**				**$658,649**
	2.01	Excavation of portion of railway embankment (excavate trench 1-2m in light soil)	m3	300	55	$16,470
	2.02	Minor planking, strutting and shoring (sides of trench, light soil)	m2	60	29	$1,734
	2.03	Preparation and site movement of Culverts (via crane)	Lump sum	10	800	$8,000
	2.04	Pipe Culvert Jacking (10 localised crossings) (Tunnelcorp)	Lump sum	10	63,000	$630,000
	2.05	Backfilling excavated (on-site) material	m3	300	8	$2,445
3		**CULVERTS**				**$212,976**
	3.01	Concrete for headwall / Abutments for culverts (upstream and downstream) - Concrete	m3	6	496	$2,976
	3.02	Concrete (class 2) circular culverts through railway - 10 x 1.5m diameter culverts (20m in length)	m	200	1,050	$210,000
					SUBTOTAL	**$896,275**
6		**ENGINEERING DESIGN**				**$89,628**
	6.01	Preparation of engineering design plans (10%)				$89,628
7		**PROJECT MANAGEMENT**				**$179,255**
	7.01	Supervision, Project Management etc (20%)				$179,255
8		**OTHER CONTINGENCIES**				**$358,510**
	8.01	General (40%)				$358,510
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$1,520,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Tacoma Relief Floodway	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$55,815**
	1.01	Site Establishment (allowance only)	Lump sum	1	4,000	$4,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	2,000	$2,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	1150	16.50	$18,975
	1.06	Erosion and Sediment control - Floating Silt Curtain along Wyong River	m	360	69.00	$24,840
2		**EARTHWORKS FOR RELIEF FLOODWAY**				**$1,409,930**
	2.01	Earthworks to demolish/regrade roadway to maximum elevation of 2m (light Soil) (Reduce levels and deposit within 500m light soil)	m3	1560	5	$8,190
	2.02	Crushed Lime (aglime) for use in Acid Sulphate Soil Treatment (neutralising value of 75%, effective neutralising value of 63%, bulk density of 1.4 t/m3, net acidity of 3%, safety factor of 1.2)	Tonnes	11500	41.00	$471,500
	2.03	Acid Sulphate Soil Treatment of stockpiled material prior to subsequent use	m3	8400	8.15	$68,460
	2.04	Acid Sulphate Soil Treatment (Broadscale mechanical application by tilling of exposed soil to 0.2m deep)	m3	18800	8.15	$153,220
	2.05	composite	m	260	520	$135,200
	2.06	Bulk Earthworks (Excavate to reduce levels and deposit, spread and level within 1km - light soil)	m3	42000	8.40	$352,800
	2.07	Additional Cartage of excavated fill (additional 2 km - [3km in total])	m3	42000	1.08	$45,360
	2.08	Compaction of Fill to 90% - light soil	m3	42000	4.10	$172,200
	2.09	Forestry Mulching (Selective retention of some trees, automatic spreading of mulch and stabilising)	m2	15000	0.20	$3,000
4		**LANDSCAPING AND POST TREATMENT**				**$30,080**
	4.01	Sprayed Grass Seed Compound Hydro Mulch	m2	94000	0.32	$30,080
					SUBTOTAL	**$1,495,825**
6		**ENGINEERING DESIGN**				**$149,583**
	6.01	Preparation of engineering design plans (10%)				$149,583
7		**PROJECT MANAGEMENT**				**$299,165**
	7.01	Supervision, Project Management etc (20%)				$299,165
8		**OTHER CONTINGENCIES**				**$598,330**
	8.01	General (40%)				$598,330
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$2,540,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Debris Control Structures (Mardi Creek)

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$4,238**
	1.01	Site Establishment (allowance only)	Lump sum	1	1,000	$1,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	75	16.50	$1,238
2		**EARTHWORKS FOR TRASH RACK ACCESS TRACK**				**$7,701**
	2.02	Clearing/Fill for Access Road - consolidated (General Filling)	m3	91	85.00	$7,701
3		**TRASH RACK**				**$13,000**
	3.01	Trash Rack supply and installed	each	1	13,000	$13,000
4		**OPERATION AND MAINTENANCE**				**$18,956**
	4.01	Trash Rack Maintenance (inpections/cleaning x 4 times per year x 50 years) **(NPV @ 7%)**	Item	1	16,561	$16,561
	4.02	Trash Rack Component Replacement at year 25 **(NPV @ 7%)**	Item	1	2,395	$2,395
					SUBTOTAL	**$43,895**
6		**PROJECT MANAGEMENT**				**$8,779**
	6.01	Supervision, Project Management etc (20%)				$8,779
7		**OTHER CONTINGENCIES**				**$8,779**
	7.01	General (20%)				$8,779
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$60,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Floodplain Vegetation Clearing

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$29,290**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	6,000	$6,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Erosion and Sediment control adjacent watercourses - Jute Mesh (temporary use until grass takes hold - biodegradable)	m2	9113	0.80	$7,290
2		**EARTHWORKS AND BULK VEGETATION CLEARING/MULCHING**				**$706,600**
	2.01	Manual Vegetation Removal/heaping (Extremely selective removal of invasive species and non endangered ecological species by appropriately knowledgeable/skilled personnel - Labourer Group 1)	m2	237000	2.80	$663,600
	2.02	Bulk mulching of removed vegetation and disposal offsite (assumed tonnage)	Tonnes	50	860.00	$43,000
3		**OPERATION AND MAINTENANCE**				**$345,019**
	3.01	Maintenance of cleared area (annually x 50 years at $25000/year) **(NPV @ 7%)**	Item	1	345,019	$345,019
					SUBTOTAL	**$1,080,909**
3		**ADDITIONAL STUDIES**				**$54,045**
	3.01	Preparation of riparian vegetation retention plan				$54,045
	3.02	EIS				$108,091
4		**PROJECT MANAGEMENT**				**$108,091**
	4.01	Supervision, Project Management etc (10%)				$108,091
5		**OTHER CONTINGENCIES**				**$432,364**
	5.01	General (40%)				$432,364
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,680,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
Dredging of the Lower Wyong River (Pacific Hwy to Tuggerah Lake)		

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 34, 2016

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$49,600**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	QA & ITP	Lump sum	1	4,000	$4,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	6,000	$6,000
	1.04	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.05	Site	m	400	69.00	$27,600
2		**RIVER DREDGING AND SPOIL MANAGEMENT**				**$2,185,000**
	2.01	Dredge setup, Dismantling and Removal	Lump sum	1	40,000	$40,000
	2.02	Dredging in sand or silt and deposit on adjoining land (350m3/hr)	m3	300000	4.20	$1,260,000
	2.03	Dewatering (Excavate dredged material stockpile, cart, spread, level for dewatering)	m3	300000	2.95	$885,000
	2.04	Disposal post-dewatering (Excavation from dewatering site and cartage to local spoil deposit location within 5km)	m3	300000	3.00	$900,000
3		**OPERATION AND MAINTENANCE**				**$8,404,654**
	3.02	Dredging Operations (assume 20% volume silt-sand redeposited/annually x 50 years) **(NPV @ 7%)**	m3	60000	4.20	$3,477,788
	4.02	Spoil Management (assume 20% volume silt-sand redeposited/annually x 50 years) **(NPV @ 7%)**	m3	60000	5.95	$4,926,866
					SUBTOTAL	**$10,639,254**
3		**DREDGING PLAN & BATHEMETRIC SURVEY**				**$212,785**
	3.01	Preparation of dredging plan and bathemetric survey (2%)				$212,785
4		**PROJECT MANAGEMENT**				**$212,785**
	4.01	Supervision, Project Management etc (2%)				$212,785
5		**OTHER CONTINGENCIES**				**$531,963**
	5.01	General (5%)				$531,963
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$11,600,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Voluntary (Wet) Flood Proofing

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Cost estimates are based on the average household floor area of 130m^2 (13m x 10m perimeter) and have been factored up to 2016$ from 2005$

Reference: Reducing Vulnerability of Buildings to Flood Damage (HNFMSC, 2006)

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$1,000**
	1.01	Site Establishment (allowance only)	No.	1	1,000	$1,000
2		**FLOOD PROOFING**				**$40,371**
	2.01	Flooring - replace particle board with plywood	No.	1	8,459	$8,459
	2.02	Wall Linings - Timber lined wall panelling	No.	1	4,191	$4,191
	2.03	Joinery and Fittings - replace particle board with solid timber or plywood	No.	1	13,015	$13,015
	2.04	Floor Coverings - Sanded and polished floors	No.	1	8,459	$8,459
	2.05	Electrical Services - Power Point Replacement and Raising (dual plug GPO)	No.	1	3,904	$3,904
	2.06	Electrical Services - Switchboard Raising	No.	1	781	$781
	2.07	Sewerage System - Non return valve in suitable pit	No.	1	1,562	$1,562
					SUBTOTAL	**$41,371**
3		**OTHER CONTINGENCIES**				**$16,548**
	3.01	Consultation with property ownsers, prelim. Investigations etc (40%)				$16,548
		TOTAL COST PER PROPERTY (Rounded to nearest $1,000)				**$58,000**
4		**TOTAL COST ESTIMATES**				
	4.01	Flood proofing of 7 properties	No.	7	58,000	**$406,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Voluntary House Raising	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Cost estimates are based on the average household floor area of 130m^2 (13m x 10m perimeter)

Reg. Index: 1

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$1,000**
1.01	Site Establishment (allowance only)	No.	1	1,000	$1,000
2	**HOUSE RAISING**				**$81,000**
2.01	Raising of house to a floor level of 2.5m AHD	No.	1	81,000	$81,000
	TOTAL COST PER PROPERTY (Rounded to nearest $1,000)				**$82,000**
3	**TOTAL COST ESTIMATES**				
	Raising of 1 property	No.	1	82,000	**$82,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Voluntary House Purchase

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates are based on CoreLogic automated property valuations

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$8,000**
	1.01	Consultation with home owners (allowance only)	No.	8	1,000	$8,000
2		**Property Purchase Prices**				**$6,284,213**
	2.01	Property 1 (Valuation Range: $787,005-$1,109,392)	No.	1	948,199	$948,199
	2.02	Property 2 (Valuation Range: $1,041,796-$1,222,979)	No.	1	1,132,388	$1,132,388
	2.03	Property 3 (Valuation Range: $493,733-$756,224)	No.	1	624,979	$624,979
	2.04	Property 4 (Valuation Range: $942,551-$1,122,370)	No.	1	1,032,461	$1,032,461
	2.05	Property 5 (Valuation Range: $404,041-$659,226)	No.	1	531,634	$531,634
	2.06	Property 6 (Valuation Range: $683,829-$819,092)	No.	1	751,461	$751,461
	2.07	Property 7 (Valuation Range: $312,527-$431,586)	No.	1	372,057	$372,057
	2.08	Property 8 (Valuation Range: $762,081-$1,019,986)	No.	1	891,034	$891,034
3		**Miscellanaous**				**$80,000**
	3.01	Legal Fees (Allowance only)	No.	8	10,000	$80,000
4		**TOTAL COST ESTIMATE**				
		Volantary purchase of 8 properties (rounded to nearest $100,000)				**$6,400,000**

APPENDIX E

COMMUNITY CONSULTATION

11. COUNCIL IS CONSIDERING THE OPTIONS LISTED IN THE TABLES BELOW TO HELP MANAGE THE RISK OF FLOODING. WHICH OF THESE OPTIONS DO YOU SUPPORT / NOT SUPPORT?

Flood Modification Options: Options aimed at modifying the way floodwaters move, thereby reducing the extent, depth and velocity of floodwater.

Flood Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Installation of flood gates along Mardi Creek to help prevent "backwater" inundation of Anzac Rd						
Installation of debris control structures along Mardi Creek to help prevent blockage of culverts						
Regular maintenance and clearing of Mardi Creek						
Mardi Creek Detention Basin west of Pacific Motorway						
Construction of new channel/culverts beneath railway to allow Mardi Creek to drain more freely						
Construction of floodway channel south of South Tacoma to allow Wyong River floodwaters to "escape"						

Property Modification Options: refers to planning controls and property modifications that reduce the potential for flooding or improve the resilience of buildings.

Property Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Voluntary raising of some low lying properties						
Voluntary flood proofing on some low lying properties						
Updates to Council planning documents						

Response Modification Options: are options aimed at improving the way emergency services and the general public responds before, during and after a flood.

Response Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Upgrade of flood warning system						
Install boom gates / signs at roadway overtopping points						
Updates to SES local flood plan						
Improve flood access for South Tacoma						
Improve flood access for Yarramalong valley						
Improve flood access along McPherson Rd						

Wyong River Floodplain Risk Management Study

Community Questionnaire

The following questionnaire should only take around 10 minutes to complete. The responses that you provide will help Central Coast Council understand how best to reduce the impact of flooding on the community. Try to answer as many questions as you can and give as much detail as possible (attach additional pages if necessary). Once complete, please return the questionnaire via email or mail (no postage stamp required) by **14 October 2016**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: http://wyongriver.fprms.com.au

CONTACT DETAILS

Please provide your address to help us identify where floods have been (or haven't been) problematic. It would also be helpful to have a means of contacting you if required. Your contact details will remain confidential at all times.

Name: ______________________________

Address: ______________________________

____

Phone No. ______________________________

Email: ______________________________

1. WHAT TYPE OF PROPERTY DO YOU LIVE IN / OWN?

☐ Residential

☐ Commerical

☐ Industrial

☐ Other (Please specify:______________________________)

2. HOW LONG HAVE YOU LIVED / WORKED IN THE AREA?

(a) At this address? ______________________________

(b) In the area? ______________________________

Central Coast Council

3. HAVE YOU EXPERIENCED PREVIOUS FLOODS IN THIS AREA?

☐ Yes - what year(s)____________________________________

☐ No (go to Question 5)

4. HOW DID THE BIGGEST OF THESE FLOODS AFFECT YOU?

Tick all that apply:

☐ flooding over main building floor – please describe depth = ______m

☐ flooding of garage/sheds – please describe depth = ______m

☐ lost access due to flooding of roads – which roads and for how long? __________

____

☐ other (Please specify: ____________________________________)

☐ not applicable / not affected

5. DO YOU KNOW IF YOUR HOUSE / BUSINESS HAS A RISK OF BEING FLOODED?

Tick one:

☐ Yes, I know my house/business could be flooded

☐ Yes , I know my house/business cannot be flooded

☐ No I don't know/I'm not sure whether my house/business could be flooded (go to Question 7)

6. DO YOU KNOW IN WHAT SIZE OF FLOOD YOUR HOUSE / BUSINESS COULD BE FLOODED?

Tick one:

☐ my house/business could be flooded in a so-called 1% AEP flood

☐ my house/business could be flooded in a so-called probable maximum flood

☐ my house/business could be flooded but I'm not sure of the name of the flood

7. HOW DO YOU ANTICIPATE YOU WOULD RESPOND IN A FUTURE MAJOR FLOOD IN THIS AREA?

Tick one:

☐ evacuate early to an official evacuation centre in Wyong

☐ evacuate elsewhere – please describe: __________________________

☐ remain at my house

☐ other – please describe ____________________________________

☐ don't know/not sure

8. IF YOU ARE LIKELY TO EVACUATE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

Please rank the following options from 1 (most important) to 4 (least important):

☐ discomfort/inconvenience/cost of being isolated by floodwater

☐ need for uninterrupted access to medical facilities

☐ safety of our family

☐ other – please describe ____________________________________

☐ not applicable (I intend to remain at my house)

9. IF YOU ARE LIKELY TO REMAIN AT YOUR HOUSE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

Please rank the following options from 1 (most important) to 5 (least important):

☐ discomfort/inconvenience/cost of evacuating

☐ need to care for animals

☐ my house cannot be flooded and we can cope with isolation

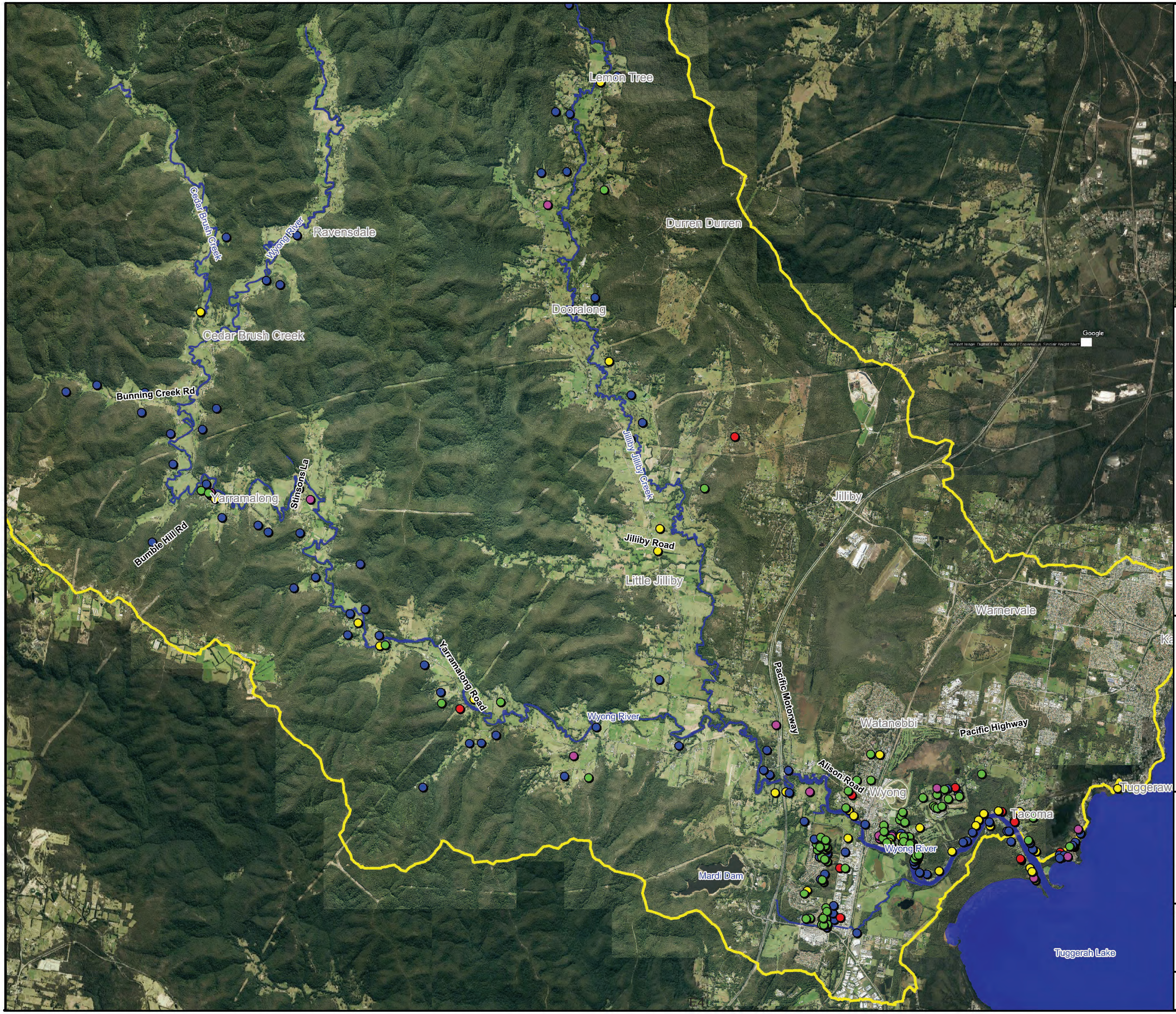
☐ concern for security of my property if I evacuate

☐ other – please describe ____________________________________

☐ not applicable (I intend to evacuate from my house)

10. A LIST OF POTENTIAL OPTIONS FOR MANAGING THE FLOOD RISK IS PROVIDED ON THE NEXT PAGE. IF YOU HAVE ANY OTHER SUGGESTIONS FOR REDUCING FLOODING PROBLEMS, PLEASE DESCRIBE BELOW.

APPENDIX E FIGURES



Central Coast Council

LEGEND

Catchment Boundary

Questionnaire Response Locations
Type of Flood Impact

- Not Affected
- Other
- Loss of Road Access
- Flooding of Garage/Shed
- Flooding over Main Building Floor

N W E S

Scale 1:75,000 (at A3)

0 2.0 4.0 Km

Figure E1: Types of Flood Impacts Based on Questionnaire Responses

Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigE1 - Community Responses .wor

Central Coast Council

LEGEND

Catchment Boundary

Reported Flood Response

- Offical Evacuation Centre
- Evacuate Elsewhere
- Remain at Home
- Other
- Not Sure

N
W E
S

Scale 1:75,000 (at A3)

0 2.0 4.0

Km

Figure E2:
Reported Flood Response Based on Questionnaire Responses

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigE2 - Reported Flood Response .wor

QUESTIONNAIRE RESPONSES

PAST FLOODING EXPERIENCES

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
1				1	Rural	0.333	14			1									
2	1					27	58	1					1						
3	1					10	10			1									
4	1					0.5		1	2016						1	Yarramalong Road 2 Days			
5	1					14	14	1	2007, 2005				1		1				
6	1					66	72	1	1952, 1970s										1
7			1			30	30			1									
8				1	Rural	23	23	1	1994, 1996, 2009, 2014, 2015						1	Yarramalong Road 3 Days			
9	1					18	96	1	Last Year						1	Back 2 Weeks			
10	1					29	34	1					1	1m	1	South Tacoma Rd 5 Days	1	Electricity out	
11	1					19		1	Every year						1	Lauffs Lane, Yarramalong Rd	1	Loss of driveway	
12	1					1	85	1	1927				1	0.3m					
13	1					67	67	1											1

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
14				1	Rural	30		1	1987-1992				1	1m					
15	1					15	15			1									
16	1					15	30	1	2007 plus all the next				1	0.75m	1	1 week			
17	1					8	19			1									
18				1	Rural	37	50	1	Every flood since 1979						1	3 days			
19	1					5				1									
20	1					35		1							1	Durren Road 24 hours			1
21	1					28	28	1											1
22	1					10		1	April 2015, June 2006, 2007						1	Yarramalong Road 2-3 Days, Amber land bridge 6 metre under			
23	1					28		1	1990, 2007, 2015		1	0.3m	1	0.7m	1	1 week McDonough Road			
24		1				12		1	Several years						1	Anzac Road			
25				1	ural Residential			1	1992, 2004, 2007, 2015										1
26				1	Small Farm	63		1	1964, 1991 and a few other small ones						1	Boyce Ave 3 Days			
27	1					35	35	1	2015, June 2007, 1990/1991, 1980s/ 1985				1	0.15m	1	South Tacoma Road 3-4 Days			
28				1	Rural	35		1	1982 plus 3 others						1	Bunning Creek Road for 2 Days Max			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
29				1	e Rated as Res	18	42	1	June 2007, June 2011, Jan/Feb/Mar 2013, April 2015, Jan 2016						1	Yarramalong Rd June 2007, 10 days 8th - 17th	1	Lost power, phone service	
30	1					20	72	1	1947, 1947, 1950, 1953, 1955, 1962 - 2007						1	Pacific Highway 2 - 3 days Yarramalong			
31				1	Rural	25		1	1990, 1996, 2003, 2007, 2016				1	0.5m	1	2 days Yarramalong Road	1	Access Bridge under for 2-3 days	
32	1					54				1									1
33	1					12				1									
34	1					10	54	1	2006, 2015				1		1	approx 1 week, Rivier road, wyong and Warner Avenue, tuggerawong			
35	1					8		1	Every year doing heavy rain		1	4-4.5m	1	4-4.5m	1	Few hours	1	Water from back property (child care centre) and Alison Street	
36	1					35		1	Late 1980 - early 2000 and 2014				1	0.15	1	Lewis Ave 2 days			
37	1					3	3	1	Every year						1	Johnson Road/ Roundabout/ Woodbury Park Rd			
38	1												1		1				
39				1	Rural	1	1	1	2016						1	Yarramalong Road 24 hours			
40	1					3	8	1	2014, 2015						1	3 days Yarramalong Heading West			
41	1					12	25	1	Jun-07						1				

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
42	1					1.5	14	1	2015				1	0.8m	1	Hastings St for approx 5 days			
43				1	Rural	12	28	1	1990-1993, 2007, 2008, 2011, 2015						1	Mandalong Road, Dicksons Road, Jilliby Road for 4 days			
44	1					15	26	1	1989, 2007, 2013						1	Tuggerawong Road, Boyce Avenue, Wolsely 4 days in 2007	1	Electricity out 2003 3.5 days	
45	1					3.5	3.5	1	April 2015, 2016						1	2015 Chandlers Lane 5 days. 2016 Chandlers Lane 2 days			
46	1					13	13			1									
47	1					16	35	1											1
48	1					11		1	2007						1	4 days Panonia, Warner, parts of Rockleigh			
49				1	Rural		54	1	2007, 2014						1	Dooralong Road 2 Days			
50	1					6	56	1	1964, 1991						1	Yarramalong Road, Several Days, some floods also caused loss of power and telephone.			
51	1					3.8	3.8	1	2014, 2015, 2016						1	1 week			
52		1				20	30	1	2016, 2015, 2014						1	Ace Cres up to 3 days			
53	1					17	17	1	1999 - 2016										1
54				1	d/primary Pro	21	21	1	2007						1	Yarramalong Road heading west to Yarramalong 2 days	1	At least half our land goes under water, power and phone outages	

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
55	1					37	56	1	2007				1	0.33m					
56				1	Farmland	34	34	1					1	1m	1	Dooralong Road, Durren Road 1-5 days	1	Paddocks	
57	1					30		1	1998, 2007, 2015		1	0.1m	1	0.6m	1	Hillcrest and McDonald Road	1	No sewage no power	
58	1					20	30			1									
59	1					4	4	1	2015/ 2014								1	Tree's fell down in backyard	
60	1					8.5	9.5	1	2007-2016						1	6 days			
61				1	Farm			1	Every 5 years										1
62	1					17		1	various						1	Jilliby and dooralong 1 day to 3 days			
63	1	1				5	15	1	2007, 2009, 2015						1	Henry St Chitaway 7 days	1	Gavenlock Road Tuggerah 1 day (2007)	
64	1					15		1	2007, 2004										1
65	1					14		1	June 2007, and again 2.5 years ago						1	6 days south tacoma road. Cannot get from and property to the flood			
66	1	1				30	30	1	Most years there is at least one flood		1	0.5m			1	2 days			
67				1	Rural	6	6	1	2011, 2012, 2013, 2015, 2016						1	Property access to Yarramalong Road, longest 3.5 days in 2011. Deepest 7.5m in 2013.			
68				1	Rural	16	54	1	2007, 2014						1	Dooralong Road 2 Days			
69	1					5		1	2014				1	10 - 15 m					

Catchment Simulation Solutions

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
70		1		1	Farm	25	35	1	Several						1	Yarramalong Road varies 2 - 3 days on occasions.	1	some paddocks underwater, damage to fences phone and power outages, stock losses.	
71	1					1	1	1	2015								1	Flooding of pasture/ paddocks for 2 weeks	
72	1					20		1											
73	1					5	15	1	2013, 2014										1
74				1	Rural	16	36	1	1976, 1987		1	0.6m	1	0.45m	1	3 days Jilliby was the longest, Dickson Road			
75	1					14				1									
76	1					14				1									
77	1					12	6	1	2007, 2010, 2014						1	Yarramalong Road, Phil Tunks Road (several days)			
78		1				17	21	1	2007						1	River Road Wyong 4 days			
79	1					9	44	1	2007						1	some secondary roads around wyong			
80	1	1				20	60	1	2007, 2015, 1992						1				
81	1					9.66	23	1	Jun-07				1	0.025	1	2 days on green close, betty ann place			
82	1					11	16			1									
83	1					38	45	1					1	0.2	1	Roads were Flooded			
84	1					4	50	1	mid 1980s						1	Few days under railway bridge			
85	1					0.66				1									
86	1					28	60	1	Since 1988						1	Marathon St, Panonia Road Short period			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
87	1			1	Farm	2	44	1	Since mid 70s						1	Yarramalong Road less than 24 hours	1	Needed to remove pump from creek	
88	1					15	35			1									
89	1					3	3			1									
90	1					22	22			1									
91	1					1				1									
92	1					30	60	1	2007						1	1 week			1
93	1					5	40	1							1	2 days Johnson Road Anzac Road			
94	1					22		1	1995										
95	1					13	32	1	2007, 2014						1	3 days 2007, 2days 2014			
96	1					10	10	1	2007, 2015						1	Yarramalong Road Stevensons Bridge 1-2 days	1	Loss of electricity and phone	
97	1					7	12			1									
98				1	Rural	24	61	1	1964, 1966, 1990, 1991, 2007, 2015						1	Mardi Road 24 - 48 hours			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
99				1	Farm	2	2	1	Two since being here						1	Ravensdale Road and Yarramalong Road. One week each			
100	1					25		1	1989, 2007, 2015		1	1m	1	1m	1	Hastinggs Street and Tacoma Road			
101	1					4.5	4.5	1							1	1 - 2 Days Johnson Ave, Anzac Road			
102	1					50	52	1	2015, 2007, 1990, 1970		1	0.1m	1	0.1m	1	Pollock Ave 48 hours	1	Paddocks and stables	
103				1	Plant Nursery		10			1									1
104	1	1				27	34	1	1990, 2007, 2016				1	0.5m	1	3 days South Tacoma Road			
105			1			16		1	2007						1	Gavenlock Road, Mildon Road 24 hours			
106	1					25	25	1	2007						1	4 hours			
107	1					45	54			1									
108	1					5	20	1							1	2 Days			
109	1					44	50	1					1						
110	1					3	63	1	2015, 2007								1	my property is good across the Rd	
111	1					16		1	2007, 2015						1	2 Days			
112	1					16.33				1									
113	1					20	20			1									
114	1					16				1									
115	1					23		1	Jun-07				1		1	McDonagh Rd 4 Days			
116	1					10	11	1	2007, 2008, 2011, 2013, 2015, 2016						1				
117				1	Church	13	25	1	Jun-07				1	1.5m	1	Gavenlock Road			
118	1					0.8		1	Jun-16						1	Access into Mardi via Roads			
119	1					30	30	1	1989, 2007						1	Wolsley Avenue Colblack Close 1 week			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
120	1					1		1	2015, 2016								1	Roads Flooded in Mardi (corner of woodbury park Drive plus Gavenlock Road) as well as children's park	
121	1					10	44	1	2007										1
122	1					0.66				1									
123	1					1.5	1.5			1									
124	1					20	40	1	2007, 2015				1	0.35m	1	South Tacoma Road 5 Days both Occassions			
125	1					5	5			1									
126	1					3.5		1	2014						1	Mcdonagh Road Wyong 5 Days			
127	1					33	33	1	1983 -						1	blocked to old school and Wyong about 1 km to both sides at Bradleys saw mill for longer			
128	1					18.5	18.5	1	2007						1	3 Days Boyce, Panonia			
129	1					14	14	1	2007, 2008, 2013, 2015, 2016						1	Yarramalong uo to 48 hours			
130	1					7	10			1									
131	1					10	10			1									
132	1					20		1									1	From river to footings of houses	
133	1					6	63	1	60s, 70s, 90s, 200s, 2010						1	Boyce Ave 2 days			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
134	1					5	5			1									
135	1					2	2	1											
136	1					22		1							1	Hasting plus Bayview roads 4 days			
137	1					10	14	1	2015, 2006						1	Days Macpherson Road, Johnson Road, Gavenlock Road	1	Power Phone Outage	
138	1					2		1	2015, 2016						1	Yarramalong Road for a week	1	lost power	
139	1					31	35	1									1	Rear properly that is bounded by Wyong river	
140				1	Rural	13	13	1	2007						1	Jilliby Rd and mandalong Rd			
141	1					35	35	1							1	7 Days Boyce Ave			
142	1					62	90	1	16/06/1950										
143	1					15		1	2007										1
144	1					21	28	1	2007, 2013				1	0.1m	1	Durren Rd near Jilliby Road, Mandalong Rd 2-3 days			
145	1					18	42	1	2008				1	1m	1	Wolseley Avenue 4 days loss of access	1	Sewer, Power	
146	1					17	17	1							1	South tacoma Rd 5 days			
147	1					8	8			1									
148	1					48	58	1	2015										1
149				1	Rural	76	76	1	all floods since 1940						1	Ravensdale Rd, Yarramalong Road, 2 days most ever was 6			
150	1					11	11	1	2007, 2015		1	1.5m	1	1.5m	1	Wolseley Ave Closed for a week			

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
151	1					23	23	1	2007						1	Yarramalong			
152	1					2	2	1	2015, 2016						1	Unnamed entrance road.	1	Water across entrance rd	
153	1					16	16	1	2007, 2015						1	Tuggerawong Rd, McDonagh Rd			
154	1					1.5	1.5	1	2015, 2016				1	0.5m	1	3 hours	1	Telecomunnic ations Services	
155				1	Rural	30	35	1	1985,, 1990, 2007, 2013, 2015, 2016				1	0.46m	1	Yarramalong Road for at least 2 days			
156				1	Rural	46	65	1							1	Jilliby Road 24 hours			
157	1					21	23	1	mid 70s and 80s				1	0.5 - 1 m	1	Intersection of pacific highway and Cutter Dr for about 1-2 days	1	Water passed through backyards	1
158				1	Rural	4	4.5	1	Each year						1	Jilliby Road 0.5 day	1	Paddocks inundatd	
159	1					40	63	1	2009				1	0.1	1	8 hours Collies Lane			
160	1					8	14	1	2014										1
161	1					14	29	1					1						
162			1			40	50	1	2007		1	0.25	1	0.3	1	2 Days	1	Drives and access off Gavenlock Road 0.45m	
163			1			40	50	1	2007		1	0.5	1	0.5	1	4 days Cobbs Road Auson Road and Pacific highway			
164	1					54		1	1964, 1974, 1990, 1992, 2007				1	0.1	1	2 days			
165	1					2.5	2.5	1	April 2015, Jan 2016, Jun 2016, Nov 2015						1	April 7 days, other 3 floods 5 days no access to colblack close	1	Flooding to sub floor area	
166	1					13	40	1	2007, 2015						1	5 days in 2007 and 2015 on Tacoma Road			
167	1					1				1									
168	1					18	18	1	2007								1	SES Volunteering	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
169	1					3	3	1	2015				1	0.05	1	Storm Surge from lake backing up drain			
170				1	12.875 acres	30	30			1									1
171	1					18				1									
172	1					17				1									
173	1					0.583333333		1	2016								1	Back yard Completely under water	
174	1					26		1					1		1				
175	1					26	26	1	1992, 2007, 2013				1	0.5					
176	1					16	40	1	approx 1 year						1	Durren Road for a day or two			
177	1					31.75	31.75	1	1990 2005 Christmas King tides combined with extremely heavy rain which yook several days b4 flooding. 2007 low can down from Qld,and flooded with in 20 mins b4 river broke banks.- This wads an unusual occasion as this was close to class one cyclone conditions even though it was				1						
178	1					4		1	2013, 2014m 2015, 2020						1	Dooralong Rd, courseway to property 5 days			
179	1					2	15	1	2015						1	Tuggerawong & Jensen Roads			
180	1					18		1	1999 to 2016					3/4metres	1				

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
181	1					0.5	10	1	We were aware of severe flooding in the 2007 storms but no the full extent to the street/ house								1	We have discussed with neighbours regarding the affect on our property in the 2007 flood- The garage flooded; flood level under the house (but not sure of exact height); water pump, hot water system and air con unit flooded; the isolation due to no mobile reception presented a	
182	1					4.5			42095				1						
183	1					12	17	1	Worst June 2008								1	Area sceptics flooded: power loss 5 days	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
184	1					0.5	10	1	2007- We were aware of flooding in the area as we had friends in the area who were affected- just not aware of the extent of flooding around our current house/street						1			Our neighbour has advised us in 2007- the street flooded, as did our garage, the water was under our house (as we are raised on the ground poles), the was no access in and out, there was loss of power to the area thus water pumps, septics and flood lights could not be used, the	
185	1					42	43	1	Approximately 5 floods						1			Access cut off maxium time 5 Days.	
186	1					8	8	1	2010 2012 2013 2015 2016									4 days,Yarramalong Rd and 4 metres over our council provided access bridge	
187	1					1	23			1									
188	1					1	23			1									

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
189	1					1.5	1.5	1	2015 2016						1			Loss of income as unable to get to work. Damage to fencing with fallen trees affected by flood water	
190	1					29												Worst flood witnessed would need to be over one metre higher to threaten our house	1
191	1					10	40	1	2007, 2016, 2015, 2013						1			Yarramalong Road, Up to 4 days	
192				1	ural Residenti	5		1	2012, 2013, 2014, 2015						1			Roads under water at Bunning Creek Road and Yarramalong Road	
193								1	All since 1988								1	Became an island each time	
194	1					56		1	1974										1

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
195	1					26	65	1	Panonia Road - 1990 ("recent" highest), 2007								1	Worst effect for us was losing power/sewer in 2007	
196		1				3	16	1	2015						1				
197	1					16	16	1	2007, 2013 twice, 2015, 2016. I may not have recorded all of them, particularly minor ones.				1					Flooding of garage (315mm above floor), Yarramalong Rd closed due to flooding and Bumble Hill Rd due to power lines down.	
198	1					2				1									1
199	1					15	15	1	2007						1			McDonagh from no. 65 towards Wyong, 2 days	

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
200	1					6	6	1	2010,2013, 2015						1			Bunning creek road floods at the bridge - which despite lots of local feedback, the council rebuilt a few years ago and didn't raise the height to address this issue. We've been flooded in for up to 5 days, which means we can't get to work, and more importantly can't access	
201	1					1.5	4			1									1
202	1					30	60	1	Surely you (Wyong Shire Council/Central Coast Council) would have a better idea of the particular years that floods have impacted on this part of town.								1	The flood water would rise to the level of the steps at the front of my house. But! in the wisdom of Wyong Shire Council planners over the years, and the strategy of dumping stormwater from properties in Byron Street down into Leppington Street, without first	
203	1							1	2007								1	no proper drainage on our road	
204				1	Rural	5	5	1	2011, 2014, 2015, 2016						1				

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
205	1					4	4	1	2013								1	Yarramalong Rd - 1 or 2 days. Also, paddocks flooded on Lauff Lane.	
206	1						2			1									1
207	1					5	5	1	2015				1					Flooding to depth of 300mm, unable to leave property for 5 days as adjacent roads flooded	
208	1					50	65	1	1.9552E+31						1			10inches of water in garages. McDonagh Rd. closed 4 days	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
209	1					37	47	1	1970, 2007						1			MARDI ROAD AND MCPHERSON ROAD	
210	1					38		1	APPROX: 1994, 2005						1			RIVERVIEW DRIVE, BOYCE AVE.	
211	1					15	57	1	Most years, significantly - 2007, 2012 2016				1					1.2M & also no road access, no electricity, no phone	

Response Number	Property Type					How long have your lived in area?		Have you experienced previous floods in this area?			How did the biggest of these floods affect you								
	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
212	1					14	16	1	2007, 2015						1			South Tacoma Road, 3 days on each occasion	
213	1					5	20	1	2015						1			Yarramalong Road for a little more than a day	
214	1					3	3	1	2014, 2015								1	mandalong road, jilliby road, 24 hours + // debris pushed over fencelines.	
215	1					22	45	1	2006 & 2014						1			tick 2 & 3 - Depth over garage floor - 0.30m and Mcdonagh Rd & Wolsley Ave for 3 days	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
216	1					5	30	1	Mild flooding often when it rains								1	Local roads flooded. Gavenlock rd and johnson rd tuggerah	
217	1					3.5	20	1	2014,2015 and 2016						1			Lost Access to Yarramalong Road in both directions - 4 days on each occasion	
218	1					5	29			1									1
219	1					2	2	1	2015						1			Water in Boyce Lane prevented car exiting garage at rear of property	
220	1					14	14			1									
221	1					2	27	1	2006						1			Had to take a different route to walk to my car which was parked halfway up northern end of Margaret St	
222	1					10	47	1	2007, 2012, 2015				1					Lost access, lost power	
223	1					10	47	1	2007, 2012, 2015				1					Lost access, lost power	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
224	1					15	30	1	1965; 2012; 2014								1	Backyard flooded due to Lake coming up but not near house.	
225	1					4	16												
226	1					1.5	1.5	1	2004 and 2007 (house is built in 1997)								1	Flooding around house on both occasions, but water has never entered house as it is built on an appropriate mount.	
227	1					1.25				1									1
228	1					2	21			1									1
229	1					15	25	1	2015, 2016		1							All points 1,2 & 3 Apply to this question, 300mm to 400mm flooding through out Property	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
230	1					5	5	1	No flooding since I've lived here but I believe St Peter's College dam flooded a few years ago. Houses on this side of the street flooded up to my address which did not flood.										1
231	1					25	25	1	2015, 2013						1			Yarramalong Rd	
232	1					11	11		2007										1
233				1	Rural - primary pr	3	18	1	2007 (Jun), 2013 (Feb), 2015 (Apr 5 & 22), 2016 Jan						1			Driveway & Yarramalong road are flooded sometimes for days	
234	1					5	29	1	2012 and 2015								1	Flooding in back yard - no house damage, no property damage	
235	1					2	2			1									1

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
236	1					4	4	1	2015 (I think)									River was high but did'nt cross the road	1
237				1	Residential and H	9	9	1	Annualy since 2007						1			Brush Creek Road and Yarramalong Road	
238	1					6	26	1	upon arrival 1990 plus subsequent floods in the shire									Dickson road House on high ground, however land flooded from jilliby creek	
239	1					34	38												1
240	1					10	44	1	2007										1
241	1					16	50	1	i think it was 2005 till 2007								1	flooding under house	
242	1					10	25	1	2006, 2015?						1			Jilliby Rd, Mandalong Rd - approx 3 days	
243	1					2		1	2015 & 2016						1			No Access out of Bunning Creek Road or Yarramalong Road	

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	Residential	Commercial	Industrial	Other	Please Specify	Current Address	In the general area?	Yes	What Years	No	Flooding over main building floor	please describe depth	flooding of garage/ shed	please describe depth	Lost access due to flooding of roads	which roads and for how long	other	please specific	Not affected
244	1					14	21	1	can't remember years but about 7-8 floods of differant sizes						1			yarramalong road max 3 days	
245	1					5	30			1									1
246	1					4	4			1					1			River Rd / Panonia Rd was flooded under the existing road and rail bridges	
247	1					25	25	1	about 8-10 yrs ago						1			sheds under water,unable to leave home for approx 5 days,no power as well	
248	1					9	9			1									
249				1	Rural and residen	21	21	1	many times but worst one in 2007								1	Stinsons Lane at the bridge about 20m north of our house, and Yarramalong Road in both directions.	
250			1			20	25	1	unknown						1				
251	1						9	1	2007, 2016,						1				
252	1					6.5	21			1									1
253	1					5	33			1									1
254	1					0.5	17			1									1
255	1					2	2	1	2015 and 2016						1			Yarramalong Road closed for up to 1 week no access in or out	
256																			

QUESTIONNAIRE RESPONSES

FLOOD EMERGENCY RESPONSE INFORMATION

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
	Yes, I know my house/business could be flooded	Yes, I know my house/business cannot be flooded	No I don't know/I'm not sure whether my house could be flooded	my house/business could be flooded in a 1%AEP flood	my house/business could be flooded in a PMF	my house/business could be flooded but I'm not sure of the name of the flood	Evacuate early to an offical evacuation centre in Wyong	Evacuate elsewhere	please describe	remain at my house	other	please describe	don't know/not sure	Discomfort/inconvenience /cost of being isolated by floodwater	need for uninterrupted access to medical facilities	safety of our family	other	please describe	Not applicable (remain at home)	Discomfort/inconvenience/cost of being isolated by floodwater	need for care for animals	my house cannot be flooded and we can cope with isolation	concern for security of my property if I evacuate	other	please describe	Not applicable (remain at home)
1		1								1						1						1				
2	1				1					1						1							1			
3	1			1						1				4	5	4	2	Personal Safety	1	5	2	1	3	4	Personal safety	
4		1								1									1	3	2	4	5	1	Alternate Access Over Dormant Fire Trails	
5	1					1					1	stay as long as I can stay		1									1			
6		1								1									1		2	1				
7			1								1	Wait till water recedes from factory, then access the situation		1												
8		1								1									1	1	2	4	3			5
9		1			1		1								1							1				
10	1				1					1									1	3	2	5	1	4	Power Failure	
11		1								1									1	4	5	1	3	2	in a major flood we wish to care fore property from runoff	
12			1	1						1				2	1					1						
13	1			1																						
14		1				1				1									1		1					
15			1				1							2	3	1										
16	1			1						1									1	3	2	4	1			
17	1					1				1									1	2	1	3				
18		1								1									1			1				
19			1							1									1			1				
20		1								1									1			1				
21	1			1						1									1	1	2	3	5	4	I have had health problems	
22		1								1					1						1	1	1			
23	1					1				1									1	1	3		2			
24	1			1							1	Close business					1	Loss of Business								1
25		1				1				1									1			1				
26		1			1					1									1			1				
27	1					1				1									1	2	3	1	4			

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	Yes, I know my house/business could be flooded	Yes, I know my house/business cannot be flooded	No I don't know/I'm not sure whether my house could be flooded	my house/business could be flooded in a 1%AEP flood	my house/business could be flooded in a PMF	my house/business could be flooded but I'm not sure of the name of the flood	Evacuate early to an offical evacuation centre in Wyong	Evacuate elsewhere	please describe	remain at my house	other	please describe	don't know/not sure	Discomfort/inconvenience /cost of being isolated by floodwater	need for uninterrupted access to medical facilities	safety of our family	other	please describe	Not applicable (remain at home)	Discomfort/inconvenience/cost of being isolated by floodwater	need for care for animals	my house cannot be flooded and we can cope with isolation	concern for security of my property if I evacuate	other	please describe	Not applicable (remain at home)
28	1													3	2	1						1	2			
29											1	Remain on the property because of animals							1	2	1					
30		1								1												1				
31	1				1						1	Depends on the size of flood					1	loss of stock and buildings			1			1	Make decision based on my experience	
32			1							1						1						1				
33			1								1	Go to family		1	3	2			4							1
34	1				1					1						1			2	3	2		1			
35	1					1				1				2	3	1			4	1	4		2	3	Access to medical facilities	5
36		1				1				1									1			1				
37			1					1	Family in Area							1										1
38	1					1				1									1	1	1		1			
39		1								1										3	1	2	4	5		
40		1								1									1	4	5	5	5			
41			1					1	Probably Newcastle					1			2	Aged and living alone		1			2			
42	1					1		1	to family		1	would remain at house but for pets		1			1	fear of scavengers		3	2	5	1	4	Lack of function toilet	
43		1			1								1	3	4	1	2			2	1	3	5			4
44	1				1					1				3	4	1	2	Sudden Medical Emergency		4	5			1	Safety, food, sewage	
45			1			1				1									1	2	1	4	3			
46			1										1			1							2			1
47		1		1			1									1						1				
48	1					1				1						1				3	1		2	4	we can cope for a couple of weeks with food	
49		1								1									1	2	3	1	4	5	Assist Neighbour	
50		1								1				1	2					2		3	1			
51			1				1	1	Possibly at friends home					3	2	1	4	Safety of animals (lower paddicks flood)		3	1	5	2	4	no electricity (happened in last flood 6 days out of power)	
52	1					1		1	Employees will be sent home								1	Loss of business		1						

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53		1		1							1	My house is not flood affected		1	4	4			4	1	1	1	1	5	not flood affected	
54	1			1						1									1	2	1		4	3	Would rather be flooded in that flooded out due to animals	
55			1							1									1	2	1	4	3			
56		1								1									1			1		1	in case of no power loss of water access	
57	1			1						1										1						
58			1							1									1		1	1	1			
59	1			1			1							2	3	1										1
60			1													1					1					
61		1								1									1			1				
62		1								1									1	4	3	1	2			
63	1				1					1				1						1						
64		1								1									1					1	We will not be affected other than losing electricity due to the storm	
65			1							1										3	4		2	1	Power	
66	1					1				1									1	1	1		1			
67		1				1				1									1	4	2	1	3			
68		1								1									1	2	3	1	4	5	Assist Neighbour	
69	1			1			1														2		4	1	my books	
70		1				1				1	1	Move stock to higher ground open appropriate gates stock up on essentials.		1			1	inconvenience if power outage			1	1		1	back up generator power but somewhat limited	
71		1				1				1				4	5	3	2	look after livestock	1	4	1	3	2			
72		1				1	1							3	2	1										1
73		1		1									1			1						1				
74		1								1				3	4	2	5		1	4	3	1	2			5
75			1				1							2	3	1										
76		1				1				1				1								1				
77			1										1	1		1	1	Safely of horses		1	1					
78	1					1		1	stay home					3	4	2	1	Business is secure		2	3	4	1	5		
79		1			1					1									1	1		1				
80	1					1				1				1								1				

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81		1								1									1	3	4	1	2			
82		1		1						1									1	1						
83	1					1				1									1	2	3		1			
84		1				1				1				1						1		3	2	5	this house is 50 years old never flooded	4
85			1							1									1			1				
86	1				1					1									1	4	3	1	2			
87	1					1				1									1	2	1	5	3			
88			1										1	3	2	1	4	Power/water/seweage at avacuation location		2	5	4	3	1	Fairly safety,medical	
89		1				1				1									1	2		3	1			
90			1			1				1									1			1				
91			1			1	1							1												1
92		1								1						1	1	Pets			1	1				
93			1		1			1	36 riveroak drive Mardi						1	1							1			
94			1							1				3	2	1										
95	1					1										1				2			1			
96	1			1				1	Sydney								1	Need for electricity and phone						1	not having electricity need it for water	
97	1		1			1				1				2	1	3			4	1	2		3			
98		1								1									1			1				
99	1					1				1									1	1	1	1	1			
100	1					1	1							3	2	1	4									1
101			1							1					1	1				1			1			
102	1					1		1	Daughters home					2	1											1
103		1				1							1	1								1				
104	1					1				1									1	3	1	2	4	5	Electricity, sewerage	
105		1											1	1		2										
106	1				1						1	call 000		1							1					
107		1					1									1										1
108			1										1	2	1	3				3	1		2			
109			1		1					1					1	1						1	1			
110		1				1				1									1			1	1	1	my house is on high side of street I've not seen water come over my front step	
111	1					1				1				1	3	2			4	1			2			
112		1								1				2	3	1			4			1				

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113			1					1	goto my mothers place					1							1					
114			1				1									1					1					
115	1			1						1	1	Unless strongly advised otherwise		3	4	1	2	Knowing peak AHD of flood	5	4	5	1	2	3	Supply of fresh water	6
116		1								1					1		2	Access to powers, food		3	2	1	4			
117	1					1		1	Fallow Flood plan						2	1										1
118			1					1	East Gosford					3	2	1			4							1
119		1				1				1				3	4	2			1	3	5	1	2			4
120			1										1	2	3	1	1	I don't know, never been in the situation		2	1	4	3	1	don't know until in situation	
121		1								1									1			1				
122			1								1	to friends home outside of flood area		3	2	1	4			2			1			
123		1			1					1									1	3	5	1	2			
124	1				1					1									1	2	3	4	1			
125		1					1	1	Family members home					2	3	1			4	2	5	4	3			1
126			1										1	2	3	1				3	2		1	4	Safety of family	5
127		1								1									1			1				
128			1										1	2	3	1	4	Help elderly people out of their villas		2	3		1	4	Care for the elderly in villa complex	
129		1								1									1	3	2	1	4			
130			1							1									1				1			
131		1											1						1	1		1	1			
132			1							1									1		1		1			
133	1					1							1				1	only if house loos like going under			1		1			
134			1										1	1		2				3	1		2			
135	1			1			1													3	1		2			
136						1		1	motel						1											1
137	1					1	1							1		1										
138			1										1	2		1	3	loss of power	4	3	1		2	4	loss of power	
139		1									1	Move stock to higher ground open appropriate gates stock up on essentials.							1		1	2	3			
140		1			1					1									1	3	1	4	2			

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141					1					1				1	1					3	1					
142		1								1									1			1				
143	1				1					1									1	1						
144		1			1					1									1	3	1	2	4			
145			1							1									1			1				
146	1					1				1									1	2	3	1	4			
147			1							1										1			1			
148		1								1									1			1				
149		1								1									1			1				
150	1					1							1	2	3	1	4	safety of our animals		3	2		1			
151			1							1									1	3	2	4	1			
152					1					1				4	3	1	2	horses and live stock		4	2	3	1			
153		1		1						1				2					1			1				
154	1				1					1									1		1	2				
155		1								1									1	4	1	2	3			
156		1								1									1			1				
157	1				1						1			2	4	1	3	communute to work		1	3	5	2	4	commute to work	
158			1							1				2	3	1				3	2	1	4			
159	1				1					1									1			1				
160		1								1	1	Relocate to family					1	Loss of sewer and power	1	4	2	1	3			
161			1			1							1	1		1							1			
162	1	1				1		1	Elevated area								1	Plant and equipment stock						1	Possible evacuate personel	
163	1					1	1							1						1	1	1				
164	1			1						1				3	2	4			1	2	3		1	5		4
165	1				1			1	hotel	1	Depending as we are one storey			2		1				3	1	2	4			
166			1		1						1	by the time we find out its too late		1	2	3			1	4	3		2	1	sewerage, medical and food supply	
167			1							1									1	4	2	1	3			
168			1				1							3	2	1				3	2	1	4			
169	1				1					1										1	5	2	3			
170			1																							
171			1				1							2	3	1	4						1			
172	1					1	1			1				3	4	1	2			2	4	3	1	5		
173	1					1				1										1				2	Access to work	
174	1					1				1									1							
175			1		1					1									1	1	1					
176		1								1									1			1				

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177		1				1				1						1					1	3	2			
178		1				1				1				3	2	1	4			2	1	3	4			
179			1		1					1				2		1				4	2	3	1			
180		1								1					3	2						5	2	3		
181			1			1					1	We would remain- however we plan to have an evacuation plan in place so we need to evacuate and will do so up bumble hill road- we have two cars thus they will be packed in a higher area away from the house so we can leave when required. We		2		1	3			3	2		1			
182	1					1				1				2		1				2			1			
183			1			1				1				4	3	2	1			4	2	3	5	1		

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184	1			1																						
185	1					1				1				2		1	3			3	2	1	4			
186	1					1				1		and have to repair access road afterwards at a cost of apron $2000								2	3	1	4	5		
187	1				1								1	2	3	1	4									
188	1				1								1	2	3	1	4							1		
189			1							1				2	3	1				2	1	4	3	5		
190			1									Depends on water height.1	1	2	3	1				2	3	1	4			
191		1								1										3	2		4			
192		1								1		We keep adequate provisions and have tank water plus a power generator.								1	2	4	3			
193			1							1											2	1				

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
	Yes, I know my house/business could be flooded	Yes, I know my house/business cannot be flooded	No I don't know/I'm not sure whether my house could be flooded	my house/business could be flooded in a 1%AEP flood	my house/business could be flooded in a PMF	my house/business could be flooded but I'm not sure of the name of the flood	Evacuate early to an offical evacuation centre in Wyong	Evacuate elsewhere	please describe	remain at my house	other	please describe	don't know/not sure	Discomfort/inconvenience /cost of being isolated by floodwater	need for uninterrupted access to medical facilities	safety of our family	other	please describe	Not applicable (remain at home)	Discomfort/inconvenience/cost of being isolated by floodwater	need for care for animals	my house cannot be flooded and we can cope with isolation	concern for security of my property if I evacuate	other	please describe	Not applicable (remain at home)
194		1			1					1																
195										1		unless the prediction was for a higher level than ever before		2		1	3			2			1			
196			1	1				1						2	4	1							2			
197	1			1							1	Remain at house until Linga Longa Rd floods.		2		1	3			2	1		3	4		
198			1			1							1			1					1					
199	1				1					1		Upstairs living, so even if water did get in at ground floor, we would be dry upstairs. This is NOT a safety issue as has been put forward by the SES and council staff who have said it gives a false sense of security and encourages people to stay when they should								3	1		2			
200			1							1		Our house is not at risk at flooding, so it is safe for us to remain their, and we have livestock that needs to be looked after. We have evacuated for short times in the past, mainly to ensure we can meet our work commitments - generally one person remains to		2	3	1	4			3	1	2	4			
201			1										1	1	3	2	4			1			2			
202	1			1						1										5						
203			1		1					1				3	2	1	4			4	3	2	1	5		

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
	Yes, I know my house/business could be flooded	Yes, I know my house/business cannot be flooded	No I don't know/I'm not sure whether my house could be flooded	my house/business could be flooded in a 1%AEP flood	my house/business could be flooded in a PMF	my house/business could be flooded but I'm not sure of the name of the flood	Evacuate early to an offical evacuation centre in Wyong	Evacuate elsewhere	please describe	remain at my house	other	please describe	don't know/not sure	Discomfort/inconvenience /cost of being isolated by floodwater	need for uninterrupted access to medical facilities	safety of our family	other	please describe	Not applicable (remain at home)	Discomfort/inconvenience/cost of being isolated by floodwater	need for care for animals	my house cannot be flooded and we can cope with isolation	concern for security of my property if I evacuate	other	please describe	Not applicable (remain at home)
204										1				1	2	3				2	3	4	1			
205		1						1	Weekend property so wopuld probably return home to Sydney					3		1						2				
206	1					1		1						1	4	2	3			1	2		3	4		
207	1					1				1				2	4	1	3			2	1		3	4		
208	1					1				1		Have a petrol generator for power.		1	3	2	4			1	5	3	2	4		
209		1			1					1		HOUSE BLOCK HAS NEVER BEEN UNDER WATER SINCE 1920									4	1		5		
210	1					1					1	ASSESS AT TIME OF FLOOD		3		2	1			5			4	3		
211	1				1					1		Not practical to evacuate, the road would be cut by the time I realised that I needed to.		1		2	3			1	2		3	4		

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
	Yes, I know my house/business could be flooded	Yes, I know my house/business cannot be flooded	No I don't know/I'm not sure whether my house could be flooded	my house/business could be flooded in a 1%AEP flood	my house/business could be flooded in a PMF	my house/business could be flooded but I'm not sure of the name of the flood	Evacuate early to an offical evacuation centre in Wyong	Evacuate elsewhere	please describe	remain at my house	other	please describe	don't know/not sure	Discomfort/inconvenience /cost of being isolated by floodwater	need for uninterrupted access to medical facilities	safety of our family	other	please describe	Not applicable (remain at home)	Discomfort/inconvenience/cost of being isolated by floodwater	need for care for animals	my house cannot be flooded and we can cope with isolation	concern for security of my property if I evacuate	other	please describe	Not applicable (remain at home)
212	1					1				1		Take vehicle/s to higher ground in Wyong before river rises and cuts off Sth Tacoma Road or is likely to flood residence		2		1				1			2			
213			1										1							2	1	3	4			
214	1					1				1				1	2	3				2	1	5	3	4		
215	1					1		1				Parents house in Wyong		2		1	3									
216	1					1					1	I don't think my house would flood I'd stay home until it receeded		2	3	1	4			3	2	1	4			
217			1			1				1		keep track of run off from hill behind and look after animals		1	3	2				1	2	4	3			
218			1	1			1							3	2	1	4			2		4	1	3		
219			1			1							1	2	3	1	4			2	3	4	1	5		
220	1			1			1							2	3	1				3	2		1			
221		1			1			1	Parent's home in Lakehaven					3	2	1	4			2	3	1	4			
222			1							1										2	1		3			
223	1					1				1										2	1		3			

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
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224			1								1	This house is a holiday house and in case of major flood I would go home however it is built on piers so I don't anticipate that the house would flood.		2		1				2		1	3			
225																										
226		1		1				1	Move to our house in Sydney					2	3	1	4			1	3	2	4			
227			1					1	go to relatives							1						1				
228			1			1				1																
229	1				1					1				1	3	2				1	3		2			
230			1			1				1							1				1		2			
231		1						1	Relative's house					1		2	3			1	4	2	3			
232			1							1																
233	1					1				1										3	2	1				
234			1							1		We would remain unless the flood came higher - if that was the case we could decide to leave then. We have an access route via Bumble Hill.		1		3				1		2	4			
235	1					1		1	We would go to a relatives house			4		3	2	1	4									

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
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236		1								1				1						2		1	3			
237		1								1		In respect to questions 5 & 6 (paper version) our paddocks are regularly flooded and this impacts the cattle (business)			1	2	3			1	2	3	4			
238	1					1				1		ONE IN 100 YEAR FLOODING FOR KOOINDAH WATERS		2	3	1	4			2	3	4	1	5		
239																										
240		1								1										3		1	2			
241	1					1				1				1	2	3	4									
242		1								1										3	1	2	4			
243		1								1													1			
244		1								1											2	1				
245		1		1								Highly unlikely to flood in the area we reside														
246			1	1						1		I have a boat it'll float.								3	1	5	2	4		
247	1			1						1				2	3	1	4			3	1		2	4		
248			1			1		1				to a relatives house outside area		1		2	3									
249	1					1				1		We would move to the top of our property near Yarramalong Road		4	3	1	2			2	1					
250		1				1		1	stay at home					2	3	1				1		2	4			
251			1							1												1	5			
252	1					1		1	Sydney						4	1	3			2		3	1			
253		1								1												1				
254			1							1						1										

Response Number	Do you know if your house/business has a risk of being flooded			Do you know in what size of flood your house/business could be flooded			How do you anticipate you would respond in a future major flood in this area?							If you are likely to evacuate, what factors are most important to you?						If you are likely to remain at your home, what factors are most important to you?						
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255			1							1		we live high up on the hill so need to remain home for livestocks etc		1							1					
256														2	1	3	4									

Questionnaire Responses

Responses to Potential Flood Mitigation Options

Response Number	A list of potential options for managing the flood risk is provided on the next page. If you have any other suggestions for reducing flooding problems, please describe below.	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?														
		Installallation of flood gates along Mardi Creek to help prevent "backwater" inundation of Anzac Rd	Installation of debris control structures along Mardi Creek to help prevent blockage of culverts	Regular maintenance and clearing of Mardi Creek	Mardi Creek Detention Basin West of Pacific Motorway	Construction of new channel/culverts beneath railway to allow Mardi Creek to drain more freely	Construction of floodway channel south of South Tacoma to allow Wyong River floodwaters to "escape"	Voluntary raising of some low lying properties	Voluntary flood proofing on some low lying properties	Updates to Council planning documents	Upgrade of flood warning system	Install boom gates/signs at roadway overtopping points	Updates to SES local flood plan	Improve flood access for South Tacoma	Improve flood access for Yarramalong valley	Improve flood access along McPherson Rd
1		Support	Support	Support	Neutral	Support	Support	Support	Support	Support	Strongly Support	Support	Support	Support	Strongly Support	Support
2	When the entrance outlet is less then 25m in flood times the lake fills up and backs up the rivers. So keep the outlet deep and wide. Remove the centre sand bars.						Strongly Support									
3		Neutral	Support	Support	Neutral	Neutral	Neutral	Support	Support	Neutral	Support	Neutral	Neutral	Neutral	Against	Neutral
4	Most properties like mine have houses built off the flood plain on the side of the hill. Old fire trails have been allowed to become dormant. Trees obstruct vehicles from access to state forests. A simple clearing program would be good to allow emergency exits for residences. The 2007 flood lasted for 7 days with Yarramalong Rd closed. Alternate exits exist, let us use them. Privacy concerns can be addressed with the installation of locked gates.	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Support	Support	Support	Support	Support	Strongly Support	Support
5		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
6		Against	Support	Support	Support	Strongly Support	Against	Neutral	Neutral	Neutral	Support	Support	Neutral	Support	Support	Support
7	Clean all the trees/grass that has fallen into the Creek plus stopping it from flowing properly (rear of factories: between boswell close plus johnson road). Not like last time when you burnt it all plus burnt the galvenising off my fence which rusted plus I had to replace at my cost (approximately 20 years ago).	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Unsure	Unsure	Unsure	Strongly Against	Strongly Support	Strongly Against	Strongly Support	Neutral	Neutral	Strongly Support
8		Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Against	Support	Neutral	Neutral	Neutral	Neutral	Support	Support	Support
9	Need More Drains in area and repaired	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support		Support			
10	Work on the entrance channel so tuggerah lake can drain	Support	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support
11	Ground modelling on properties, swales are critical. Council maintaining drains. Mobile phone towers in Yarramalong& Dooralong Valleys.	Neutral	Strongly Support	Strongly Support	Against	Strongly Support	Neutral	Neutral	Neutral	Support	Strongly Support	Against	Strongly Support	Unsure	Neutral	Unsure
12	Look at upgrading other tuggerah straight culverts under pacific highway railway.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Against	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Support
13		Neutral	Neutral	Neutral	Support	Support	Support	Strongly Against	Strongly Against	Support	Support	Strongly Against	Support	Support	Support	Support
14																
15		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
16	Keep the entrance open the way it is at the moment 7/10/2016. Build a breakwater.	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Neutral	Neutral	Neutral	Strongly Support	Support	Support	Strongly Support		
17		Support	Support	Support	Support	Support	Support	Unsure	Strongly Support	Unsure	Support	Support	Support	Support	Support	Support
18			Support						Support		Strongly Support		Support	Strongly Support	Strongly Support	Support
19		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
20		Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
21		Unsure	Support	Support	Unsure	Support	Strongly Support	Unsure	Unsure	Support	Support		Support	Support	Unsure	Strongly Support
22			Support	Support											Support	
23		Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support

Response Number	A list of potential options for managing the flood risk is provided on the next page. If you have any other suggestions for reducing flooding problems, please describe below.	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?														
		Installallation of flood gates along Mardi Creek to help prevent "backwater" inundation of Anzac Rd	Installation of debris control structures along Mardi Creek to help prevent blockage of culverts	Regular maintenance and clearing of Mardi Creek	Mardi Creek Detention Basin West of Pacific Motorway	Construction of new channel/culverts beneath railway to allow Mardi Creek to drain more freely	Construction of floodway channel south of South Tacoma to allow Wyong River floodwaters to "escape"	Voluntary raising of some low lying properties	Voluntary flood proofing on some low lying properties	Updates to Council planning documents	Upgrade of flood warning system	Install boom gates/signs at roadway overtopping points	Updates to SES local flood plan	Improve flood access for South Tacoma	Improve flood access for Yarramalong valley	Improve flood access along McPherson Rd
24	This property was redeveloped 12 years ago. Floor levels were set by council. Although the creek has flooded several times over 12 years our business have never been flooded. The car park has had minor flooding, however loss of business due to Anzac road flooding is costly.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Support						
25	Build a breakwall at the entrance channel like you were going to do.	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
26			Support	Support		Support	Strongly Support				Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
27		Unsure	Support	Support	Unsure	Neutral	Unsure	Unsure	Unsure	Unsure	Strongly Support	Support	Support	Support	Unsure	Support
28	only damage from flood was the fencing. The apporach to Bunning Creek Bridge could be improved to stop the bridge flooding allowing access.								Strongly Support						Strongly Support	
29	Historical records show that major flooding occurred in the mid to late 1800's, one notable record from Newcastle in 1871 mentions 267mm rain in just over 2 hours. Buildings and dwellings built in that period were all constructed at an obvious level above the river. Major earthworks along the river flood plain have happened recently.	Unsure													Support	
30	More work on Yarramalong Road, jilliby road and at Porters creek. Stabilise the banks of wyong river.	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Against
31		Unsure	Support	Support	Against	Support	Support		Support		Support				Support	Support
32				Support												Support
33		Unsure	Support	Support	Support	Support	Support	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
34		Unsure	Unsure	Support	Unsure	Unsure	Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
35	There needs to be more rubble pits installed in the area of 62-64 Alison road (child care cenre) and the unit of 66 Alison Road.	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral	Neutral
36	In Golding Grove there are 4 culverts/drains for escape of excess water from McDonough Road and Riverview Road. These drains are blocked in my 35 years and have nevcer been cleared.	Support	Support	Support	Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Against	Neutral	Support	Support	Support
37		Neutral	Support	Strongly Support	Unsure	Unsure	Support	Support	Support	Unsure	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support
38		Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
39		Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Neutral	Neutral	Neutral	Support	Support	Neutral	Neutral	Neutral	Neutral
40		Neutral	Support	Support		Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Support
41																
42	Rocky Point will always flood when high tides plus a low system occur. Not sure if any of your proposals will help.	Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support							Strongly Support	Strongly Support	Strongly Support

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43							Strongly Support		Strongly Support	Strongly Support						
44	Regular Cleaning of drains into lakes. Dredge seaweed entrance to Wyong river. Open the entrance at the entrance. Build the seawall.	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Support	Support	Against	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support
45		Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Support	Neutral	Support	Support	Support	Support
46		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
47	Road access. At Panonia Road and overpassing rail line on Bridge is too low. Should be raised. Keep floodway clear at Riverview and Remane floodway			Strongly Support		Strongly Support			Strongly Support			Strongly Support				Strongly Support
48	Keep storm water drains clear. Raising properties only voluntary	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against
49		Unsure	Support	Support	Unsure	Support	Support	Support	Support	Unsure	Support	Unsure	Support	Neutral	Support	Neutral
50		Support	Support	Support	Support	Support	Strongly Support				Support			Strongly Support	Strongly Support	Support
51	Council would need to look at redirecting the water build up to a non residential catchment.	Unsure		Strongly Support	Unsure	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
52		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
53	Don't build in flood areas.	Strongly Against	Strongly Against	Strongly Support	Strongly Against	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
54	Upgrading phone coverage. Flood guidelines and preparation plans. Hazards studies on other possiblities.	Against	Neutral	Neutral	Against	Support	Support	Unsure	Unsure	Unsure	Strongly Support	Support		Neutral	Support	Neutral
55	Chain link fence at nearby golf course impeded floodwater causing flooding across property	Neutral	Support	Support	Support	Support	Support	Support	Support	Neutral	Support	Support	Support	Support	Support	Support
56		Unsure	Unsure	Support	Unsure	Unsure	Unsure	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Unsure
57	Keep the entrance open	Unsure	Support	Support	Unsure	Unsure	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
58		Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Support	Support	Unsure	Support	Support	Support
59		Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support
60											Unsure	Unsure	Support	Unsure	Strongly Against	Unsure
61							Support								Support	
62		Support	Support	Support	Support	Support	Support	Neutral	Neutral	Unsure	Neutral	Against	Support	Support	Strongly Support	Support
63		Support	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Strongly Support	Against	Neutral	Neutral	Support	Support
64		Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Support	Support	Support
65	Text message sent to residents in south tacoma, as most people will stay on their property if not warned.						Strongly Against		Strongly Against		Strongly Against			Strongly Against		

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66	The council could facilitate swails plus better drainage higher up in the forest to slow and manage excessive water that traverses this property,	Unsure	Support	Support	Unsure	Support	Support	Unsure	Support	Support	Support	Support	Support	Unsure	Support	Unsure
67	Open access to fire trails. Open access between public roads (Amber Lane) along Yarramalong. Improve flood warning BOM station at yarramalong. Extend mobile phone access up the valley (not just yarramalong village as currently planned).	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Neutral	Strongly Support	Neutral	Strongly Support	Neutral
68		Unsure	Support	Support	Unsure	Support	Support	Support	Support	Unsure	Support	Unsure	Support	Neutral	Support	Neutral
69		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
70	Raise key sections of Yarramalong Road	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Neutral	Unsure	Strongly Support	Support	Neutral	Unsure	Strongly Support	Unsure
71		Support	Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Support	Unsure	Support	Unsure
72		Support	Support	Support	Support	Support	Support	Neutral	Neutral	Support	Support	Against	Support	Neutral	Neutral	Neutral
73		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against
74	The new Dickson Road has improved the risk of being isolated. The road should have been closed as the waves from cars increased damage	Neutral	Neutral	Neutral	Against	Strongly Against	Strongly Against				Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
75		Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Support	Support	Support	Support	Support	Support	Support
76		Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral			Strongly Support	Against	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support
77		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support	Support
78		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
79		Unsure	Support	Support	Unsure	Unsure	Support	Unsure	Unsure	Unsure	Support	Support	Support	Neutral	Neutral	Unsure
80	The only time our commerical property is flooded is when the run off from Alison Rd flows into our property and floods our buildings. This happens not only in flood time but with any major down dour. More adequate drainage is needed and clear out of drains regular	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support
81																
82		Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure
83		Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support				Strongly Support		Strongly Support			
84	Improved road and storm water drainage in the area would help most flooding.	Neutral	Support	Support	Neutral	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Neutral	Support	Support	Support	Neutral
85		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
86		Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Unsure	Neutral	Neutral	Support	Support	Support	Support	Neutral	Neutral	Neutral
87	Removal of debris in Wyong Creek to entrance flow. Open the entrance channel to allow flood escape. Review 1 - 100 flood levels in Wyong creek area, 300mm change. Review capacity of paths under M1 to cope with large floods	Unsure	Support	Support	Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Support	Neutral	Support	Support	Support	Support
88		Unsure	Support	Strongly Support	Neutral	Support	Unsure	Unsure	Support	Support	Strongly Support	Strongly Support	Support	Unsure	Neutral	Support

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89	Undertake major work arround the dairy property sections. East of Tuggerah stright from Tuggerah station to rail bridge Tacoma Rd. Do work to all drains from Gavenlock Rd to Tuggerah Straight Anzac Ave to rail bridge. Remove all debris from arround drains, headwalls.	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Neutral	Support	Strongly Support	Support	Neutral	Support	Support	Support	Support
90		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
91		Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Support	Support	Support
92	Open up the entrance channel and put in a break wall. Clear stormawter drains into wyong river along Wolseley Ave Tacoma.	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
93		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
94		Support	Support	Support	Unsure	Support	Unsure	Support	Support	Support	Support	Support	Support	Support	Support	Support
95	Restrict housing development which will impact runoff. Systematic river bank restoration tree planting to stablise the banks. Find a method of draining excess water from wetlands behind Tacoma houses.	Neutral	Neutral	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral
96	Flood water subsides quickly no access isnt as much of an issue. Having mobile reception would be an improvement.															
97	Decent run off kerb side not graded to fall at outlet. Build up of water causes run off onto low lying properties	Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support	Neutral	Neutral	Strongly Support	Strongly Support	Support	Strongly Support	Support	Support	Support
98		Against	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Support	Support	Support	Support	Strongly Support
99	If the roads Ravensdale and Yarramalong were raised and proper suized culverts installed the roads would be much safer.	Strongly Against	Strongly Support	Strongly Support	Unsure	Support	Unsure	Neutral	Neutral	Strongly Support	Strongly Support	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support
100	Dredge and clean the lake.										Strongly Support	Strongly Support		Strongly Support		
101		Support	Support	Strongly Support	Support	Support	Support	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
102	Maintenance drains on Polloc ave	Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Neutral	Support	Support	Support	Neutral	Support	Support	Support	Support
103		Support	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Support	Support	Support	Unsure	Unsure	Unsure
104	Raise soil levels along river in the 3 main spots where road goes under along the housing area. Dredging the entrancing.	Support	Support	Support	Support	Support	Strongly Support	Strongly Against	Neutral	Against	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
105		Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
106		Unsure	Unsure	Support	Support	Support	Support	Support	Support	Support	Support	Support		Support	Support	Support
107	Keep drainage clear at all time	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Strongly Support	Support	Support	Strongly Support	Support	Support	Support
108		Neutral	Neutral	Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Unsure	Support	Strongly Support	Support	Unsure	Unsure	Unsure
109		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
110	Increase height of road by approx 100 mm would make a huge difference to the flow from the river. This would be the southern end of Leppington St from approx No 22.	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Neutral	Support	Support	Support	Support
111	Increase the height of gutters and kerbs	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support	Support	Support	Support	Support
112		Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Neutral	Neutral	Strongly Support	Strongly Support	Support	Support			Support
113		Support	Unsure	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
114		Support	Support	Support	Support	Support	Support	Neutral	Support	Support	Support	Support	Support	Support	Support	Support
115	Stop draining subcatchments into lower ones as this only increases flooding arround wyong river. Raise free board	Unsure	Support	Support	Strongly Support	Strongly Against	Strongly Against	Against	Neutral	Unsure	Strongly Support	Strongly Against	Strongly Support	Neutral	Neutral	Neutral

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116							Strongly Support								Strongly Support	Strongly Support
117		Support	Support	Support	Support	Support	Support	Unsure	Unsure	Support	Strongly Support	Unsure	Strongly Support	Support	Support	Support
118		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Support	Support	Strongly Support	Neutral	Support	Support	Support	Strongly Support
119	The drainage ditch running into the lake should be deep enough to take run off roads should be kept cleared out of silt and vegetation	Support	Support	Support	Unsure	Support	Strongly Support	Support	Support	Support	Strongly Support	Neutral	Support	Strongly Support	Support	Support
120	There is a swamp at the back of Brushwood Circuit plus Greenwich place that should be looked at. The drainage at the round about off Woodbury Park Drive is not sufficient to take the amount of water it receive	Unsure	Unsure	Support	Unsure	Support	Support	Support	Support	Support	Strongly Support	Support	Strongly Support	Support	Support	Support
121		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
122		Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Support	Unsure	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Unsure	Unsure	Unsure
123		Unsure	Unsure	Strongly Support	Unsure	Unsure	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure
124	Focus on the Entrance	Neutral	Support	Support	Unsure	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Neutral
125		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
126	Drainage is inadequate along McDonagh Rd. I am no sure however it appears to me that kooindal waters lands contribute to the problem.	Support	Support	Support	Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support
127	Since the pump station is working at Mardi floods are quicker solved	Neutral	Support	Strongly Support	Strongly Support	Support	Support	Neutral	Support	Support	Support	Support	Support	Support	Support	Neutral
128	Fix Drainage in Boyce Avenue Remove Grass that Covers Drains so it has a better flow to get away especially outside houses. When it rains it builds up.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
129		Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Neutral	Neutral	Support	Neutral	Neutral	Neutral	Neutral	Neutral
130		Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
131		Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support
132		Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support	Support	Support	Support	Support	Support
133	Council to maintain drains so as not to have large build up of wastes materials blocking them which happens on a lot of the roads	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
134		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Support	Support	Support	Support	Support	Support
135		Support	Support	Support	Unsure	Support	Strongly Support	Unsure	Strongly Support	Unsure						
136		Unsure	Support	Support	Unsure	Unsure	Unsure	Against	Neutral	Support	Strongly Support	Support	Strongly Support	Support	Unsure	Unsure
137	Clearing out of waterways plus debris near the drainways a regular basis. Anzac road always floods can't you do something to ensure the water has a better way to flow away?	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
138		Unsure	Unsure	Support	Unsure	Strongly Support	Unsure	Unsure	Unsure			Unsure	Support	Unsure	Strongly Support	Unsure

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139	Major work at the back of properites. River needs major cleaning. Consider raising height of weir on Wyong river. Maybe install a further weir upstream.															
140	Open up Tuggerah Lakes at the entrance permantly to sea. Also open up Wyong river exit at Tacoma. Deeper and wider.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support				Strongly Support	Strongly Support	Strongly Support
141	Continue to dredge the entrance. Create new drain from pioneer dairy.	Support	Support	Support	Support	Support	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Support
142																
143		Support	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Support	Support	Support	Unsure	Unsure	Unsure
144				Support		Strongly Support	Strongly Support	Neutral	Support	Support	Strongly Support	Support	Support	Support	Support	Support
145	Upgrade the channels and the pipe access to Wyong River. Traffic control could be improved to prevent further damage.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
146		Unsure	Support	Support	Support	Strongly Support	Strongly Support	Strongly Against	Against	Strongly Against	Neutral	Against	Neutral	Strongly Support	Strongly Support	Strongly Support
147											Support	Support	Support	Support	Support	Support
148							Strongly Support		Strongly Support				Strongly Support			Strongly Support
149		Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Against	Support	Neutral	Neutral	Neutral	Neutral	Neutral
150		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
151	Stop erosion of river bank at jack year reserve, behind no 17 Linga Longa Rd Yarramalong Village. Keep sediment trap clear.	Neutral	Support	Strongly Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Strongly Support
152		Support	Support	Support	Support	Support	Strongly Support	Neutral	Support	Support	Support	Support	Support	Support	Strongly Support	Support
153		Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Against	Strongly Against	Strongly Against	Neutral	Strongly Against	Strongly Support	Neutral	Neutral	Strongly Support
154	Roads need to be above flood plain. Telecommunications Services need to be above flood plain.	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Support	Support	Support	Support	Support	Support
155		Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Unsure	Strongly Support	Support
156		Neutral	Strongly Support	Strongly Support	Neutral	Support	Support	Unsure	Unsure	Unsure	Support	Support	Support	Support	Support	Support
157	Opening the entrance	Against	Strongly Support	Strongly Support	Unsure	Neutral	Unsure	Unsure	Unsure	Unsure	Support	Against	Support	Support	Support	Support
158	Regular checking of culverts and drains	Neutral	Support	Support	Neutral	Against	Against	Strongly Support	Strongly Support	Strongly Support	Support	Support	Neutral	Neutral	Neutral	Neutral
159		Strongly Against	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Support	Support	Strongly Against	Support	Support	Support
160	Insurance premiums are too high	Neutral	Against	Support	Neutral	Neutral	Neutral	Strongly Against	Strongly Against	Strongly Against	Support	Neutral	Strongly Support	Neutral	Neutral	Neutral
161		Support	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Support	Support	Support	Strongly Support	Support	Support
162		Unsure	Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Unsure	Support	Unsure	Support	Support	Support	Strongly Support	Unsure	Strongly Support
163		Unsure	Support	Support	Unsure	Strongly Support	Strongly Support	Support	Support	Unsure	Support	Support	Support	Strongly Support	Unsure	Strongly Support
164	Clean drains and waterways particularly at the entrance		Strongly Support	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support			Strongly Support		Strongly Support

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165		Support	Support	Strongly Support	Support	Support	Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
166	Upgrade Sewerage, list area on SES, alternative evacuation routes, offer medical supply.	Unsure	Support	Support	Unsure	Unsure	Strongly Support	Unsure	Unsure	Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Support	Support
167		Neutral	Support	Support	Unsure	Support	Support	Unsure	Unsure	Strongly Support	Neutral	Support	Support	Support	Neutral	Support
168		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
169																
170																
171		Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support	Support
172	A Weir at Bunning Creek with pumps to send water into Mangrove Creek Dam.	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
173	Open the Entrance further if possible to speed up draining of Tuggerah lake during flood events						Support		Support		Support	Against		Strongly Support	Neutral	Support
174							Strongly Support									
175	Keep entrance opened	Neutral	Support	Support	Unsure	Support	Unsure	Strongly Against	Strongly Against	Strongly Support	Support	Support	Support	Support	Support	Support
176		Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Strongly Support	Support	Support	Support	Neutral	Neutral	Support	Neutral
177		Strongly Against	Support	Strongly Support	Neutral	Unsure	Unsure	Strongly Against	Strongly Against	Strongly Against	Support	Support	Support	Neutral	Neutral	Neutral
178		Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral
179		Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Neutral	Neutral
180	Bunning Creek road on either side of Bunning Creek bridge could be built up to stop the deep culvert caused through river breaking banks in a big flood.	Support	Support	Support	Support	Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support
181	After discussions with our neighbours (as we are new to the area) and wanted to have a better understanding of the past flooding - we have a few suggestions: * From our understanding from the internet and from our neighbours, Mardi dam is partly fed from Wyong river - if the Mardi to mangrove link is able to remove an excess of water from the dam during flood periods this would prevent a back flow further up the river thus reducing flood heights in the valley. If this is correct what contingency plans are in place to ensure power is NOT interrupted to the pumping stations? * Isolation is a key factor in the valley- there is NO mobile reception, there is no tv reception	Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support

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182	Minor flooding occurs frequently water coming from the swamp to the rear of our property.Clearing the Sewage Plant Overflow drain would help(Adjacent to the fish co-op).The wife and I moved from north of Taree off a grazing property and seen many a flood.Rain fall average 1.5 M Min .6M Max 10.9 M.Port Macquarie City was not flooded Laurieton town on th Camden Haven was not flooded.Taree City was flooded.The difference Port and Laurieton have a good break wall and access to the sea.Wyong River has very minor tidal change.I ask is the NAME THE ENTRANCE missed named.I watch the recently renovated dredge wondering when it will be put to good use.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
183	Surely to free up water flow inlet/ outlet at The Entrance would make a difference. Mainly to take measure to keep Wyong Creek easy flowing by regular maintenance.	Neutral	Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support	Neutral	Support	Neutral	Support	Neutral
184																
185	Prevent the Flood Water from the River, coming back up through the storm water drains.Which causes premature flooding.	Unsure	Support	Support	Strongly Support	Unsure	Strongly Support	Neutral	Neutral	Support	Support	Neutral	Support	Strongly Support	Support	Support
186		Neutral	Neutral	Neutral		Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Neutral
187	Kerb and guttering and proper storm water drainage around all the low lying areas along the wyong river and water front. Such as : Leppington St Wyong - Marathon St Wyong - Rockleigh St Wyong. Marathon St should be a priority due to the fact that when we have heavy rain the parents and school children walk on the road because of the bad drainage.	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
188																

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189	Stop speedboats from speeding along Wyong river eroding the banks Provide guttering in south Tacoma road Open the trails in the bush to the public again so that they can be worn down, therefore they don't flood	Support	Support	Support	Support	Support	Strongly Support	Against	Support	Support	Support	Support	Support	Strongly Support	Support	Support
190	Improve clearance of floodwater from creeks and particularly the lake. There was a high water mark on a pump station at Killarney Vale which was 10+ feet above sea level during one of the higher floods.	Unsure	Support	Support	Support	Unsure	Strongly Support	Support	Support	Support	Support	Neutral	Support	Support	Neutral	Support
191	Yarramalong Rd has many short Low areas that are not over the main watercourse and are only affected by still water that backs up. If these were raised by, in most cases, less that 50cm there would be better access out of the valley as well as entry for emergency services. If the electricity lines are damaged valley residents rely on electricity for their water supply as well as phone contact.	Neutral	Neutral	Support	Against	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Neutral
192	Council needs to ensure that all controls are enforced where there are illegal structures that could impede floodwaters and create a hazard if structures and/or contents are washed away. Our immediate neighbours have SEVERAL buildings that were constructed in the floodway without council approval and we have seen them inundated in recent flood events. They are a significant potential hazard to us and other residents, both in times of peak flood and as waters are rising.	Support	Strongly Support	Neutral	Unsure	Support	Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support
193					Strongly Support	Strongly Support	Strongly Support		Strongly Support	Strongly Support						
194		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
195	No, but any "improvements" have to be thoroughly planned (with common sense involved) to ensure that they don't become an added problem. Added information:- Our house at 53 Panonia Road was not flooded in the Big Flood of 1949(?) but the block was covered.	Against	Against	Strongly Support	Neutral	Strongly Support	Unsure	Support	Unsure	Neutral	Support	Support	Support	Unsure	Unsure	Unsure
196		Neutral	Support	Support	Support	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
197	1. Is there anything that can be done to assist Wyong River to move the water down river so the river doesn't rise so quickly and break the banks causing flooding? There seems to be a bottleneck somewhere in Yarramalong valley. 2. We need a community evacuation plan. Plan should include what to do when neighbours are not home and their pets or livestock are at risk of drowning. 3. It would be useful to have the option of having a copy of the survey we fill out emailed to ourselves.	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Support	Support	Unsure	Strongly Support	Against	Support	Unsure	Strongly Support	Unsure
198		Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure

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199	Raising the height of selected roads to ensure emergency vehicle access to most areas for the duration of the flooding. Fixing the the pooling of water in Mardi/Tuggeragh area west of the railway line due to raising of land in that area over the past few years - creating more points where the water can escape to the east side of the area	Neutral	Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Against	Support	Support	Support	Support
200	For Bunning Creek road, Raising the height of the bridge by approx. 1 m would significantly reduce the amount of time we are flooded in. I am not familiar with the creek at Mardi, so can't comment on the proposed modifications there	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Against	Against	Strongly Support	Support	Neutral	Support	Neutral	Strongly Support	Neutral
201		Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
202	Increase the capacity of the stormwater drains in my street (Leppington) to accommodate the increased volume of housing, runoff, and of cause rates that are all contributing to the stormwater that affects my property and the property of many others that, for no reason of their own are affected by the previous decisions of town planners that approve such developments.	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
203		Support	Support	Support	Support	Support	Support	Neutral	Support	Neutral	Support	Neutral	Support	Neutral	Neutral	Neutral
204	raise a Lemon Tree bridge on Dooralong Road; provide higher ford on Phil Tunks Road.	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Neutral
205		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Neutral	Strongly Support	Support	Neutral	Strongly Support	Strongly Support
206		Support	Neutral	Support	Unsure	Support	Strongly Support	Support	Support	Support	Neutral	Support	Support	Support	Support	Support

Catchment Simulation Solutions

Response Number	A list of potential options for managing the flood risk is provided on the next page. If you have any other suggestions for reducing flooding problems, please describe below.	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?														
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207	Better drainage from wet lands in front of our house. This is where the flood waters come from.	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure
208	McDonagh Road drain under the road is totally block with debry, needs to be thoroughly cleaned out to allow water to flow through and into the drain into Wyong River' Drain from McDonagh Road to Wyong River is also blocked and needs to be cleared of debry as this has stopped the water from flowing into the river. The following drains have not been cleared for approx. 40 years these are a chain of drains to the Wyong river and Tuggerah Lakes. McDonagh Road, Pollock Avenue, Warner Avenue, Tuggerawong Road. At a small cost, this would remedy the water which is still lying around in these areas We have had water in our drain at the front of our property for 2 years which confirms the	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Against	Unsure	Support	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support
209	AT FLOODING WYONG RIVER BREAKS IT'S BANK EAST OF M1 AT MARDI RD, IT THEN FLOWS SOUTH TOWARD MC PHERSON RD, HEN EAST ALONG 7G WETLAND. HERE IS A MAJOR PROBLEM CAUSING BACK UP OF FLOODWATER. 155 MCPHERSON RD HAS HAD ELEGAL LAND FILL LEVY APROX 200,000 M3 FILL STOPPING THE FLOW . THIS IS EFFECTING ADJACENT PROPERTIES AND PROPERTIES UPSTREAM BY IMPEDING THE FLOW AT 7G WETLAND. THIS NEEDS TO BE REMOVED BEFORE NEXT FLOOD. THE PROPERTY IS UP FOR AUCTION 30/10/16 AND SHOULD BE STOPPED UNTILL LAND FILL IS REMOVED. MCPHERSON ROAD HAS BEEN RAISED AT AREA 155 MCPHERSON	Neutral	Neutral	Neutral	Against	Strongly Against	Strongly Against	Strongly Against	Strongly Against	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Strongly Against
210	Do not have sufficient technical expertise to commenton "flood modifications" However, in our streets culvert pipes leading to the river require cleaning out to allow drainage from the streets to flow to river. Also, the iron flap valves require checking to ensure they are effective in preventing the river water flowing back to the streets in times of flood.							Unsure	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
211	It is essential that mobile phone coverage be extended into Yarramalong Valley. In the more severe floods, the road is cut off, electricity and landline phone and internet services are cut off, so if there is an emergency then there is no way to seek help. This is unacceptable.	Unsure	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support

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212	Maintain The Entrance Channel open to the sea to allow for flood waters to escape. From our experience in the 2007 floods, once The Entrance Channel sand barrier overtopped and flood waters escaped through the channel, the subsequent water level in the lake and river dropped below the normal water level range and exposed sand/mud banks/flats for a short period of time (a few days) before water levels returned to "normal". It was like someone pulled the plug from the bath.	Support	Strongly Support	Support	Strongly Support	Neutral	Strongly Against	Neutral	Neutral	Support	Support	Neutral	Support	Strongly Support	Support	Support
213		Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Support	Neutral	Neutral	Support	Support
214	more regular maintenance on culverts and stormwater drains under road. these get blocked and force water over road, and when they finally "break" they create a gush of water. clearing of local creeks of debris and weeds to allow floodwaters to dissapate quickly.	Unsure	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Support	Strongly Support	Unsure	Strongly Support	Strongly Support
215	A flood plan - drainage system needs to be designed due to the impact Kooindah Waters Golf Resort has caused on the natural flow of flood water from the wetlands area being filled. Since the mass land filling of this natural wetlands area (which should never have been approved by Council) the water has been forced to pool and flood McDonagh Rd and our property. Once Wyong river reaches capacity the water backs up the unkept and badly maintained drain ditches along McDonagh Rd and in 2006 the water reached a depth of 1.4m in our driveway. Prior to the development of Kooindah we had never experienced such regular and such depths of flood water along	Support	Strongly Support	Support	Strongly Support	Neutral	Strongly Support	Against	Against	Support	Support	Support	Support	Support	Neutral	Neutral
216	Fix road drainage on anzac rd and johnson road tuggerah				Unsure		Strongly Support		Support	Strongly Support	Strongly Support					
217	As we are Rural we have no town water and no mobile reception. In all the floods we have lost phone access for at least 1-2 days. In the April 2015 flood we lost power for 7 days of which 4 days we were isolated without water/power or telephone access. We have purchased a generator for future needs but we have lost income on all occasions. So flooding once a year is costing us money. Every time it rains heavy for more than a day we feel we need to prepare for flooding. The flooding appears to be happening more frequently than in the past.	Support		Strongly Support					Support						Strongly Support	
218		Strongly Support								Strongly Support						Strongly Support

Catchment Simulation Solutions

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219							Support				Support					
220						Unsure	Strongly Support			Unsure	Unsure		Support			
221						Neutral	Support		Support		Support					
222								Strongly Support	Support						Strongly Support	Support
223																
224	Dredging the Lake to make it deeper and eradicating the weed from especially around Rocky Point. It was never like that back in the 60's. The sand that is dredged could be mined for minerals. That a flood wall be constructed at Chittaway Point and than the Entrance could be opened up as the Lake needs flushing and re stocked with fish. Ban Commercial Fishing.					Neutral	Strongly Support		Support	Neutral				Strongly Support		Support
225																
226		Strongly Support	Support	Unsure	Neutral	Strongly Against	Against	Neutral	Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Against		Unsure
227				Unsure	Strongly Support		Support			Strongly Support	Strongly Support					
228					Support		Strongly Support	Neutral	Support	Strongly Support	Support		Strongly Support			Neutral
229	1. Re-open and Maintain the fire trails and tracks at rear of properties on South Tacoma Road, 2. Removal of boom gates on the trail in the Central Coast wetlands, for easier maintenance and CES and Fire Brigade access, 3. Continual and Regular Maintainance of all wetlands access roads. Note: Since the closure of the Central Coast Wetlands we have seen a significant increase in flooding, the flow out of the lake chanel has reduced Monumentally and residual water lays on our properties for a vaster period of time.						Strongly Support			Strongly Support				Strongly Support		

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230		Strongly Support	Support							Support	Support					
231							Strongly Support				Support				Strongly Support	
232																
233	1. Increased mobile phone coverage of the valleys so emergency texts can be used to warn residents of potential floods. Same applies for fire risk management. 2. Awareness campaign of tools to alert valley residents to river heights eg BOM website 3. Council to notify new residents on purchase of a property as to flood risks for the property eg 1 in 50 and 100 year flood map as found on this website	Strongly Against	Against	Neutral	Unsure	Support	Strongly Support	Strongly Against	Against	Unsure	Support	Strongly Against	Unsure		Strongly Support	
234						Support	Unsure			Unsure		Strongly Support	Support			Unsure
235				Strongly Support			Support									
236	There is no evidence that my house has ever been flooded and is raised about a metre. My next door neighbour tells me that the 2007 flood came up to his driveway but access was not restricted. At the end of Boyce Ave (the road at the back of my place) does get flooded and restricts some residents access. When it floods, the drains at the bottom end of Boyce Ave become blocked and makes the flooding worse. Regular cleaning of these drains should ease the flooding.				Unsure	Support	Strongly Support	Neutral	Unsure	Support		Neutral	Support	Strongly Support		
237							Unsure			Unsure					Support	

Response Number	A list of potential options for managing the flood risk is provided on the next page. If you have any other suggestions for reducing flooding problems, please describe below.	Council is considering the options listed in the tables below to help manage the risk of flooding. Which of these options do you support/not support?													
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238	BASICALLY IN FAVOUR OF ALL AND ANY IMPROVEMENTS, TO THE BENEFIT OF WYONG AS PART OF THE CENTRAL COAST REGION.	Strongly Support	Strongly Against	Support	Neutral	Against	Unsure	Neutral	Support	Strongly Support	Support		Strongly Support	Unsure		
239																
240																
241		Support					Strongly Support		Strongly Support					Strongly Support		
242					Neutral	Support	Strongly Support	Strongly Against	Support	Neutral					Strongly Support	
243	Improve access out of Bunning Creek Road by Raising the Bridge. Improve access out of Yarramalong Road by Raising Bridges						Unsure								Strongly Support	
244				Support			Neutral		Neutral	Support			Support			
245		Strongly Support								Strongly Support	Strongly Support					
246					Unsure	Strongly Support	Support	Strongly Support	Support	Neutral	Support	Neutral				
247	Every time a new home is built along the street they fill the land to raise it out of the flood zone,which means this puts all the older established properties at a greater risk of flooding as we are then the lowest properties & any excess flood water goes directly to us rather than the newer properties.						Strongly Support		Strongly Support		Unsure	Neutral		Strongly Support		
248					Unsure	Support	Strongly Support	Support			Support					
249																
250		Against	Strongly Support	Support	Neutral	Unsure	Strongly Against	Neutral	Support	Against	Strongly Support		Against	Neutral	Unsure	Support
251							Support	Against	Support	Neutral						Support
252		Unsure	Support	Neutral	Against	Strongly Against			Strongly Support	Support	Support					
253					Neutral		Strongly Support			Neutral	Strongly Support		Support			Neutral
254							Strongly Support			Unsure						
255				Unsure						Neutral					Strongly Support	
256																

APPENDIX F

GEOTECHNICAL INFORMATION

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Warabrook
NSW 2304 Australia

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f: +61 2 4016 2380

coffey.com

9 March 2017

Our ref: NTLEN202327-L02

Central Coast Council
2 Hely Street
WYONG NSW 2259

Attention: Sam Budden

Dear Sam

PROPOSED FLOOD MITIGATION WORKS, SOUTH TACOMA ROAD, TUGGERAH NSW PRELIMINARY IN-SITU WASTE CLASSIFICATION, VENM ASSESSMENT AND ACID SULFATE SOIL ASSESSMENT

1. Introduction

Central Coast Council (Council) is proposing to excavate soil from a property located off South Tacoma Road, Tuggerah NSW. Council is proposing to use the excavated soil as fill for a sports complex development. Excavations of up to 1m depth across the majority of the site are proposed.

For the purposes of this project, the "site" is referred to as the location of the proposed excavations. The site location is shown on Figure 1 (attached).

In order to facilitate the works, Council commissioned Coffey to carry out the following works:

- A preliminary in-situ waste classification of the soils proposed to be excavated, in order to assess offsite disposal options;
- An assessment of the suitability of the soil to be re-used as fill at the proposed sports complex (a Virgin Excavated Natural Material (VENM) assessment); and
- An assessment of acid sulfate soils (ASS) at the site, including the preparation of an acid sulfate soil management plan (ASSMP), if required.

This assessment was carried out in accordance with the relevant sections of the following references:

- NSW EPA (2014) Waste Classification Guidelines; and
- QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual.

Coffey Environments Australia Pty Ltd
ABN: 65 140 765 902

1.1. Objectives

The objectives of the assessment were to:

- Provide a preliminary waste classification of the material proposed to be excavated;
- Assess the VENM status of natural soils proposed to be excavated;
- Assess the ASS status of the soils across the site;
- Identify the need for ASS management, including preparation of an ASSMP if required; and
- Provide a preliminary assessment on the geotechnical suitability of the soil proposed to be re-used offsite, including preliminary recommendations as required.

1.2. Scope of works

In order to meet the above objectives, the following works were undertaken:

- A desktop review of the proposed development, ASS risk mapping and geomorphologic setting;
- A preliminary site history review, in order to identify if potentially contaminating activities have occurred on the site in the past;
- Drilling of four boreholes at the site and collection of representative soil samples;
- Laboratory analysis of selected samples for waste classification, VENM and ASS assessment purposes; and
- Data assessment and preparation of this report.

2. Site setting

2.1. Site identification and location

The site is located on an alluvial floodplain located on the banks of Wyong River, off South Tacoma Road, Tuggerah NSW. The site occupies part of Lot 3 DP 1186260 and has an area of approximately 11.3 hectares.

The site is bordered by South Tacoma Road and Wyong River to the north, the Tuggerah Nature Reserve to the east and south, and open grassed paddocks to the west.

2.2. Site observations

A site walkover was carried out by a senior Coffey Environmental Scientist on 24 February 2017. The site layout is shown on Figure 2 (attached). The following features were noted during the site walkover:

- The site is divided into fenced grassed paddocks;
- The Wyong River Model Aero Club occupies the north-western corner of the site. This area is fenced off from the remainder of the site and consists of a model aeroplane flying facility and several cleared tracks;
- The remainder of the site consists of paddocks with overgrown grass cover; and
- A drainage channel is located on the eastern part of the site, running north towards South Tacoma Road.

Photographs 1 and 2 below show the site at the time of the site walkover.

	
Photograph 1 – Looking at the Wyong River Model Aero Club portion of the site	**Photograph 2** – Looking across the southern portion of the site, overgrown with long grass

2.3. Site topography and drainage

Reference to the Gosford 1:25,000 topographic map indicates that the site is situated in a low-lying alluvial floodplain on the banks of Wyong River. The elevation of the site is less than 5m AHD.

Drainage at the site occurs mainly through land infiltration. Excess surface water generated during heavy rainfall events is anticipated to either pool on site, or drain via the drainage channel in the eastern part of the site towards Wyong River. Wyong River is located approximately 40m north of the site, and drains to Tuggerah Lake, located approximately 2.5km east of the site.

2.4. Soils and geology

2.4.1. Regional geology

Reference to the Gosford 1:100,000 Geological map indicates that the site is underlain by Quaternary Alluvium deposits, comprising gravels, sands, silts and clays.

2.4.2. Acid sulfate soil risk mapping

Reference to the Wyong ASS Risk Map indicates that the site is situated on an alluvial plain at an elevation of 2m to 4m AHD. The site is within a high probability of ASS being encountered between 1m and 3m of the ground surface.

2.4.3. Hydrogeology

Groundwater beneath the site is anticipated to be present as an unconfined aquifer in alluvial sands or clays at depths of less than 5m bgs (below ground surface).

Groundwater beneath the site is anticipated to flow to the north towards Wyong River, located approximately 40m north of the site, and eventually discharge to Tuggerah Lake, located approximately 2.5km east of the site.

3. Background information on acid sulfate soils

3.1. Coastal acid sulfate soils

Coastal ASS are soils which contain significant concentrations of iron sulfide or pyrite which, when exposed to oxygen in the presence of sufficient moisture, oxidises, resulting in the generation of sulfuric acid. Unoxidised pyritic soils are referred to as potential ASS. When the soils are exposed to air, the oxidation of pyrite occurs and sulfuric acids are generated, and the soils are said to be actual ASS.

Pyritic soils typically form in waterlogged, saline sediments rich in iron and sulfate. Typical environments for the formation of these soils include tidal flats, salt marshes and mangrove swamps below about RL 5 mAHD. They can also form as bottom sediments in coastal rivers and creeks.

Pyritic soils of concern on low lying NSW and coastal lands have mostly formed in the Holocene period, (i.e. 10,000 years ago to present day) predominantly in the 7,000 years since the last rise in sea level. It is generally considered that pyritic soils which formed prior to the Holocene period (i.e. >10,000 years ago) would already have oxidised and leached during periods of low sea level which occurred during ice ages, exposing pyritic coastal sediments to oxygen. There is still some potential for these older soils to contain stored acidity that could be released on exposure.

3.2. Significance of coastal acid sulfate soils

Disturbance or poorly managed development and use of coastal ASS can generate significant amounts of sulfuric acid, which can lower soil and water pH to extreme levels (generally <4) and produce acid salts, resulting in high salinity.

The low pH, high salinity soils can reduce or altogether preclude vegetation growth and can produce aggressive soil conditions which may be detrimental to concrete and steel components of structures, foundations, pipelines and other engineering works.

Acidic conditions often release aluminium, iron and other naturally occurring elements from the otherwise stable soil matrices. High concentrations of these elements, coupled with low pH and alterations to salinity can be potentially harmful to aquatic life. In severe cases, affected waters flowing off-site into aquatic ecosystems can have a detrimental impact (e.g. fish kills).

4. Field investigations and laboratory analysis

4.1. Soil sampling

Borehole drilling and soil sampling was carried out by a Coffey Geotechnician on 27 February 2017.

As requested by Council, Coffey drilled four boreholes at the site, to a maximum depth of 2m bgs. The boreholes (identified as STBH1 to STBH4) were drilled using a mechanical auger on a trailer attached to the field vehicle. The approximate borehole locations are shown on Figure 2 (attached).

Soil samples were collected from the surface from each borehole, and then at approximate 0.5m depth intervals until each borehole was terminated. The samples were collected by hand from the auger, and care was taken to minimise the potential for cross contamination. The samples were placed into laboratory-supplied glass jars (for waste classification and VENM testing) and also wrapped in air tight plastic film and placed into zip-lock plastic bags (for ASS testing). The samples were then stored in an ice-cooled esky.

4.2. Laboratory analysis

4.2.1. Waste classification and VENM assessment

The waste classification and VENM assessment samples were dispatched to the NATA-accredited Envirolab laboratory in Chatswood, NSW, for analysis.

Four samples were analysed for:

- Heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc);
- Total Recoverable Hydrocarbons (TRH);
- Benzene, Toluene, Ethylbenzene and Total Xylenes (BTEX); and
- Polycyclic Aromatic Hydrocarbons (PAH).

4.2.2. Acid sulfate soils

The ASS samples were also dispatched to the NATA-accredited Envirolab laboratory in Chatswood, NSW, for analysis.

Eight samples were screened in accordance with the methodology detailed in the QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual, in order to assess the potential presence of ASS.

Based on the results of the ASS screening, two samples were further analysed using the Chromium Reducible Sulfur (S_{CR}) method, to confirm the field screening results.

5. Assessment criteria

5.1. Waste classification criteria

In order to provide a waste classification of the soils assessed, the waste classification laboratory results were compared to the Contaminant Threshold (CT) and Specific Contaminant Concentration (SCC) values in the NSW EPA (2014) Waste Classification Guidelines.

The adopted waste classification criteria are provided in Table LR1 (attached).

5.2. Acid sulfate soil action criteria

In order to provide an ASS assessment of the soils assessed, the ASS laboratory results were compared to the action criteria provided in the QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual. The action criteria were adopted based on more than 1,000 tonnes of fine texture soils proposed to be disturbed during excavation.

6. Quality assurance / quality control

The samples were received at the laboratory in good condition and within holding times.

In order to assess field quality assurance / quality control (QA/QC) procedures, one duplicate sample (STQC1) was collected and analysed with primary sample STBH1 1.5m.

Table LR2 (attached) presents the relative percentage differences (RPDs) between the primary samples and the duplicate samples analysed. A review of the Coffey QA / QC results indicates that RPDs were within the acceptable range of 0 to 50% for the analytes tested.

The laboratory internal QA / QC reports indicated that the appropriate laboratory QA / QC procedures and rates were undertaken for contamination studies, and that:

- Laboratory blank samples were free of contamination;
- Matrix spike recoveries were recorded within control limits for copper;
- Laboratory duplicate RPDs were recorded within the control limits; and
- Surrogates and laboratory control samples were within the acceptable range of 70 to 130%.

Based on the QA/QC assessment, is considered that the laboratory methods are appropriate and that the data obtained is usable and considered to reasonably represent the concentrations at the sampling points at the time of sampling.

7. Results of investigation

7.1. Subsurface conditions

The borehole logs are attached. The subsurface conditions encountered during the field works are summarised in Table 1 below.

Table 1 – Summary of subsurface conditions

Soil type	Soil description	Approximate depth range (m bgs)
Topsoil	Silty Sand, fine to medium grained, black	0.0-0.3
Alluvium	Clay, high plasticity, pale grey/orange/brown with silty sand layers, black and grey, fine to medium grained	1.8->2.0 (depth of investigation)

**m bgs = metres below ground surface*

No apparent evidence of odours or discolouration was observed in the samples collected. No groundwater inflows were recorded in the borehole. No apparent visual evidence of potential asbestos containing materials (ACM) was observed during drilling or in the samples collected.

7.2. Laboratory results

7.2.1. Waste classification and VENM assessment

The waste classification and VENM assessment results are summarised in Table LR1 (attached). The laboratory reports are also attached.

In summary, the laboratory results indicated that concentrations of contaminants were below the CT criteria for General Solid Waste in each sample analysed.

7.2.2. Acid sulfate soils

Screening results

The field screening results are attached, and the results are summarised below:

- Soil samples mixed 1:5 with distilled water had pH's between 4.8 and 5.7, being slightly acidic. A pH less than or equal to 4 is likely to indicate the presence of Actual Acid Sulfate Soils (AASS);
- A final pH ranging between 2.9 and 4.3 pH Units, with slight to moderate reaction, after oxidation in hydrogen peroxide, were observed for the samples. A final pH of less than 3 can be indicative of Potential Acid Sulfate Soils (PASS); and
- The total pH drop was in the range of 1.0 and 2.2 pH units. A pH drop of more than 1 unit, plus temperature, effervescence, colour and odour factors can be indicative of PASS.

The field screening results indicated that there was a probability of ASS being encountered in the alluvial soils from approximately 0.5m depth to approximately 2m depth (limit of investigation). In order to validate the screening results, two samples were further analysed.

Chromium reducible sulfur results

The results of the laboratory analysed samples were compared to the action criteria provided in the QASSIT (2014) Queensland Acid Sulfate Soil Technical Manual, based on greater than 1,000 tonnes of fine texture soils to be disturbed. The results have been summarised below in Table 2. The laboratory report is attached.

Table 2 - Summary of acid sulfate soil laboratory results

Borehole ID	Depth (mbgs)	Laboratory Results				
		pH in KCL	TAA (moles/tonne)	% SCR	Net Acidity (moles/tonne)	Liming Rate (kg $CaCO_3$/tonne)
STBH2	0.5-0.6	4.4	**31**	0.005	**36**	2.7
STBH4	1.7-1.8	3.6	**61**	<0.005	**63**	4.7
Action Criteria		-	*18*	*0.03*	*18*	-

Note: KCl: potassium chloride solution; TAA: titratable actual acidity; SCR: chromium reducible sulfur.
Bold values exceed the action criteria.

The laboratory results for sample STBH2 0.5-0.6m is assessed as being non ASS. The evidence for this conclusion includes the log description of pale grey brown red and orange clay which is more indicative of alluvium, pH_{KCL} (4.4) and pH_{FOX} (3.5) and the low net acidity (0.06%). The deeper sample is assessed as being indicative of actual ASS because of the field description, grey clay, low pH_{KCL} (3.6) and pH_{FOX} (2.9) and the higher net acidity (0.1%).

8. Conclusions

8.1. Waste classification

According to the procedure outlined in the NSW EPA (2014) Waste Classification Guidelines, the following is assessed:

- The soils assessed are not classified as a Special Waste;
- The soils assessed are not a Liquid Waste;
- The soils assessed are not a Pre-classified Waste; and
- The soils assessed do not possess hazardous characteristics.

Therefore, the topsoil and alluvial soils (to a depth of 2m) assessed during this project are classified as **General Solid Waste.** If these soils are to be disposed offsite, they are required to be disposed of at a facility licensed to accept General Solid Waste.

8.2. Acid sulfate soils

The screening and the laboratory results indicate that actual ASS appear to be present at the site at depth. The grey and black silty layer at about 0.8 to 0.9m depth has a high probability of being ASS based on field description. Material above this layer is assessed as being topsoil and alluvium and non ASS.

The laboratory results for sample STBH2 0.5-0.6m is assessed as being non ASS. The evidence for this conclusion includes the log description of pale grey brown red and orange clay which is more indicative of alluvium, pH_{KCL} (4.4) and pH_{FOX} (3.5) and the low net acidity (0.06%).

The deeper sample (STBH4 1.7-1.8) is assessed as being indicative of actual ASS because of the field description, grey clay, low pH_{KCL} (3.6) and pH_{FOX} (2.9) and the higher net acidity (0.1%).

The material below 0.8m depth is therefore considered to contain actual ASS. If excavation of this material is proposed, an ASSMP will be required.

8.3. VENM assessment of natural soils

The NSW EPA (2014) Waste Classification Guidelines define *"Virgin excavated natural material (eg clay, gravel, sand, soil and rock) that is not mixed with any other waste and that:*

- *has been excavated or quarried from areas that are not contaminated with manufactured chemicals, or with process residues, as a result of industrial, commercial, mining or agricultural activities, and*
- *does not contain sulfidic ores or soils, or any other waste.*

And includes excavated natural material that meets such criteria for virgin excavated natural material as may be approved from time to time by a notice published in the NSW Government Gazette."

The site is located in a low-density residential and bushland area of Tuggerah. A review of aerial photography of the site dating back to 1954 indicates that the site has been a grassed paddock over the last 50 to 60 years. No potentially contaminating activities appear to have been undertaken on the site during this time.

The results of the laboratory analysis carried out on samples collected from the natural soils indicated low to non-detectable levels of contaminants were recorded, and are considered to represent background conditions.

The elevation of the site is less than 5m AHD. The ASS Risk Map for Wyong indicates that the site is situated in an area with a high probability of ASS being encountered between 1m and 3m of the ground surface. The results of the ASS laboratory testing indicated that ASS is present in the alluvial soils below about 0.8mm depth.

Therefore, the following applies regarding the VENM classification of the soils assessed at the site:

- The silty sandy topsoil (from the surface to approximately 0.1m depth) does not meet the definition of VENM and cannot be re-used on another site and, if removed from site, must be disposed of according to the waste classification provided in this report.
- The alluvial silty sand and clay from approximately 0.1m depth to approximately 0.8m depth is classified as VENM. This material can be re-used on another site that is permitted to accept VENM.
- The silty sand layer and the alluvial clay below 0.8m depth does not meet the definition of VENM given the presence of sulfidic ores. This material cannot be re-used on another site and, if removed from site, must be disposed of according to the waste classification provided in this report following treatment of the ASS.

If Council proposes to remove the VENM from the site for re-use on another site, Coffey recommends the following be carried out:

- The material classified as VENM (0.1-0.8m depth) is excavated separately from the overlying topsoil and underlying alluvial soils.
- An environmental consultant is present during excavation works to assist in the visual classification of soils and to ensure the VENM is appropriately separated from the overlying topsoil and underlying ASS.

8.4. Preliminary assessment on geotechnical suitability of soil as fill

Near surface topsoil is not considered suitable for reuse as controlled fill and should be stockpiled for landscaping purposes. The majority of soils underlying the topsoil was identified as high plasticity clay and will likely be suitable for use as controlled fill for the proposed sports complex development.

We recommend the reactivity to moisture variation of the clay materials be assessed prior to being used for the development. Shrink swell tests and Emersion dispersion tests are recommended for assessing reactivity and dispersivity of the materials. California Bearing Ratio (CBR) tests are recommended for pavement design if the clay materials are planned to be used under pavement.

9. Limitations

The extent of testing associated with this assessment is limited to discrete borehole locations, and variations in ground conditions can occur between and away from such locations. If conditions other than those described in this report are encountered during construction, further advice should be sought without delay. This report should be read in conjunction with the attached sheet entitled *“Important Information about Your Coffey Environmental Report”.*

This report was prepared for Central Coast Council with the objectives of providing a waste classification for the soils proposed to be excavated, providing a VENM assessment of the natural soils proposed to be excavated, assessing the ASS status of the site and the need for an ASSMP, and providing a preliminary assessment on the geotechnical suitability of the soils proposed to be excavated as fill. No warranty, expressed or implied, is made as to the information and professional advice included in this report. Anyone using this document does so at their own risk and should satisfy themselves concerning its applicability and, where necessary, should seek expert advice in relation to the particular situation.

This report does not cover hazardous building materials issues. Information within the report including borehole logs should not be used for geotechnical investigation purposes.

If you have any questions regarding this report, please do not hesitate to contact the undersigned on (02) 4016 2300.

For and on behalf of Coffey

Damien Hendrickx
Senior Environmental Scientist

Attachments:
Table LR1 – Waste Classification Results
Table LR2 – Soil Duplicate Results
Figure 1 – Site Location Plan
Figure 2 – Borehole Location Plan
Borehole Logs
Laboratory Reports
Important Information about your Coffey Environmental Report

Central Coast Council
Table LR1
Waste Classification Results
NTLEN202327-L02
South Tacoma Road, Tuggerah NSW

Method_Type	ChemName	Units	EQL	Field_ID	STBH1	STBH2	STBH3	STBH4
				Sample_Depth	1.4-1.5	0.0-0.1	0.0-0.1	1.0-1.2
				Sampled_Date	27/02/2017	27/02/2017	27/02/2017	27/02/2017
				SampleCode	162600-11	162600-13	162600-16	162600-23
				NSW 2014 General Solid Waste (No Leaching)				
Heavy Metal	Arsenic	mg/kg	4	100	<4	<4	<4	<4
	Cadmium	mg/kg	0.4	20	<0.4	<0.4	<0.4	<0.4
	Chromium	mg/kg	1	100	10	10	13	4
	Copper	mg/kg	1		4	9	10	2
	Lead	mg/kg	1	100	9	13	15	3
	Mercury	mg/kg	0.1	4	<0.1	<0.1	<0.1	<0.1
	Nickel	mg/kg	1	40	<1	3	3	<1
	Zinc	mg/kg	1		2	3	5	<1
Inorganic	Moisture Content (dried @ 103°C)	%	0.1		17	18	21	12
Organic	TRH C6-C10 less BTEX (F1)	mg/kg	25		<25	<25	<25	<25
	TRH >C10-C16 less Naphthalene (F2)	mg/kg	50		<50	<50	<50	<50
	TRH >C10 - C16	mg/kg	50		<50	<50	<50	<50
	TRH C6 - C10	mg/kg	25		<25	<25	<25	<25
	TRH >C16 - C34	mg/kg	100		<100	<100	<100	<100
	TRH >C34 - C40	mg/kg	100		<100	<100	<100	<100
	TRH C6 - C9	mg/kg	25	650	<25	<25	<25	<25
	Naphthalene	mg/kg	1		<1	<1	<1	<1
PAH	Acenaphthene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Acenaphthylene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Anthracene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Benzo(a)anthracene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Benzo(a)pyrene	mg/kg	0.05	0.8	<0.05	<0.05	<0.05	<0.05
	Benzo(a)pyrene TEQ (lower bound) *	MG/KG	0.5		<0.5	<0.5	<0.5	<0.5
	Benzo(a)pyrene TEQ (medium bound) *	MG/KG	0.5		<0.5	<0.5	<0.5	<0.5
	Benzo(a)pyrene TEQ (upper bound) *	MG/KG	0.5		<0.5	<0.5	<0.5	<0.5
	Benzo(g,h,i)perylene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Benzo(b, j+k)fluoranthene	mg/kg	0.2		<0.2	<0.2	<0.2	<0.2
	Chrysene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Dibenz(a,h)anthracene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Fluoranthene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Fluorene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Indeno(1,2,3-c,d)pyrene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Phenanthrene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Pyrene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
	Total PAHs	mg/kg	0.05	200	<0.05	<0.05	<0.05	<0.05
	Naphthalene	mg/kg	0.1		<0.1	<0.1	<0.1	<0.1
TPH	TRH C10 - C14	mg/kg	50		<50	<50	<50	<50
	TRH C15 - C28	mg/kg	100		<100	<100	<100	<100
	TRH C29 - C36	mg/kg	100		<100	<100	<100	<100
	TRH C10 - C36 (Sum of total)	mg/kg	50	10000	<50	<50	<50	<50
Volatile	Benzene	mg/kg	0.2	10	<0.2	<0.2	<0.2	<0.2
	Ethylbenzene	mg/kg	1	600	<1	<1	<1	<1
	Toluene	mg/kg	0.5	288	<0.5	<0.5	<0.5	<0.5
	Xylene (m & p)	mg/kg	2		<2	<2	<2	<2
	Xylene (o)	mg/kg	1		<1	<1	<1	<1
	Xylene Total	mg/kg	1	1000	<1	<1	<1	<1

Notes:

Value — Exceeds general solid waste criteria (no leaching)

Criteria:

NSW EPA (2014) Waste Classification Guidelines - general solid waste and general solid waste with leaching

Table LR2 - Soil Duplicate Results

All results in mg/kg unless indicated

Sample ID	STBH1	STQC1	RPD %
Depth (m)	1.4-1.5		
Date of Sampling	27/02/2017	27/02/2017	
Laboratory	Envirolab	Envirolab	
Metals			
Arsenic	<4	4	NC
Cadmium	<0.4	<0.4	NC
Chromium	10	14	33%
Copper	4	4	0%
Lead	9	8	12%
Mercury	<0.1	<0.1	NC
Nickel	<1	<1	NC
Zinc	2	2	0%
Total Petroleum Hydrocarbons			
C6 - C10 Fraction (F1)	<25	<25	NC
C10 - C16 Fraction (F2)	<50	<50	NC
C16 - C34 Fraction (F3)	<100	<100	NC
C34 - C40 Fraction (F4)	<100	<100	NC
BTEX			
Benzene	<0.2	<0.2	NC
Toluene	<0.5	<0.5	NC
Ethylbenzene	<1	<1	NC
Total Xylene	<1	<1	NC
Polycyclic Aromatic Hydrocarbons			
Benzo(a)pyrene	<0.05	<0.05	NC
Total PAHs	<0.05	<0.05	NC

Notes:

RPD RPD exceeds control limit of 50%

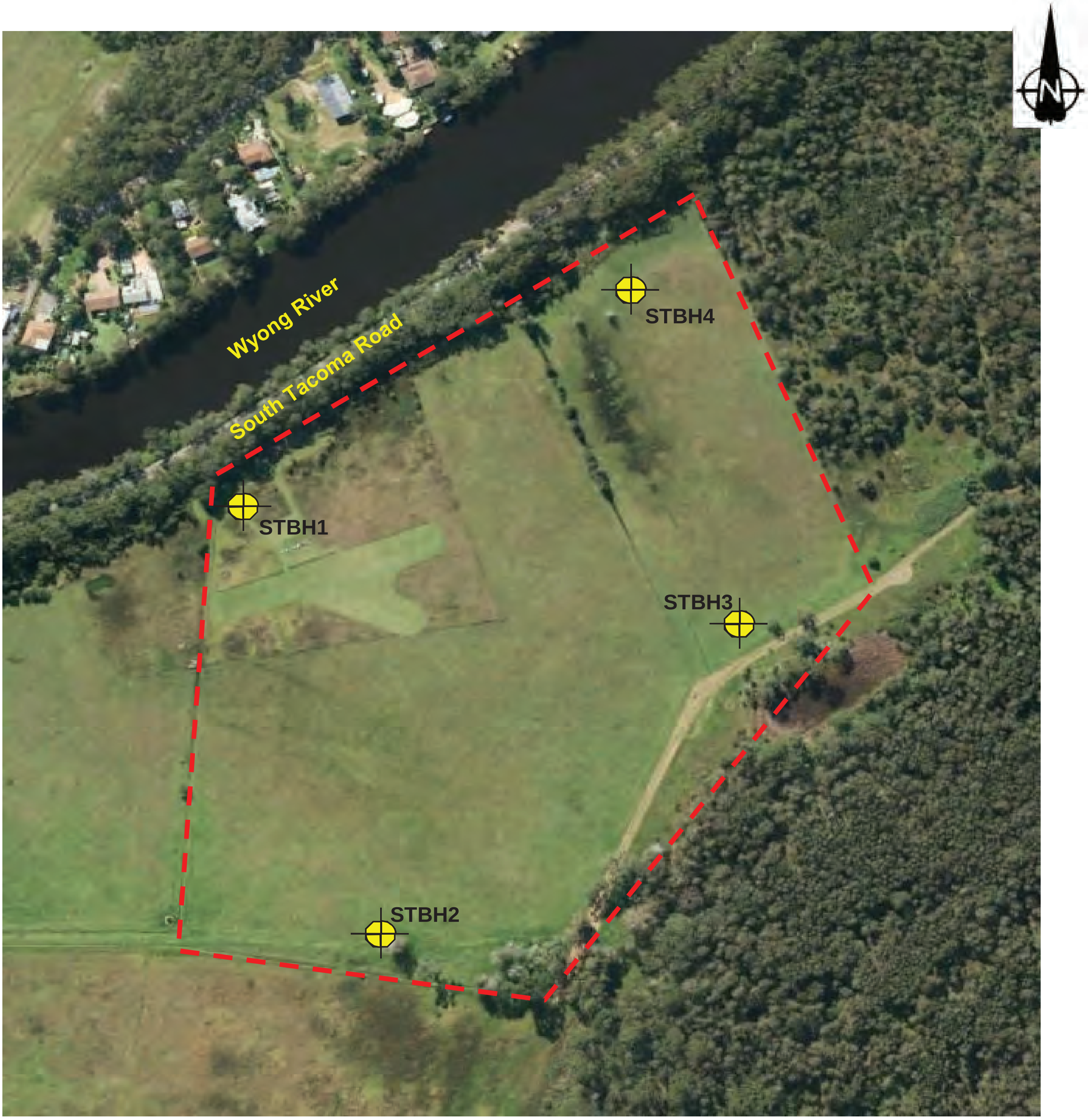
NC RPD not calculated either the primary or duplicate samples (or both) did not produce results

\- Not Analysed

SITE

Source: UBD (2006) Central Coast and Newcastle Street Directory, 2nd Edition, Map 49

drawn	DCH	coffey A TETRA TECH COMPANY	client:	CENTRAL COAST COUNCIL
approved			project:	WASTE CLASSIFICATION, VENM AND ACID SULFATE SOIL ASSESSMENT, SOUTH TACOMA ROAD, TUGGERAH NSW
date	28/02/2017		title:	SITE LOCATION PLAN
scale	NOT TO SCALE		project no:	ENAUWARA04828AA
original size	A4		figure no:	1



Site Boundary

Borehole Location

Source: Google Earth, 2015

drawn	DCH	coffey A TETRA TECH COMPANY	client:	CENTRAL COAST COUNCIL	
approved			project:	WASTE CLASSIFICATION, VENM AND ACID SULFATE SOIL ASSESSMENT, SOUTH TACOMA ROAD, TUGGERAH NSW	
date	28/02/2017				
scale	NOT TO SCALE		title:	BOREHOLE LOCATION PLAN	
original size	A4		project no: ENAUWARA04828AA	figure no:	2

Engineering Log - Excavation

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A TETRA TECH COMPANY

Excavation No.	*STBH1*
Sheet	1 of 1
Office Job No.:	*754-NTLEN202327*
Date started:	*27.2.2017*
Date completed:	*27.2.2017*
Logged by:	*CB*
Checked by:	*DCH*

Client: ***Central Coast Council***

Principal:

Project: ***Proposed Drainage Works***

Test pit location: ***South Tacoma Road, Tuggerah***

equipment type and model: Pit Orientation: Easting: m   R.L. Surface:

excavation dimensions: m long m wide   Northing: m   datum: AHD

excavation information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency/ density index	pocket penetro-meter kPa (100 200 300 400)	structure and additional observations
SS			None Observed	E					**Silty SAND:** fine to medium grained, black.	M			TOPSOIL
				E		0.5		CH	**CLAY:** high plasticity, pale grey / yellow / brown.				ALLUVIUM
								SM	**Silty SAND:** fine to medium grained, pale grey.				
				E		1.0							
								CH	**CLAY:** high plasticity, pale grey / orange / brown.				
				E		1.5							
				E		2.0							
									Test pit STBH1 terminated at 2m				
						2.5							
						3.0							
						3.5							
						4.0							

method

DT	diatube
PT	push tube
SS	soild stem flight auger
HS	hollow stem flight auger
VT	V Bit, T Bit
AH	air hammer
CP	cable percussive
HA	hand auger
NDD	non-destructive digging
RC	rock corer

support
S shoring   N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests

U_{50}	undisturbed sample 50mm diameter
U_{63}	undisturbed sample 63mm diameter
D	disturbed sample
V	vane shear (kPa)
Bs	bulk sample
E	environmental sample
R	refusal

classification symbols and soil description
based on unified classification system

moisture

D	dry
M	moist
W	wet
Wp	plastic limit
W_L	liquid limit

consistency/density index

VS	very soft
S	soft
F	firm
St	stiff
VSt	very stiff
H	hard
Fb	friable
VL	very loose
L	loose
MD	medium dense
D	dense
VD	very dense

TEST PIT_FULL PAGE ENAUWARA0428AA LOGS.GPJ COFFEY.GDT 28.2.17

Form GEO 5.2 Issue 3 Rev.2

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Engineering Log - Excavation

Excavation No. **STBH2**

Sheet 1 of 1

Office Job No.: **754-NTLEN202327**

Client:	*Central Coast Council*	Date started:	*27.2.2017*
Principal:		Date completed:	*27.2.2017*
Project:	*Proposed Drainage Works*	Logged by:	*CB*
Test pit location:	*South Tacoma Road, Tuggerah*	Checked by:	*DCH*

equipment type and model: Pit Orientation: Easting: m R.L. Surface:

excavation dimensions: m long m wide Northing: m datum: AHD

excavation information							material substance						
method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
SS			None Observed	E				SM	**Silty SAND:** fine to medium grained, black.	M			TOPSOIL
				E		0.5		CH	**CLAY:** high plasticity, pale grey / orange / brown.				ALLUVIUM
				E		1.0							
									terminated at 1.2m due to auger refusal. Test pit STBH2 terminated at 1.2m				
						1.5							
						2.0							
						2.5							
						3.0							
						3.5							
						4.0							

method
DT diatube
PT push tube
SS soild stem flight auger
HS hollow stem flight auger
VT V Bit, T Bit
AH air hammer
CP cable percussive
HA hand auger
NDD non-destructive digging
RC rock corer

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Form GEO 5.2 Issue 3 Rev.2

TEST PIT_FULL PAGE ENAUWARA0428AA LOGS.GPJ COFFEY.GDT 28.2.17

Engineering Log - Excavation

coffey
A TETRA TECH COMPANY

Excavation No.	**STBH3**
Sheet	1 of 1
Office Job No.:	**754-NTLEN202327**
Client:	**Central Coast Council**
Date started:	**27.2.2017**
Principal:	
Date completed:	**27.2.2017**
Project:	**Proposed Drainage Works**
Logged by:	**CB**
Test pit location:	**South Tacoma Road, Tuggerah**
Checked by:	**DCH**

equipment type and model: Pit Orientation: Easting: m R.L. Surface:

excavation dimensions: m long m wide Northing: m datum: AHD

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
SS			None Observed	E				SM	**Silty SAND:** fine to medium grained, black.	M			TOPSOIL
				E		0.5		CH	**CLAY:** high plasticity, pale grey / yellow / brown.				ALLUVIUM
				E		1.0							
				E		1.5							
				E		2.0							
						2.5			Test pit STBH3 terminated at 2m				
						3.0							
						3.5							
						4.0							

method
DT diatube
PT push tube
SS soild stem flight auger
HS hollow stem flight auger
VT V Bit, T Bit
AH air hammer
CP cable percussive
HA hand auger
NDD non-destructive digging
RC rock corer

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
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VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
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TEST PIT_FULL PAGE ENAUWARA0428AA LOGS.GPJ COFFEY.GDT 28.2.17

Form GEO 5.2 Issue 3 Rev.2

coffey
A TETRA TECH COMPANY

Engineering Log - Excavation

Excavation No.	STBH4
Sheet	1 of 1
Office Job No.:	754-NTLEN202327

Client:	*Central Coast Council*	Date started:	*27.2.2017*
Principal:		Date completed:	*27.2.2017*
Project:	*Proposed Drainage Works*	Logged by:	*CB*
Test pit location:	*South Tacoma Road, Tuggerah*	Checked by:	*DCH*

equipment type and model: Pit Orientation: Easting: m R.L. Surface:

excavation dimensions: m long m wide Northing: m datum: AHD

excavation information | **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material (soil type: plasticity or particle characteristics, colour, secondary and minor components.)	moisture condition	consistency/density index	pocket penetro-meter kPa 100 200 300 400	structure and additional observations
SS			None Observed	E				SM	**Silty SAND:** fine to medium grained, black.	M			TOPSOIL
				E		0.5		CH	**CLAY:** high plasticity, pale grey / brown / red / orange.				ALLUVIUM
				E		1.0		SM	**Silty SAND:** fine to medium grained, black.				
				E		1.5		CH	**CLAY:** hugh plasticity, pale grey.				
						2.0			Test pit STBH4 terminated at 2m				
						2.5							
						3.0							
						3.5							
						4.0							

method
DT diatube
PT push tube
SS soild stem flight auger
HS hollow stem flight auger
VT V Bit, T Bit
AH air hammer
CP cable percussive
HA hand auger
NDD non-destructive digging
RC rock corer

support
S shoring N nil

penetration
1 2 3 4
no resistance ranging to refusal

water
water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
V vane shear (kPa)
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

TEST PIT_FULL PAGE ENAUWARA0428AA LOGS.GPJ COFFEY.GDT 28.2.17

Form GEO 5.2 Issue 3 Rev.2

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Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS **162600**

Client:
Coffey Environment (Warabrook)
Lot 101, 19 Warabrook Blvd
Warabrook
NSW 2304

Attention: Damien Hendrickx

Sample log in details:

Your Reference:	**ENAUWARA04828AA**
No. of samples:	27 soils
Date samples received / completed instructions received	28/02/17 / 28/02/17

Analysis Details:
Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	1/03/17 / 1/03/17
Date of Preliminary Report:	Not Issued

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Accredited for compliance with ISO/IEC 17025 - Testing **Tests not covered by NATA are denoted with *.**

Results Approved By:

David Springer
General Manager

Envirolab Reference: 162600
Revision No: R 00

ACCREDITED FOR TECHNICAL COMPETENCE

vTRH(C6-C10)/BTEXN in Soil						
Our Reference:	UNITS	162600-1	162600-6	162600-11	162600-13	162600-16
Your Reference	-------------	ADBH1	ADBH1	STBH1	STBH2	STBH3
Depth	------------	0.1	2.5	1.5	0.1	0.1
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
TRHC$_6$ - C$_9$	mg/kg	<25	<25	<25	<25	<25
TRHC$_6$ - C$_{10}$	mg/kg	<25	<25	<25	<25	<25
vTPHC$_6$ - C$_{10}$ less BTEX (F1)	mg/kg	<25	<25	<25	<25	<25
Benzene	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	mg/kg	<1	<1	<1	<1	<1
m+p-xylene	mg/kg	<2	<2	<2	<2	<2
o-Xylene	mg/kg	<1	<1	<1	<1	<1
Total +ve Xylenes	mg/kg	<1	<1	<1	<1	<1
naphthalene	mg/kg	<1	<1	<1	<1	<1
Surrogate aaa-Trifluorotoluene	%	90	88	92	86	79

vTRH(C6-C10)/BTEXN in Soil				
Our Reference:	UNITS	162600-23	162600-26	162600-27
Your Reference	-------------	STBH4	ARCQC1	STQC1
Depth	------------	1.0	-	-
Date Sampled		27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017
TRHC$_6$ - C$_9$	mg/kg	<25	<25	<25
TRHC$_6$ - C$_{10}$	mg/kg	<25	<25	<25
vTPHC$_6$ - C$_{10}$ less BTEX (F1)	mg/kg	<25	<25	<25
Benzene	mg/kg	<0.2	<0.2	<0.2
Toluene	mg/kg	<0.5	<0.5	<0.5
Ethylbenzene	mg/kg	<1	<1	<1
m+p-xylene	mg/kg	<2	<2	<2
o-Xylene	mg/kg	<1	<1	<1
Total +ve Xylenes	mg/kg	<1	<1	<1
naphthalene	mg/kg	<1	<1	<1
Surrogate aaa-Trifluorotoluene	%	86	87	91

svTRH (C10-C40) in Soil						
Our Reference:	UNITS	162600-1	162600-6	162600-11	162600-13	162600-16
Your Reference	-------------	ADBH1	ADBH1	STBH1	STBH2	STBH3
Depth	------------	0.1	2.5	1.5	0.1	0.1
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	28/02/2017	28/02/2017	28/02/2017
TRHC $_{10}$ - C $_{14}$	mg/kg	<50	<50	<50	<50	<50
TRHC $_{15}$ - C $_{28}$	mg/kg	<100	<100	<100	<100	<100
TRHC $_{29}$ - C $_{36}$	mg/kg	<100	<100	<100	<100	<100
TRH>C $_{10}$-C $_{16}$	mg/kg	<50	<50	<50	<50	<50
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	mg/kg	<50	<50	<50	<50	<50
TRH>C $_{16}$-C $_{34}$	mg/kg	<100	<100	<100	<100	<100
TRH>C $_{34}$-C $_{40}$	mg/kg	<100	<100	<100	<100	<100
Total +ve TRH (>C10-C40)	mg/kg	<50	<50	<50	<50	<50
Surrogate o-Terphenyl	%	90	86	92	94	101

svTRH (C10-C40) in Soil				
Our Reference:	UNITS	162600-23	162600-26	162600-27
Your Reference	-------------	STBH4	ARCQC1	STQC1
Depth	------------	1.0	-	-
Date Sampled		27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017
TRHC $_{10}$ - C $_{14}$	mg/kg	<50	<50	<50
TRHC $_{15}$ - C $_{28}$	mg/kg	<100	<100	<100
TRHC $_{29}$ - C $_{36}$	mg/kg	<100	<100	<100
TRH>C $_{10}$-C $_{16}$	mg/kg	<50	<50	<50
TRH>C $_{10}$ - C $_{16}$ less Naphthalene (F2)	mg/kg	<50	<50	<50
TRH>C $_{16}$-C $_{34}$	mg/kg	<100	<100	<100
TRH>C $_{34}$-C $_{40}$	mg/kg	<100	<100	<100
Total +ve TRH (>C10-C40)	mg/kg	<50	<50	<50
Surrogate o-Terphenyl	%	90	97	92

PAHs in Soil						
Our Reference:	UNITS	162600-1	162600-6	162600-11	162600-13	162600-16
Your Reference	-------------	ADBH1	ADBH1	STBH1	STBH2	STBH3
Depth	------------	0.1	2.5	1.5	0.1	0.1
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Naphthalene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Fluorene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Phenanthrene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Fluoranthene	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1
Pyrene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Chrysene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(b,j+k)fluoranthene	mg/kg	<0.2	<0.2	<0.2	<0.2	<0.2
Benzo(a)pyrene	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05
Indeno(1,2,3-c,d)pyrene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Dibenzo(a,h)anthracene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(g,h,i)perylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Benzo(a)pyrene TEQ calc (zero)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(half)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(PQL)	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5
Total +ve PAH's	mg/kg	0.1	<0.05	<0.05	<0.05	<0.05
Surrogate p-Terphenyl-d14	%	95	96	99	103	115

PAHs in Soil Our Reference: Your Reference Depth Date Sampled Type of sample	UNITS ------------- - -------------	162600-23 STBH4 1.0 27/02/2017 Soil	162600-26 ARCQC1 - 27/02/2017 Soil	162600-27 STQC1 - 27/02/2017 Soil
Date extracted	-	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	28/02/2017	28/02/2017	28/02/2017
Naphthalene	mg/kg	<0.1	<0.1	<0.1
Acenaphthylene	mg/kg	<0.1	<0.1	<0.1
Acenaphthene	mg/kg	<0.1	<0.1	<0.1
Fluorene	mg/kg	<0.1	<0.1	<0.1
Phenanthrene	mg/kg	<0.1	<0.1	<0.1
Anthracene	mg/kg	<0.1	<0.1	<0.1
Fluoranthene	mg/kg	<0.1	0.1	<0.1
Pyrene	mg/kg	<0.1	0.1	<0.1
Benzo(a)anthracene	mg/kg	<0.1	<0.1	<0.1
Chrysene	mg/kg	<0.1	<0.1	<0.1
Benzo(b,j+k)fluoranthene	mg/kg	<0.2	<0.2	<0.2
Benzo(a)pyrene	mg/kg	<0.05	<0.05	<0.05
Indeno(1,2,3-c,d)pyrene	mg/kg	<0.1	<0.1	<0.1
Dibenzo(a,h)anthracene	mg/kg	<0.1	<0.1	<0.1
Benzo(g,h,i)perylene	mg/kg	<0.1	<0.1	<0.1
Benzo(a)pyrene TEQ calc (zero)	mg/kg	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(half)	mg/kg	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ calc(PQL)	mg/kg	<0.5	<0.5	<0.5
Total +ve PAH's	mg/kg	<0.05	0.3	<0.05
Surrogate p-Terphenyl-d14	%	94	98	98

Acid Extractable metals in soil						
Our Reference:	UNITS	162600-1	162600-6	162600-11	162600-13	162600-16
Your Reference	-------------	ADBH1	ADBH1	STBH1	STBH2	STBH3
Depth	------------	0.1	2.5	1.5	0.1	0.1
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Arsenic	mg/kg	<4	<4	<4	<4	<4
Cadmium	mg/kg	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium	mg/kg	12	7	10	10	13
Copper	mg/kg	21	2	4	9	10
Lead	mg/kg	21	5	9	13	15
Mercury	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Nickel	mg/kg	7	<1	<1	3	3
Zinc	mg/kg	71	2	2	3	5

Acid Extractable metals in soil				
Our Reference:	UNITS	162600-23	162600-26	162600-27
Your Reference	-------------	STBH4	ARCQC1	STQC1
Depth	------------	1.0	-	-
Date Sampled		27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil
Date prepared	-	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	28/02/2017	28/02/2017	28/02/2017
Arsenic	mg/kg	<4	<4	4
Cadmium	mg/kg	<0.4	<0.4	<0.4
Chromium	mg/kg	4	11	14
Copper	mg/kg	2	16	4
Lead	mg/kg	3	22	8
Mercury	mg/kg	<0.1	<0.1	<0.1
Nickel	mg/kg	<1	6	<1
Zinc	mg/kg	<1	71	2

Moisture						
Our Reference:	UNITS	162600-1	162600-6	162600-11	162600-13	162600-16
Your Reference	-------------	ADBH1	ADBH1	STBH1	STBH2	STBH3
Depth	------------	0.1	2.5	1.5	0.1	0.1
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	28/02/2017	28/02/2017	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
Moisture	%	19	15	17	18	21

Moisture				
Our Reference:	UNITS	162600-23	162600-26	162600-27
Your Reference	-------------	STBH4	ARCQC1	STQC1
Depth	------------	1.0	-	-
Date Sampled		27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil
Date prepared	-	28/02/2017	28/02/2017	28/02/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017
Moisture	%	12	19	17

sPOCAS field test						
Our Reference:	UNITS	162600-5	162600-6	162600-7	162600-10	162600-12
Your Reference	--------------	ADBH1	ADBH1	ADBH1	STBH1	STBH1
Depth	------------	2.0	2.5	3.0	1.0	2.0
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
pH_F (field pH test)*	pH Units	4.8	4.6	5.0	5.5	5.0
pH_{FOX} (field peroxide test)*	pH Units	2.9	3.4	3.3	3.6	3.6
Reaction Rate*	-	Slight	Slight	Moderate	Moderate	Slight

sPOCAS field test						
Our Reference:	UNITS	162600-14	162600-15	162600-18	162600-20	162600-22
Your Reference	--------------	STBH2	STBH2	STBH3	STBH3	STBH4
Depth	------------	0.5	1.0	1.0	2.0	0.5
Date Sampled		27/02/2017	27/02/2017	27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
Date analysed	-	01/03/2017	01/03/2017	01/03/2017	01/03/2017	01/03/2017
pH_F (field pH test)*	pH Units	5.7	5.4	5.2	5.3	4.8
pH_{FOX} (field peroxide test)*	pH Units	3.5	4.2	3.9	4.3	3.2
Reaction Rate*	-	Moderate	Slight	Moderate	Slight	Slight

sPOCAS field test		
Our Reference:	UNITS	162600-24
Your Reference	--------------	STBH4
Depth	------------	1.5
Date Sampled		27/02/2017
Type of sample		Soil
Date prepared	-	01/03/2017
Date analysed	-	01/03/2017
pH_F (field pH test)*	pH Units	4.9
pH_{FOX} (field peroxide test)*	pH Units	2.9
Reaction Rate*	-	Slight

Method ID	Methodology Summary
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater.
Org-016	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS. F1 = (C6-C10)-BTEX as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater. Note, the Total +ve Xylene PQL is reflective of the lowest individual PQL and is therefore "Total +ve Xylenes" is simply a sum of the positive individual Xylenes.
Org-014	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis.
Org-003	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-FID. F2 = (>C10-C16)-Naphthalene as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater (HSLs Tables 1A (3, 4)). Note Naphthalene is determined from the VOC analysis. Note, the Total +ve TRH PQL is reflective of the lowest individual PQL and is therefore "Total +ve TRH" is simply a sum of the positive individual TRH fractions (>C10-C40).
Org-012	Soil samples are extracted with Dichloromethane/Acetone and waters with Dichloromethane and analysed by GC-MS. Benzo(a)pyrene TEQ as per NEPM B1 Guideline on Investigation Levels for Soil and Groundwater - 2013. For soil results:- 1. 'TEQ PQL' values are assuming all contributing PAHs reported as <PQL are actually at the PQL. This is the most conservative approach and can give false positive TEQs given that PAHs that contribute to the TEQ calculation may not be present. 2. 'TEQ zero' values are assuming all contributing PAHs reported as <PQL are zero. This is the least conservative approach and is more susceptible to false negative TEQs when PAHs that contribute to the TEQ calculation are present but below PQL. 3. 'TEQ half PQL' values are assuming all contributing PAHs reported as <PQL are half the stipulated PQL. Hence a mid-point between the most and least conservative approaches above. Note, the Total +ve PAHs PQL is reflective of the lowest individual PQL and is therefore" Total +ve PAHs" is simply a sum of the positive individual PAHs.
Metals-020	Determination of various metals by ICP-AES.
Metals-021	Determination of Mercury by Cold Vapour AAS.
Inorg-008	Moisture content determined by heating at 105+/-5 °C for a minimum of 12 hours.
Inorg-063	pH- measured using pH meter and electrode. Soil is oxidised with Hydrogen Peroxide or extracted with water. Based on section H, Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004. To ensure accurate results these tests are recommended to be done in the field as pH may change with time thus these results may not be representative of true field conditions.

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Date analysed	-			01/03/2017	162600-1	01/03/2017 || 01/03/2017	LCS-8	01/03/2017
TRHC_6 - C_9	mg/kg	25	Org-016	<25	162600-1	<25 || <25	LCS-8	99%
TRHC_6 - C_{10}	mg/kg	25	Org-016	<25	162600-1	<25 || <25	LCS-8	99%
Benzene	mg/kg	0.2	Org-016	<0.2	162600-1	<0.2 || <0.2	LCS-8	82%
Toluene	mg/kg	0.5	Org-016	<0.5	162600-1	<0.5 || <0.5	LCS-8	97%
Ethylbenzene	mg/kg	1	Org-016	<1	162600-1	<1 || <1	LCS-8	102%
m+p-xylene	mg/kg	2	Org-016	<2	162600-1	<2 || <2	LCS-8	106%
o-Xylene	mg/kg	1	Org-016	<1	162600-1	<1 || <1	LCS-8	107%
naphthalene	mg/kg	1	Org-014	<1	162600-1	<1 || <1	[NR]	[NR]
Surrogate aaa-Trifluorotoluene	%		Org-016	97	162600-1	90 || 88 || RPD: 2	LCS-8	95%

QUALITY CONTROL svTRH (C10-C40) in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Date analysed	-			28/02/2017	162600-1	01/03/2017 || 01/03/2017	LCS-8	28/02/2017
TRHC_{10} - C_{14}	mg/kg	50	Org-003	<50	162600-1	<50 || <50	LCS-8	111%
TRHC_{15} - C_{28}	mg/kg	100	Org-003	<100	162600-1	<100 || <100	LCS-8	115%
TRHC_{29} - C_{36}	mg/kg	100	Org-003	<100	162600-1	<100 || <100	LCS-8	106%
TRH>C_{10}-C_{16}	mg/kg	50	Org-003	<50	162600-1	<50 || <50	LCS-8	111%
TRH>C_{16}-C_{34}	mg/kg	100	Org-003	<100	162600-1	<100 || <100	LCS-8	115%
TRH>C_{34}-C_{40}	mg/kg	100	Org-003	<100	162600-1	<100 || <100	LCS-8	106%
Surrogate o-Terphenyl	%		Org-003	90	162600-1	90 || 92 || RPD: 2	LCS-8	97%

QUALITY CONTROL PAHs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date extracted	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Date analysed	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Naphthalene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	LCS-8	94%
Acenaphthylene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Acenaphthene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Fluorene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	LCS-8	104%
Phenanthrene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	LCS-8	116%
Anthracene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Fluoranthene	mg/kg	0.1	Org-012	<0.1	162600-1	0.1 || 0.1 || RPD: 0	LCS-8	104%
Pyrene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || 0.1	LCS-8	105%
Benzo(a)anthracene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Chrysene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	LCS-8	99%
Benzo(b,j+k) fluoranthene	mg/kg	0.2	Org-012	<0.2	162600-1	<0.2 || <0.2	[NR]	[NR]

QUALITY CONTROL PAHs in Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Benzo(a)pyrene	mg/kg	0.05	Org-012	<0.05	162600-1	<0.05 || <0.05	LCS-8	92%
Indeno(1,2,3-c,d)pyrene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Dibenzo(a,h)anthracene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Benzo(g,h,i)perylene	mg/kg	0.1	Org-012	<0.1	162600-1	<0.1 || <0.1	[NR]	[NR]
Surrogate p-Terphenyl-d14	%		Org-012	101	162600-1	95 || 95 || RPD: 0	LCS-8	117%

QUALITY CONTROL Acid Extractable metals in soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Date analysed	-			28/02/2017	162600-1	28/02/2017 || 28/02/2017	LCS-8	28/02/2017
Arsenic	mg/kg	4	Metals-020	<4	162600-1	<4 || <4	LCS-8	108%
Cadmium	mg/kg	0.4	Metals-020	<0.4	162600-1	<0.4 || <0.4	LCS-8	97%
Chromium	mg/kg	1	Metals-020	<1	162600-1	12 || 11 || RPD: 9	LCS-8	107%
Copper	mg/kg	1	Metals-020	<1	162600-1	21 || 18 || RPD: 15	LCS-8	106%
Lead	mg/kg	1	Metals-020	<1	162600-1	21 || 20 || RPD: 5	LCS-8	98%
Mercury	mg/kg	0.1	Metals-021	<0.1	162600-1	<0.1 || <0.1	LCS-8	94%
Nickel	mg/kg	1	Metals-020	<1	162600-1	7 || 6 || RPD: 15	LCS-8	96%
Zinc	mg/kg	1	Metals-020	<1	162600-1	71 || 65 || RPD: 9	LCS-8	98%

QUALITY CONTROL sPOCAS field test	UNITS	PQL	METHOD	Blank
Date prepared	-			01/03/2017
Date analysed	-			01/03/2017
pH_F (field pH test)*	pH Units		Inorg-063	[NT]
pH_{FOX} (field peroxide test)*	pH Units		Inorg-063	[NT]

QUALITY CONTROL vTRH(C6-C10)/BTEXN in Soil	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date extracted	-	[NT]	[NT]	162600-6	28/02/2017
Date analysed	-	[NT]	[NT]	162600-6	01/03/2017
$TRHC_6 - C_9$	mg/kg	[NT]	[NT]	162600-6	89%
$TRHC_6 - C_{10}$	mg/kg	[NT]	[NT]	162600-6	89%
Benzene	mg/kg	[NT]	[NT]	162600-6	73%
Toluene	mg/kg	[NT]	[NT]	162600-6	87%
Ethylbenzene	mg/kg	[NT]	[NT]	162600-6	91%
m+p-xylene	mg/kg	[NT]	[NT]	162600-6	96%
o-Xylene	mg/kg	[NT]	[NT]	162600-6	97%
naphthalene	mg/kg	[NT]	[NT]	[NR]	[NR]
Surrogate aaa-Trifluorotoluene	%	[NT]	[NT]	162600-6	85%

QUALITY CONTROL svTRH (C10-C40) in Soil	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date extracted	-	[NT]	[NT]	162600-6	28/02/2017
Date analysed	-	[NT]	[NT]	162600-6	01/03/2017
TRHC $_{10}$ - C $_{14}$	mg/kg	[NT]	[NT]	162600-6	101%
TRHC $_{15}$ - C $_{28}$	mg/kg	[NT]	[NT]	162600-6	109%
TRHC $_{29}$ - C $_{36}$	mg/kg	[NT]	[NT]	162600-6	98%
TRH>C $_{10}$-C $_{16}$	mg/kg	[NT]	[NT]	162600-6	101%
TRH>C $_{16}$-C $_{34}$	mg/kg	[NT]	[NT]	162600-6	109%
TRH>C $_{34}$-C $_{40}$	mg/kg	[NT]	[NT]	162600-6	98%
Surrogate o-Terphenyl	%	[NT]	[NT]	162600-6	86%

QUALITY CONTROL PAHs in Soil	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date extracted	-	[NT]	[NT]	162600-6	28/02/2017
Date analysed	-	[NT]	[NT]	162600-6	28/02/2017
Naphthalene	mg/kg	[NT]	[NT]	162600-6	87%
Acenaphthylene	mg/kg	[NT]	[NT]	[NR]	[NR]
Acenaphthene	mg/kg	[NT]	[NT]	[NR]	[NR]
Fluorene	mg/kg	[NT]	[NT]	162600-6	102%
Phenanthrene	mg/kg	[NT]	[NT]	162600-6	94%
Anthracene	mg/kg	[NT]	[NT]	[NR]	[NR]
Fluoranthene	mg/kg	[NT]	[NT]	162600-6	90%
Pyrene	mg/kg	[NT]	[NT]	162600-6	94%
Benzo(a)anthracene	mg/kg	[NT]	[NT]	[NR]	[NR]
Chrysene	mg/kg	[NT]	[NT]	162600-6	85%
Benzo(b,j+k)fluoranthene	mg/kg	[NT]	[NT]	[NR]	[NR]
Benzo(a)pyrene	mg/kg	[NT]	[NT]	162600-6	88%
Indeno(1,2,3-c,d)pyrene	mg/kg	[NT]	[NT]	[NR]	[NR]
Dibenzo(a,h)anthracene	mg/kg	[NT]	[NT]	[NR]	[NR]
Benzo(g,h,i)perylene	mg/kg	[NT]	[NT]	[NR]	[NR]
Surrogate *p*-Terphenyl-d14	%	[NT]	[NT]	162600-6	103%

QUALITY CONTROL Acid Extractable metals in soil	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date prepared	-	[NT]	[NT]	162600-6	28/02/2017
Date analysed	-	[NT]	[NT]	162600-6	28/02/2017
Arsenic	mg/kg	[NT]	[NT]	162600-6	94%
Cadmium	mg/kg	[NT]	[NT]	162600-6	101%
Chromium	mg/kg	[NT]	[NT]	162600-6	103%
Copper	mg/kg	[NT]	[NT]	162600-6	103%
Lead	mg/kg	[NT]	[NT]	162600-6	99%
Mercury	mg/kg	[NT]	[NT]	162600-6	97%
Nickel	mg/kg	[NT]	[NT]	162600-6	96%
Zinc	mg/kg	[NT]	[NT]	162600-6	97%

QUALITY CONTROL sPOCAS field test	UNITS	Dup. Sm#	Duplicate Base + Duplicate + %RPD	Spike Sm#	Spike % Recovery
Date prepared	-	[NT]	[NT]	LCS-1	01/03/2017
Date analysed	-	[NT]	[NT]	LCS-1	01/03/2017
pH_F (field pH test)*	pH Units	[NT]	[NT]	LCS-1	100%
pH_{FOX} (field peroxide test)*	pH Units	[NT]	[NT]	LCS-1	100%

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

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Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS **162600-A**

Client:

Coffey Environment (Warabrook)
Lot 101, 19 Warabrook Blvd
Warabrook
NSW 2304

Attention: Damien Hendrickx

Sample log in details:

Your Reference:	**ENAUWARA04828AA**	
No. of samples:	Additional Testing on 3 Soils	
Date samples received / completed instructions received	28/02/17 /	02/03/17

Analysis Details:

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	7/03/17 /	7/03/17
Date of Preliminary Report:	Not Issued	

NATA accreditation number 2901. This document shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing **Tests not covered by NATA are denoted with *.**

Results Approved By:

David Springer
General Manager

Envirolab Reference: 162600-A
Revision No: R 00

ACCREDITED FOR TECHNICAL COMPETENCE

F34

Chromium Suite				
Our Reference:	UNITS	162600-A-5	162600-A-14	162600-A-24
Your Reference	-------------	ADBH1	STBH2	STBH4
Depth	------------	2.0	0.5	1.5
Date Sampled		27/02/2017	27/02/2017	27/02/2017
Type of sample		Soil	Soil	Soil
Date prepared	-	07/03/2017	07/03/2017	07/03/2017
Date analysed	-	07/03/2017	07/03/2017	07/03/2017
pH_{kcl}	pH units	3.7	4.4	3.6
s-TAA pH 6.5	%w/w S	0.1	0.05	0.1
TAA pH 6.5	moles H^+/t	61	31	61
Chromium Reducible Sulfur	%w/w	<0.005	0.005	<0.005
a-Chromium Reducible Sulfur	moles H^+/t	<3	3	<3
S_{HCl}	%w/w S	0.008	0.006	0.010
S_{KCl}	%w/w S	<0.005	<0.005	0.009
S_{NAS}	%w/w S	0.005	<0.005	<0.005
ANC_{BT}	% $CaCO_3$	<0.05	<0.05	<0.05
s-ANC_{BT}	%w/w S	<0.05	<0.05	<0.05
s-Net Acidity	%w/w S	0.10	0.06	0.10
a-Net Acidity	moles H^+/t	65	36	63
Liming rate	kg $CaCO_3$/t	4.9	2.7	4.7
a-Net Acidity without ANCE	moles H^+/t	65	36	63
Liming rate without ANCE	kg $CaCO_3$/t	4.9	2.7	4.7

Method ID	Methodology Summary
Inorg-068	Chromium Reducible Sulfur - Hydrogen Sulfide is quantified by iodometric titration after distillation to determine potential acidity. Based on Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 - June 2004.

QUALITY CONTROL Chromium Suite	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			07/03/2017	[NT]	[NT]	LCS-1	07/03/2017
Date analysed	-			07/03/2017	[NT]	[NT]	LCS-1	07/03/2017
pH $_{kcl}$	pH units		Inorg-068	[NT]	[NT]	[NT]	LCS-1	96%
s-TAA pH 6.5	%w/w S	0.01	Inorg-068	<0.01	[NT]	[NT]	[NR]	[NR]
TAA pH 6.5	moles H^+/t	5	Inorg-068	<5	[NT]	[NT]	LCS-1	130%
Chromium Reducible Sulfur	%w/w	0.005	Inorg-068	<0.005	[NT]	[NT]	LCS-1	95%
a-Chromium Reducible Sulfur	moles H^+/t	3	Inorg-068	<3	[NT]	[NT]	[NR]	[NR]
S_{HCl}	%w/w S	0.005	Inorg-068	<0.005	[NT]	[NT]	[NR]	[NR]
S_{KCl}	%w/w S	0.005	Inorg-068	<0.005	[NT]	[NT]	[NR]	[NR]
S_{NAS}	%w/w S	0.005	Inorg-068	<0.005	[NT]	[NT]	[NR]	[NR]
ANC_{BT}	% $CaCO_3$	0.05	Inorg-068	<0.05	[NT]	[NT]	[NR]	[NR]
s-ANC_{BT}	%w/w S	0.05	Inorg-068	<0.05	[NT]	[NT]	[NR]	[NR]
s-Net Acidity	%w/w S	0.01	Inorg-068	<0.01	[NT]	[NT]	[NR]	[NR]
a-Net Acidity	moles H^+/t	10	Inorg-068	<10	[NT]	[NT]	[NR]	[NR]
Liming rate	kg $CaCO_3$/t	0.75	Inorg-068	<0.75	[NT]	[NT]	[NR]	[NR]
a-Net Acidity without ANCE	moles H^+/t	10	Inorg-068	<10	[NT]	[NT]	[NR]	[NR]
Liming rate without ANCE	kg $CaCO_3$/t	0.75	Inorg-068	<0.75	[NT]	[NT]	[NR]	[NR]

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

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Important information about your **Coffey** Environmental Report

Introduction

This report has been prepared by Coffey for you, as Coffey's client, in accordance with our agreed purpose, scope, schedule and budget.

The report has been prepared using accepted procedures and practices of the consulting profession at the time it was prepared, and the opinions, recommendations and conclusions set out in the report are made in accordance with generally accepted principles and practices of that profession.

The report is based on information gained from environmental conditions (including assessment of some or all of soil, groundwater, vapour and surface water) and supplemented by reported data of the local area and professional experience. Assessment has been scoped with consideration to industry standards, regulations, guidelines and your specific requirements, including budget and timing. The characterisation of site conditions is an interpretation of information collected during assessment, in accordance with industry practice.

This interpretation is not a complete description of all material on or in the vicinity of the site, due to the inherent variation in spatial and temporal patterns of contaminant presence and impact in the natural environment. Coffey may have also relied on data and other information provided by you and other qualified individuals in preparing this report. Coffey has not verified the accuracy or completeness of such data or information except as otherwise stated in the report. For these reasons the report must be regarded as interpretative, in accordance with industry standards and practice, rather than being a definitive record.

Your report has been written for a specific purpose

Your report has been developed for a specific purpose as agreed by us and applies only to the site or area investigated. Unless otherwise stated in the report, this report cannot be applied to an adjacent site or area, nor can it be used when the nature of the specific purpose changes from that which we agreed.

For each purpose, a tailored approach to the assessment of potential soil and groundwater contamination is required. In most cases, a key objective is to identify, and if possible quantify, risks that both recognised and potential contamination pose in the context of the agreed purpose. Such risks may be financial (for example, clean up costs or constraints on site use) and/or physical (for example, potential health risks to users of the site or the general public).

Limitations of the Report

The work was conducted, and the report has been prepared, in response to an agreed purpose and scope, within time and budgetary constraints, and in reliance on certain data and information made available to Coffey.

The analyses, evaluations, opinions and conclusions presented in this report are based on that purpose and scope, requirements, data or information, and they could change if such requirements or data are inaccurate or incomplete.

This report is valid as of the date of preparation. The condition of the site (including subsurface conditions) and extent or nature of contamination or other environmental hazards can change over time, as a result of either natural processes or human influence. Coffey should be kept appraised of any such events and should be consulted for further investigations if any changes are noted, particularly during construction activities where excavations often reveal subsurface conditions.

In addition, advancements in professional practice regarding contaminated land and changes in applicable statues and/or guidelines may affect the validity of this report. Consequently, the currency of conclusions and recommendations in this report should be verified if you propose to use this report more than 6 months after its date of issue.

The report does not include the evaluation or assessment of potential geotechnical engineering constraints of the site.

Interpretation of factual data

Environmental site assessments identify actual conditions only at those points where samples are taken and on the date collected. Data derived from indirect field measurements, and sometimes other reports on the site, are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact with respect to the report purpose and recommended actions.

Variations in soil and groundwater conditions may occur between test or sample locations and actual conditions may differ from those inferred to exist. No environmental assessment program, no matter how comprehensive, can reveal all subsurface details and anomalies. Similarly, no professional, no matter how well qualified, can reveal what is hidden by earth, rock or changed through time.

The actual interface between different materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

For this reason, parties involved with land acquisition, management and/or redevelopment should retain the services of a suitably qualified and experienced environmental consultant through the development and use of the site to identify variances, conduct additional tests if required, and recommend solutions to unexpected conditions or other unrecognised features encountered on site. Coffey would be pleased to assist with any investigation or advice in such circumstances.

Recommendations in this report

This report assumes, in accordance with industry practice, that the site conditions recognised through discrete sampling are representative of actual conditions throughout the investigation area. Recommendations are based on the resulting interpretation.

Should further data be obtained that differs from the data on which the report recommendations are based (such as through excavation or other additional assessment), then the recommendations would need to be reviewed and may need to be revised.

Report for benefit of client

Unless otherwise agreed between us, the report has been prepared for your benefit and no other party. Other parties should not rely upon the report or the accuracy or completeness of any recommendation and should make their own enquiries and obtain independent advice in relation to such matters.

Coffey assumes no responsibility and will not be liable to any other person or organisation for, or in relation to, any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report.

To avoid misuse of the information presented in your report, we recommend that Coffey be consulted before the report is provided to another party who may not be familiar with the background and the purpose of the report. In particular, an environmental disclosure report for a property vendor may not be suitable for satisfying the needs of that property's purchaser. This report should not be applied for any purpose other than that stated in the report.

Interpretation by other professionals

Costly problems can occur when other professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, a suitably qualified and experienced environmental consultant should be retained to explain the implications of the report to other professionals referring to the report and then review plans and specifications produced to see how other professionals have incorporated the report findings.

Given Coffey prepared the report and has familiarity with the site, Coffey is well placed to provide such assistance. If another party is engaged to interpret the recommendations of the report, there is a risk that the contents of the report may be misinterpreted and Coffey disowns any responsibility for such misinterpretation.

Data should not be separated from the report

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way. Logs, figures, laboratory data, drawings, etc. are customarily included in our reports and are developed by scientists or engineers based on their interpretation of field logs, field testing and laboratory evaluation of samples. This information should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

This report should be reproduced in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

Responsibility

Environmental reporting relies on interpretation of factual information using professional judgement and opinion and has a level of uncertainty attached to it, which is much less exact than other design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. As noted earlier, the recommendations and findings set out in this report should only be regarded as interpretive and should not be taken as accurate and complete information about all environmental media at all depths and locations across the site.

APPENDIX G

SUMMARY OF PUBLIC EXHIBITION SUBMISSIONS

SUBMISSION No.	SUBMISSION COMMENTS	ISSUES/CONCERNS RAISED	ACTIONS REQUIRED TO ADDRESS SUBMISSION
1	In agreeance to river gauge triggers for specific gauges that issue phone messages or SMS. Agree to flood plan updates for C3 church and Wyong LGA	None	None
2	Mardi creek detention basin, local drainage strategy lower Wyong River. PMF refuge at Wyong age care. Flood plan update for SES Local flood plan, Wyong Christian school, C3 church and Meander village. Promote Floodsafe Home Emergency Plan preparation. All Flood warning system upgrades. Audit flood and coastal storms education strategy and develop educational messages targeting dangerous behaviours. Continue to develop social media platforms for flood safe messaging. Upgrade food evacuation route between South Tacoma and Lake road through Pioneer dairy. Formalise permissions for evacuation traffic and emergency services vehicles through route in emergencies.	Issues were raised regarding flooding in old Pioneer Dairy and how it then backs up Wyong River. This was caused by runoff from Westfields then under Tuggerah Straight and then through Pioneer Dairy and into Wyong River opposite Charlton Island. Supports South Tacoma Flood way in lowering flood levels. Suggestion to open Tuggerah Lakes channel to help alleviate flooding in Wyong River.	Revise wording for South Tacoma Floodway to suggest additional investigations be undertaken to clarify "areas of uncertainty" and more precisely establish the feasibility of this option. Update Section 7.5.1 to recommend discussions are held with RailCorp on the possibility of augmenting the culverts that currently run under the railway line in the Tuggerah Straight area. Update section 7.4.4 to note that vegetation management could be potentially undertaken as part of councils annual asset management program.
3	Supportive of all recommended options	None	None
4	Safe emergency evacuation along McDonagh Rd is an issue; make property information available.	Earlier constructed houses on McDonagh Road have floor levels more then 1m below revised flood level. How can safe evacuation be realised through these depths by SES?	Clarify/strengthen wording in report to indicate early evacuation requirements by SES, not when floodwaters are actually in the area. Also strengthen the comment to indicate past practices during a flood in this area (i.e., people not evacuating) and other areas means this will require a big change in mentality around evacuation and will require continual reinforcement in non flood times (i.e., community education very important.
5 & 6	Support of most recommendations	Educate community about impacts of boat and car wash/wave action. They also note that many of the drainage channels around McDonagh Road are poorly maintained and some culverts are completely blocked.	Provide additional recommendation in Section 9.2.3 stating that education messages will be expanded to reference impacts of cars and boat wash. Also update Section 7.5.2 to note that some culverts are completely blocked and that clearing of these structures and adjoining channels should occur.

7	No additional comments on community consultation survey	Lots of comments regarding the stormwater drainage and filling in on eastern side of railway line. Long time resident has knowledge of historical water movement in area and suggestions for potential drainage easements to help alleviate the frequent flooding now occurring in area. Recommends that new channels/culverts be constructed beneath railway line to allow better flow during minor events.	Strengthen wording in section 7.5.2 to indicate the community's concern with the impact the perceived placing of fill for development has had in the catchment has impacted on the stormwater drainage issues in the area. Discussions with Councils DA Engineers indicates that council has been aware of the issues associated with stormwater drainage and overland flow in this area for a long time, and have restricted the permissibility of fill in the area accordingly. So much so that the only fill permitted has been that to "top-dress "a properties' lawn, and anything more, considered to be fill, has been followed up by Councils compliance regulation processes and staff. Update Section 7.5.1 to "recommend" discussions are held with RailCorp on the possibility of augmenting or adding to the culverts that currently run under the railway line in the Tuggerah Straight area.
8	Supportive of: flood safe breakfast and meetings, flood warning system upgrades, need for local drainage studies FM3, improvements in mobile phone coverage and evacuation planning, strong support for opening of fire trails for flood emergency access.	Supportive of "fixing the Wyong River banks" presumably from collapse and associated silting issues.	None