Central Coast Council

Killarney Vale / Long Jetty Catchments

Floodplain Risk Management Study & Plan

Draft Report for Public Exhibition

Volume 1 of 2: Report Text & Appendices

Revision 3
January 2020

Flood Focus Consulting

Catchment Simulation Solutions

Killarney Vale / Long Jetty Catchments
Floodplain Risk Management Study & Plan

Draft Report for Public Exhibition

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Catchment Simulation Solutions

Suite 1, Level 10
70 Phillip Street
Sydney, NSW, 2000

(02) 8355 5500 dtetley@csse.com.au
(02) 8355 5505 www.csse.com.au

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Central Coast Council
PO Box 20, Wyong NSW 2259
ask@centralcoast.nsw.gov.au
(02) 4350 5555

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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.

Central Coast Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the NSW Department of Planning, Industry and Environment.

FORWARD

The State Government's 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 four sequential stages:

	Stage	Description
1	Flood Study	Determines the nature and extent of the flood problem.
2	Floodplain Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3	Floodplain Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of environmental plans to ensure new development is compatible with the flood hazard.

The *Killarney Vale / Long Jetty Catchments Floodplain Risk Management Study and Draft Plan*, represent stages 2 and 3 of the floodplain risk management process. The aim of the Floodplain Risk Management Study is to identify, assess and compare various options for managing the flood risk across each 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 Killarney Vale and Long Jetty catchments.

The project was funded by the NSW Government's *'Floodplain Management Program'* and *Central Coast Council*. Technical support for the project was provided by the *Office of Environment and Heritage*.

EXECUTIVE SUMMARY

Overview

Central Coast Council commisioned Catchment Simulation Solutions in association with Flood Focus Consulting to prepare a Floodplain Risk Management Study and Plan for the Long Jetty and Killarney Vale catchments. 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. The extent of each catchment is shown in **Figure 1**, which is enclosed in Volume 2 of this report.

The catchments are significantly urbanised and many of the original creeks and gullies have been built over and replaced by stormwater pipes. A handful of open channels remain, including Saltwater Creek which also includes several detention basins that serve to reduce the impact of flooding across downstream properties. However, the capacity of the open channels, detention basins and stormwater pipes can be exceeded during heavy rainfall in the local catchments leading to "mainstream" flooding as well as "overland" flooding. Flooding has been experienced across both catchments on a number of occasions in the past including 1981 as well as more recently in 2007 and 2010. The 1981 flood, in particular, inundated multiple properties within the Saltwater Creek catchment and is considered to be larger than the 1% AEP design flood.

Flooding of the lower lying areas adjoining Tuggerah Lake can also occur during heavy rainfall in the broader Tuggerah Lake catchment. However, inundation from Tuggerah Lake across the foreshore areas was previously assessed as part of the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* (WMAwater, 2014) and was not considered further in this study. Therefore, the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* must be reviewed in conjunction with this report to understand the potential flood risk across the forehore areas. Council will ultimately consolidate the flooding information from the various interacting floodplains and associated reports to delineate the extent of the floodplain and the most appropriate flood risk management measures for particular locations.

The Existing Flooding Problem

The extent of the existing flooding problem was quantified using a computer flood model of the Killarney Vale and Long Jetty catchments. The outcomes of the modelling determined that water can inundate properties during events as frequent as a 20% AEP (1 in 5 year) flood. Of the ~7,500 properties located within the study area:

- Over 170 properties would likely experience flooding during a 20% AEP flood (including 9 buildings with above floor inundation);
- Over 460 properties would likely experience flooding during a 1% AEP flood (including 37 buildings with above floor inundation); and,
- Over 1,600 properties would likely experience flooding during a Probable Maximum Flood (including 368 buildings with above floor inundation).

Flood hazard mapping was prepared as part of the study based upon the Australian Government's *"Technical Flood Risk Management Guideline: Flood Hazard"* (2014) to assess the potential risk that flooding may pose to vehicles, buildings and people. This involved categorising the floodplain into one of six different hazard categories, denoted H1 (least hazardous) to H6 (most hazardous). The flood hazard maps for the 1% AEP flood and probable maximum flood (PMF) are provided in **Figure ES1** and **Figure ES2**.

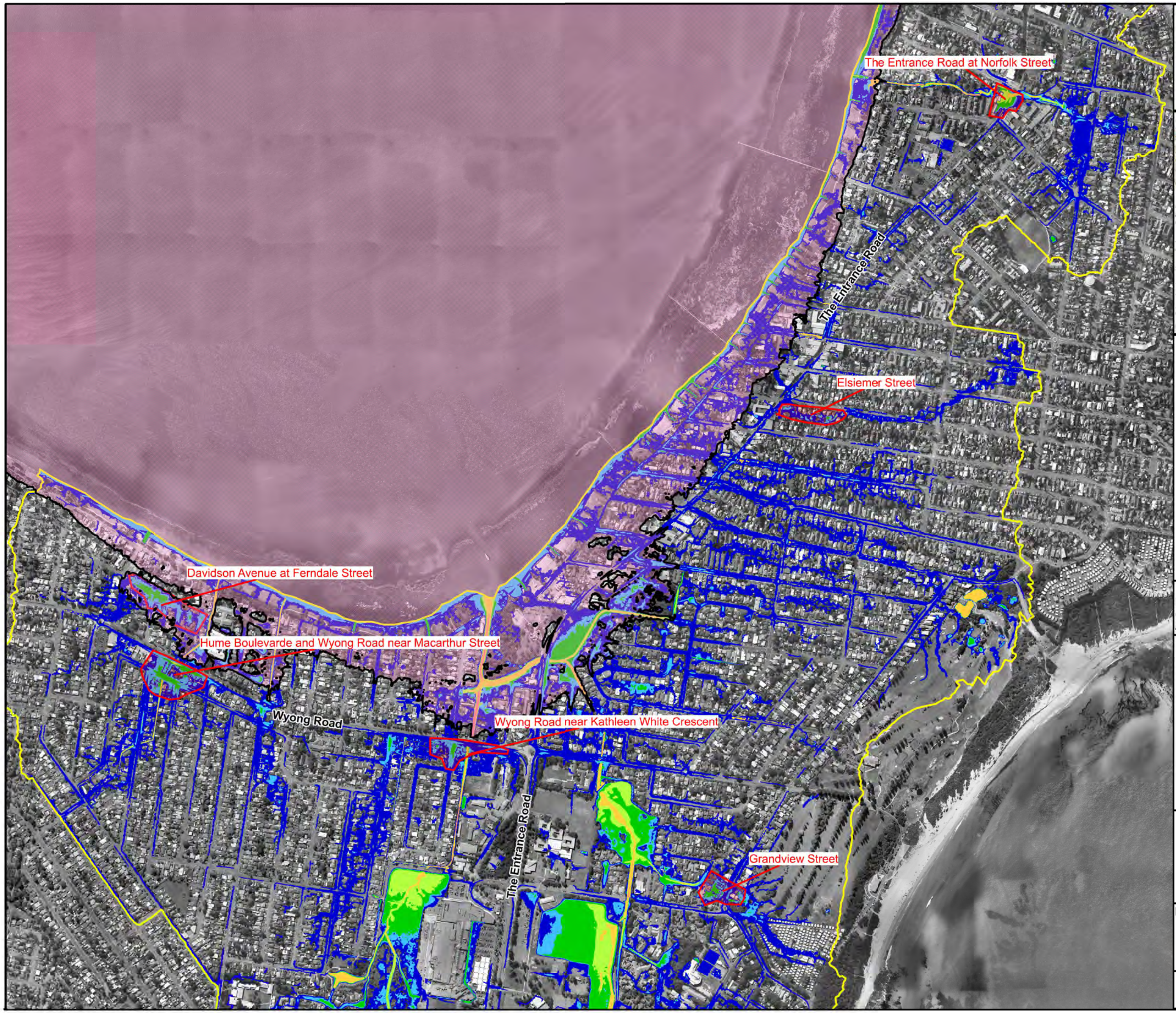
The hazard mapping indicates that the depth and speed of floodwater movement is not predicted to be sufficient to result in a significant risk to life or result in structural damage to property during floods up to and including the 1% AEP flood. However, during a probable maximum flood (PMF), many streets would not be safe for people (particularly children) or vehicles (refer to PMF flood hazard map provided in **Figure ES2**). In some localised areas, there is also potential for structural damage to buildings during a PMF. Due to the "flashy" nature of flooding and the limited amount of warning time available (i.e., less than 1 hour across most areas), there may not be an opportunity to evacuate from these buildings before the peak of the flood arrives.

A number of major roads are predicted to be cut by floodwaters in events as frequent as the 20% AEP flood. This will likely have negative impacts on emergency response during floods and may pose a risk to any motorists that attempt to drive through the floodwaters.

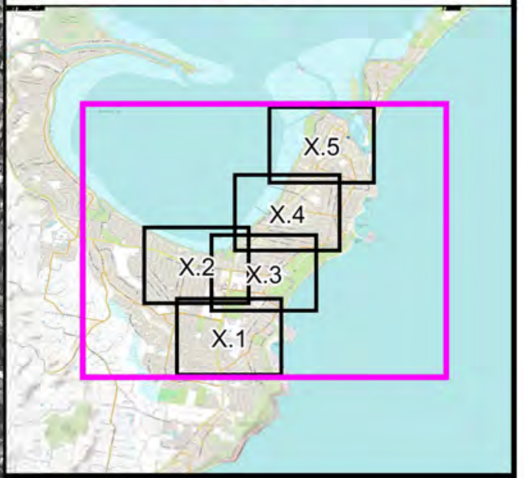
A flood damage assessment was completed as part of the study and established that the average annual cost of flooding would be about $290,000 if the "status quo" was maintained. Most of this cost would be borne by the local residents. However, commercial properties adjoining Wyong Road would also be impacted.

The assessment ultimately determined that the following areas are likely to experience significant property damage and/or risk to life during floods within the catchments (also refer to **Figures ES1** and **ES2** which shows each location and the associated flood hazard during the 1% AEP flood and PMF):

- Hume Boulevarde and Wyong Road near Macarthur Street, Killarney Vale: H3 hazard (danger to children & elderly) and above floor flooding of 8 properties during 1% AEP flood. During the PMF, hazard is predicted to increase to H4 and H5 (danger to all people and potential structural damage to buildings) and 16 properties are predicted to be flooded above floor level. The flooding problem is primarily associated with the elevated Wyong Road median and lack of culvert capacity across Wyong Road.
- Davidson Avenue at Ferndale Street, Killarney Vale: H3 hazard extending across multiple properties (danger to children & elderly) and 1 property with above floor flooding during 1% AEP flood (most of the deeper water is contained within the roadway). During the PMF, the flood hazard is predicted to increase to H4 with limited areas of H5 (danger to all people and potential structural damage to buildings) and 11 properties are predicted to be flooded above floor level. Localised sag/low point coupled with limited stormwater capacity/lack of grade is the primary cause of flooding.
- Wyong Road near Kathleen White Crescent, Killarney Vale: H2 and H3 hazard (danger to vehicles, children & elderly) but no above floor flooding during 1% AEP flood. During the PMF, hazard is predicted to increase to H5 within Kathleen White Crescent and between some buildings (potential for structural damage) and 13 properties are predicted to be flooded above floor level. The flooding problem is primary associated with the elevated



Central Coast Council



LEGEND

- Flooding Problem Areas

Hazard Categories

- H1 - Generally Safe
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles. Buildings require special design
- H6 - Unsafe for people and vehicles. All buildings vulnerable to failure
- Tuggerah Lake Inundation Area. Please refer to the 'Tuggerah Lakes Floodplain Risk Management Study and Plan' (2014) for further information

Notes:

Results are filtered based on criteria in Section 3.2.2 of Volume 1

Aerial photograph date: 2013

N W E S

Scale 1:11,000 (at A3)

0 0.3 0.6 Km

Figure ES1: Flood Hazard for the 1% AEP Flood

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: ES1 Flood Hazard 1AEP.wor

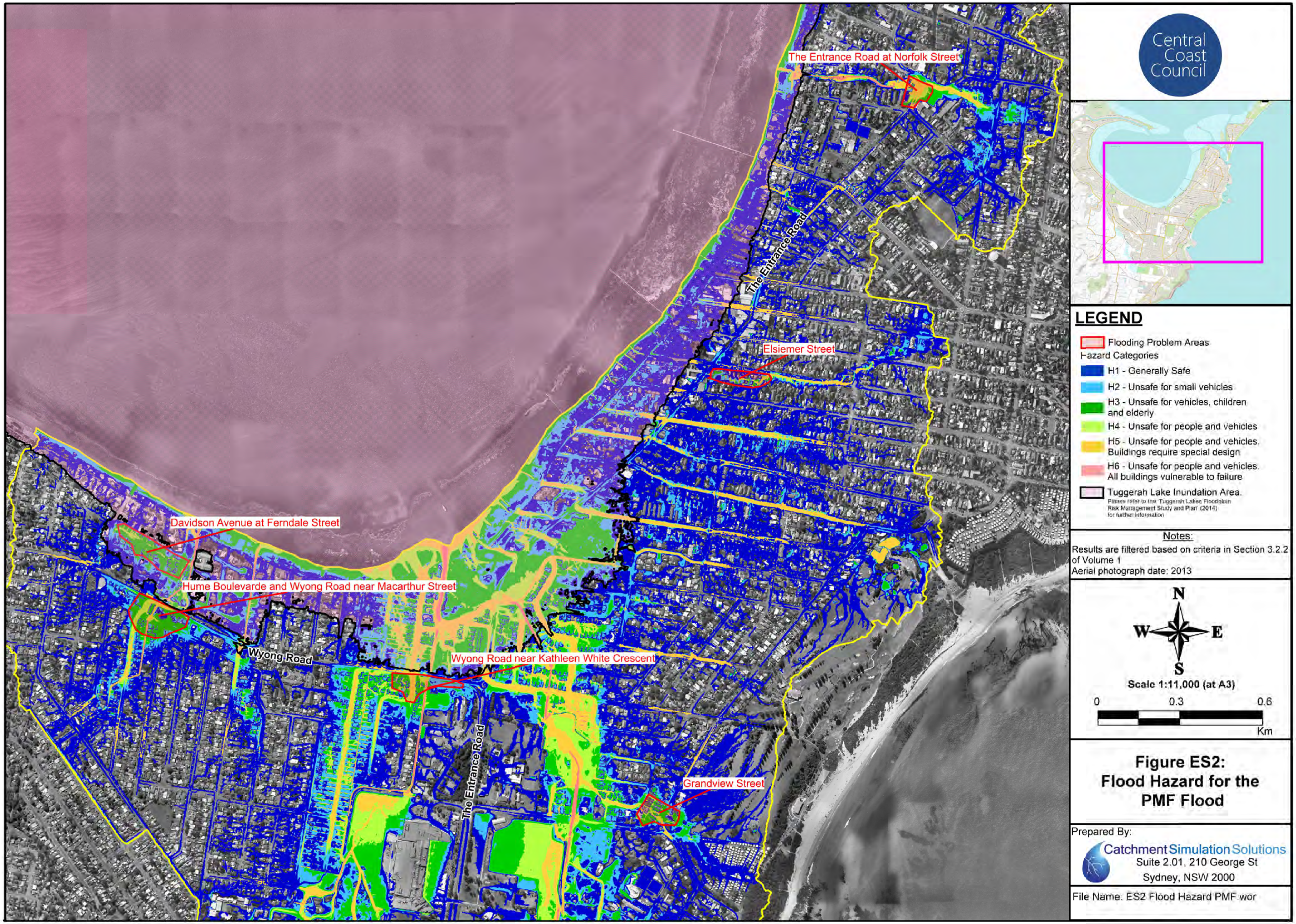


Figure ES2: Flood Hazard for the PMF Flood

Wyong Road median and lack of culvert capacity across Wyong Road. Any blockage of Wyong Road culverts further exacerbates the flooding problem.

- Grandview Street, Shelly Beach: H3 hazard (danger to children & elderly) and 4 properties with above floor flooding during 1% AEP flood (most water is contained within the roadway). During the PMF, flood hazard is predicted to increase to H4 with limited areas of H5 between buildings (danger to all people and potential structural damage to buildings) and 9 properties are predicted to be flooded above floor level. Lack of stormwater pipe capacity is the primary cause of flooding.
- Elsiemer Street, Long Jetty: Water spills from Elsiemer Street and inundates the front and rear yards of multiple properties. H2 hazard is most common during the 1% AEP flood and no properties are predicted to experience above floor inundation. During the PMF, H4 and H5 hazard are prominent and 3 properties are predicted to be flooded above floor level. Limited stormwater pipe capacity and a lack of formal kerb and gutter to contain the majority of water in the road is considered to be a key contributor to the flooding problem at this location.
- The Entrance Road at Norfolk Street, Long Jetty: H4 and limited areas of H5 are predicted during the 1% AEP flood and above floor flooding of the Reef Resort is also predicted. Extensive areas of H5 are predicted during the PMF (danger to all people and potential structural damage to buildings) and above floor flooding depths across the Reef Resort are predicted to exceed 1 metre. Localised sag/low point coupled with limited stormwater capacity and the impediment to flow afforded by the Reef Resort buildings are the primary causes of flooding.

Climate Change Impacts

Climate change induced rainfall intensity and sea/lake level increases have the potential to further increase the existing flood risk across Killarney Vale and Long Jetty.

Current climate change research indicates that current rainfall intensities may increase by up to 18.4% by the year 2090. Climate change simulations completed for the current study indicates that a 18.4% increase in rainfall would increase the number of buildings exposed to above floor inundation by nearly 50% during a 1% AEP flood. This is predicted to increase the damage costs incurred during a 1% AEP flood by about 40%.

Although it was acknowledged that sea level rise could impact on Tuggerah Lake water levels, the focus of the current study is on the more elevated sections of the catchments located away from the lake. As a result, no specific allowance for sea level rise was included as part of the current study. However, the impacts of sea level rise on Tuggerah Lake water levels was previously assed as part of the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* (WMAwater, 2014). This determined that a 0.4 metre increase in lake level would result in more than 1,000 additional properties being subject to inundation during a 1% AEP flood across the Tuggerah Lake foreshore area. A 0.9 metre increase in lake level would result in more than 2,300 properties being subject to inundation during a 1% AEP flood.

Community Consultation

Consultation with the community has been an important component of the study. Consultation was completed through a study website as well as the distribution of a community information brochure and questionnaire. 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 potential flood risk management options.

Key findings from the consultation include:

- 67% of the questionnaire respondents had been impacted by flooding on some level.
- The most commonly reported impact was roadways being cut by water followed by flooding of garages and sheds. Three respondents reported above floor inundation of their house.
- 36% of respondents did not know whether their property could be potentially flooded or not.
- During a future flood, 54% of respondents said that they would remain at home. Only 15% said they would evacuate to an official evacuation centre.
- In general, non-structural options such as DCP updates and local flood plan updates were the most favoured flood risk management measures. The least favoured flood risk management options included levees and concrete lined channels.

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 and future flood risk. Each option was evaluated against a range of criteria to provide an appraisal of its potential feasibility. This included the impact that each option would likely have 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 as well as feedback from the community, the options outlined in **Table 1** are recommended for implementation as part of the draft Floodplain Risk Management Plan for Killarney Vale and Long Jetty. Further detailed information on each option including costs, implementation schedules and funding opportunities is also provided in **Table 1**. The recommended set of options are also shown on **Figure ES3**.

It is noted that implementation of the suggested "structural" options would require a significant capital outlay (most notably for the Wyong Road modifications). Many of the options will also require an investment in time from various agencies including Central Coast Council and the State Emergency Service as well as individual property owners.

Despite the significant capital outlay that would be required to implement the Plan, the reduced frequency and severity of flooding would provide a range of non-monetary benefits to the local community including:

- Less traffic disruption (particularly for the major thoroughfares of The Entrance Road and Wyong Road) including reduced frequency of people driving through floodwaters (over half of Australia's flood fatalities are a result of people driving through floodwater);

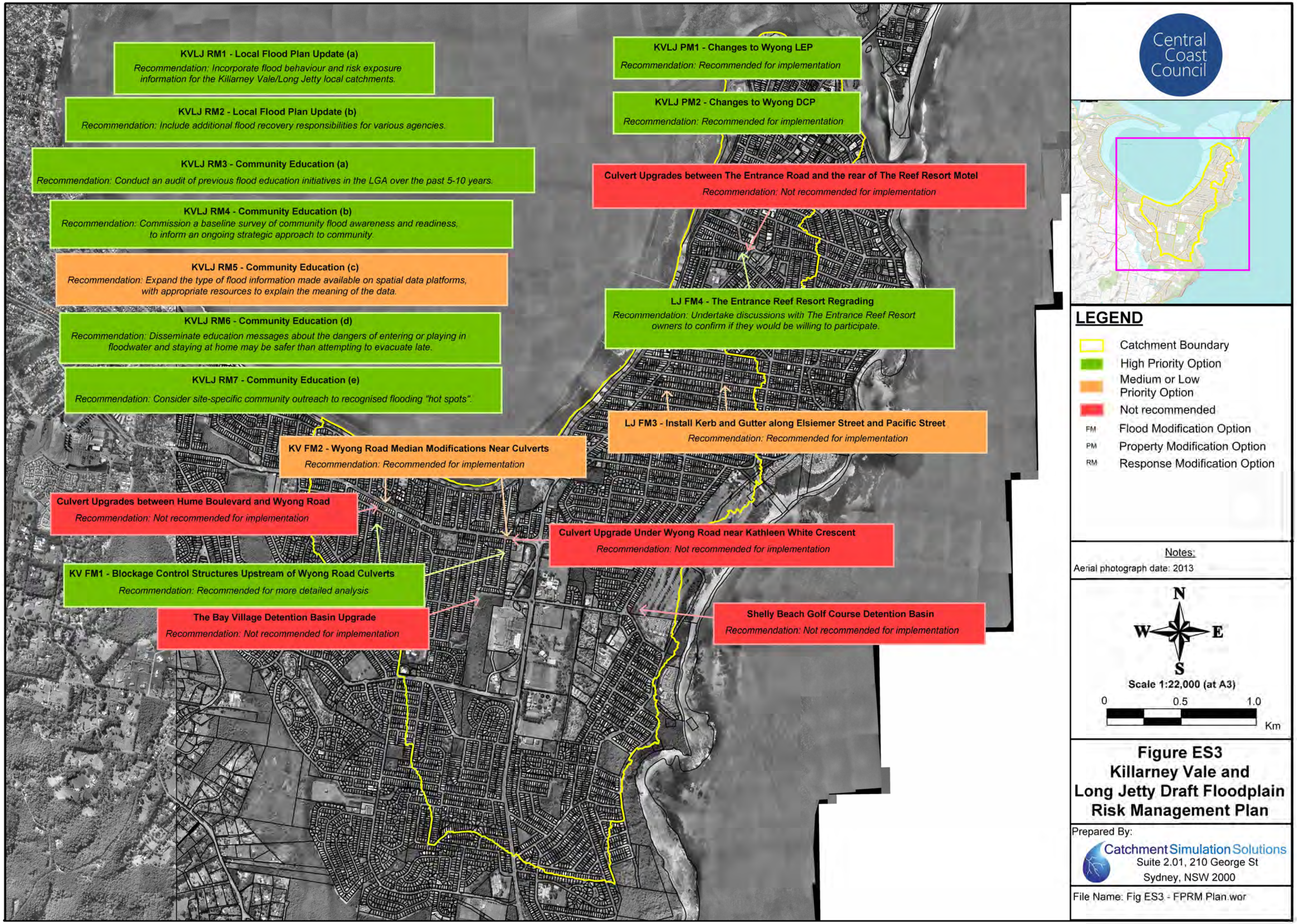


Figure ES3
Killarney Vale and Long Jetty Draft Floodplain Risk Management Plan

- Less disruption/inconvenience for residents and business owners (e.g., less frequent cleaning up after a flood and need for evacuation);
- Reduced potential for health issues resulting from sewer overflows;
- Significantly less mental stress/anxiety (associated with experiencing a flood event and post event recovery); and
- Reduced potential for injury and risk to life (e.g., drowning) during major floods;

If each of the structural options are implemented, the capital cost is expected to be just under $1.4 million. However, the number of properties exposed to above floor flooding would be reduced by 8 in the 20% AEP flood and 9 during the 1% AEP flood and total flood damages would be reduced by about $1.5 million over the next 50 years.

Implementation of the structural options will reduce the frequency and depth of inundation but will not eliminate the potential for inundation completely. Therefore, it will be necessary to also implement the remaining non-structural (i.e., planning and emergency response) options to help ensure the continuing and future flood risk is also minimised.

Table 1 Recommended Floodplain Risk Management Options for Killarney Vale and Long Jetty Catchments

#		Option Description	Report Section	Capital Cost	Implementation Responsibility	Priority
Flood Modification Options						
Killarney Vale						
KV FM1		Blockage Control Structures Upstream of Wyong Road	7.2.1	$120,000	Council	High
KV FM2		Wyong Road Median Modification near Culverts	7.4.3	$990,000	Council	Medium
Long Jetty						
LJ FM3		Roadworks and installation of kerb and gutter along Elseimer St and Pacific St	7.4.2	$170,000	Council	Medium
LJ FM4		Regrading across The Reef Entrance Resort	7.4.4	$150,000	Council + resort owners	High
Property Modification Options						
KVLJ PM1		LEP Amendments	8.2	Council time	Council	Medium
KVLJ PM2		DCP Amendments	8.3	Council time	Council	Medium
Response Modification Options						
KVLJ RM1	Local Flood Plan Updates	Incorporate flood behaviour and risk exposure information for the Killarney Vale/Long Jetty local catchments	9.1.1	SES time	NSW SES	High
KVLJ RM2	Local Flood Plan Updates	Include additional flood recovery responsibilities for various agencies	9.2.1	SES time	NSW SES	High
KVLJ RM3	Community Education	Conduct an audit of previous flood education initiatives in the LGA over the past 5-10 years	9.1.4	SES and Council time	NSW SES and Council	High
KVLJ RM4	Community Education	Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community flood education	9.1.4	$10k	Council	High

#	Option Description		Report Section	Capital Cost	Implementation Responsibility	Priority
KVLJ RM5		Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data	9.1.4	Council time	Council	Medium
KVLJ RM6		Disseminate educational messages about: • the dangers of entering or playing in floodwater • staying at home may be safer than attempting to evacuate late	9.1.4	SES time	NSW SES	High
KVLJ RM7		Consider site-specific community outreach to recognised flooding “hot spots”	9.1.4	SES and Council time	NSW SES & Council	High

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1 INTRODUCTION

1.1 Background

The Killarney Vale and Long Jetty catchments are located on the Central Coast of New South Wales and occupy a combined area of 8.8 km^2. The extent of the catchment is shown in **Figure 1** (refer Flood Study: Volume 2).

The catchments include the suburbs of Bateau Bay, Shelley Beach, Long Jetty, Killarney Vale and sections of The Entrance. As shown in **Figure 1**, the catchments drain into Tuggerah Lake which forms the western boundary of the study area. Saltwater Creek is the major watercourse within the study area, with the remaining areas drained by constructed drainage channels and a sub-surface stormwater system. The catchments are largely urbanised with small sections of bushland and parklands.

During periods of heavy rainfall across the Killarney Vale and Long Jetty catchments, there is potential for water to overwhelm the stormwater drainage system and/or overtop the banks of the creeks and drainage canals and inundate adjoining properties. Flooding has been experienced across both catchments on a number of occasions in the past including 1981 as well as more recently in 2007 and 2010.

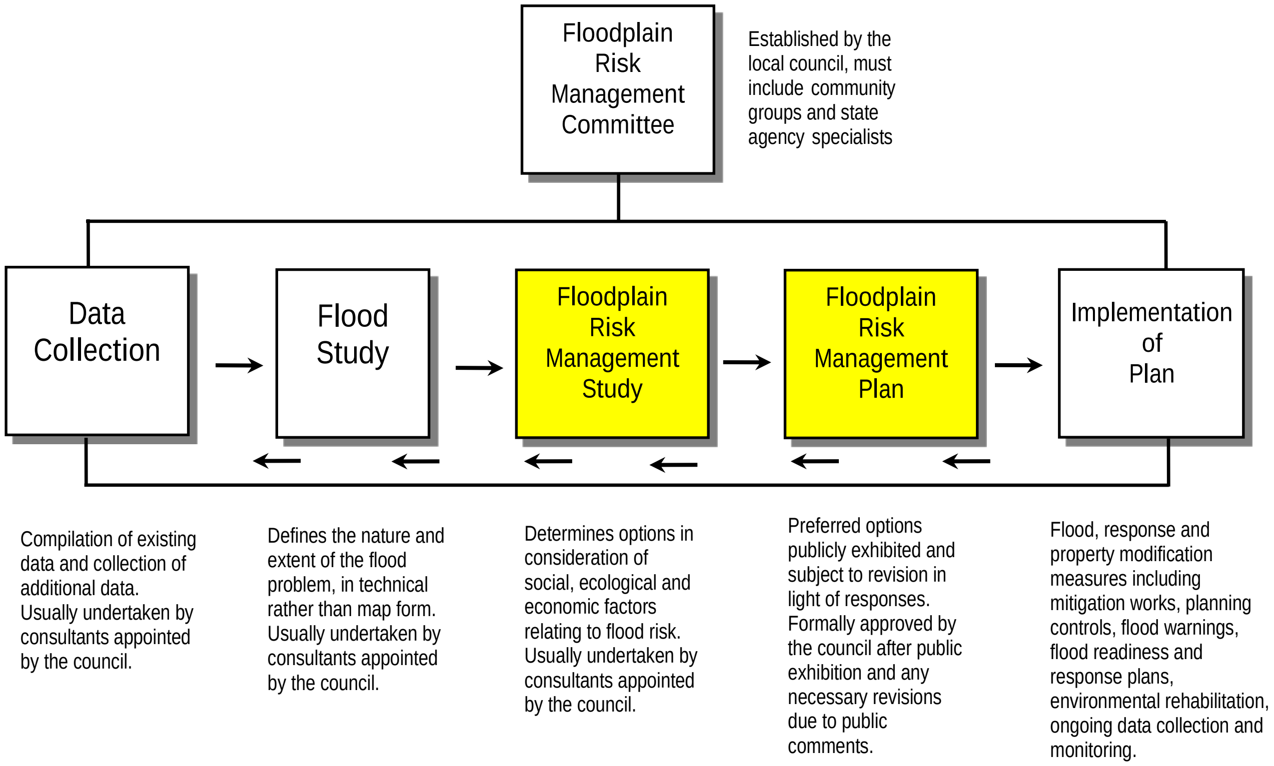
In recognition of the damage and inconvenience that has been caused by past flooding across both catchments, Central Coast Council resolved to prepare a Floodplain Risk Management Plan for the Killarney Vale and Long Jetty catchments.

1.2 The Floodplain Risk Management Process

The Killarney Vale and Long Jetty Catchments Floodplain Risk Management Study and Draft 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 *'Killarney Vale / Long Jetty Catchments Overland Flood Study'* (Catchment Simulation Solutions, 2014).

Central Coast Council engaged Catchment Simulation Solutions in association with Flood Focus Consulting to prepare the *Killarney Vale / Long Jetty Catchments Floodplain Risk Management Study and Draft Plan*, which represent stages 3 and 4 of the floodplain risk management 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 Killarney Vale and Long Jetty catchments.

It should be noted that the Killarney Vale and Long Jetty catchments drain into Tuggerah Lake. Accordingly, inundation of the study area can occur as a result of runoff from the local catchments as well as from elevated water levels within Tuggerah Lake. However, it should be noted that this study is concerned with flooding from the local catchments only. Inundation of properties 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 considered further in this study.

1.3 Report Structure

The Floodplain Risk Management Study and Plan for the Killarney Vale and Long Jetty catchments is provided as two separate volumes:

- **Volume 1**: (i.e., this document) comprises the report text and appendices.
- **Volume 2**: contains all accompanying report figures/mapping.

Volume 1 (i.e., this document), is further divided into the following sections:

- Section 2 - Catchment Information: Provides general information regarding the catchments, including the history of flooding. It also summarises the outcomes of community consultation activities.
- 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 – Existing Planning Information: summarises, with an emphasis on flooding, existing planning legislation, policy and guidelines that affect the development of land within the catchments.
- Section 5 – Existing Emergency Management Protocols: provides an overview of emergency management measures that are currently implemented across the study area to assist in managing the flood risk. Opportunities to improve these existing protocols are also discussed.
- Section 6 – Options for Managing the Flood Risk: Outlined the options that were considered to assist in better managing the flood risk across Killarney Vale and Long Jetty catchments.
- Sections 7 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 implementation by Council to manage the flood risk.

2 CATCHMENT INFORMATION

2.1 Study Area Description

The Killarney Vale and Long Jetty catchments are located on the Central Coast of New South Wales and occupy a combined area of 8.8 km^2. The extent of the catchment is shown in **Figure 1** (refer Flood Study: Volume 2).

The catchments include the suburbs of Bateau Bay, Shelley Beach, Long Jetty, Killarney Vale and sections of The Entrance. Saltwater Creek is the major watercourse within the study area, with the remaining areas drained by constructed drainage channels and a sub-surface stormwater system. The location of Saltwater Creek is shown in **Figure 1**.

The catchments are largely urbanised with scattered areas of bushland and parklands. The majority of the study area comprises low density residential development, although there are medium density residential areas concentrated near The Entrance. Limited commercial and industrial areas fringe each of the major roads in the area including Wyong Road and The Entrance Road / Central Coast Highway. A number of retirement villages, aged care facilities and schools are also located within the study area.

Most of the urbanised sections of the study area are drained by a stormwater system that drains runoff below ground and into Saltwater Creek or one of the other unnamed drainage channels.

Each of the watercourses/channels in the study area has been modified from its natural/pre-European state (refer **Plate 1**). This includes realignment and concrete lining of the channels. Accordingly, each of the watercourses is significantly modified. The location of all open channel/watercourses is shown by the blue lines in **Figure 1**.

Many of the watercourses are also traversed by bridges and culverts. During significant rainfall within the local catchment, there is potential for debris to be mobilised leading to blockage of these structures. This can significantly impact on flood levels in the immediate vicinity of these structures.

As shown in **Figure 1**, the catchments drain into Tuggerah Lake which forms the western boundary of the study area. The performance of the local drainage system can be inhibited when there are elevated lake levels (i.e., water levels "back up" and fill the pipe system). Furthermore, like the bridge and culverts discussed above, blockage of stormwater pits can also reduce the performance of the stormwater system.

A significant flood occurred within the Saltwater Creek catchment on the 6th February 1981, which caused inundation of retirement villages on the western floodplain of Saltwater Creek between Rushby and Yakalla Streets. This prompted a flooding investigation (discussed in more detail in Section 2.2.1) and ultimately led to the construction of three "online" flood detention basins on Saltwater Creek.

Plate 1 Saltwater Creek looking north from Rushby Street showing concrete-lined channel

The location of each detention basin is shown in **Figure 2**. The detention basins are designed to release flows in a controlled manner during significant rainfall events, with the excess flow being storage behind the basin walls. This aims to reduce the severity of flooding across properties located downstream of each basin.

In general, the basins comprise earthen embankments and are dedicated as flood detention basins. However, the Basin B detention area incorporates sporting fields.

It was noted that Basin A as well as the Eastern Road basin incorporates significant vegetation (refer **Plate 2**). This includes dense shrubs and well-established trees that extend up the basin walls. Accordingly, there may be potential for the roots of some of the larger trees to weaken the integrity of these particularly basin walls.

The significant vegetation contained within each basin also increases the potential for blockage of the basin outlets (refer **Plate 3**). Most of the basins do not include formalised spillways to handle flows in excess of the capacity of the outlet. Therefore, if the outlets were blocked or the capacity of the outlet is exceeded, there is potential for overtopping of the basins which also increases the potential for failure of the basin. It is noted that Basin C as well as the Bay Village basin do include spillways, so failure of these basins via the discussed mechanisms is less likely.

Plate 2 Example of significant trees/vegetation along the downstream embankment of Basin A

Plate 3 Dense vegetation around the Basin A outlet

None of the detention basins falling within the study area are “prescribed”. That is, they are not identified as posing a potential threat to the downstream community and are, therefore, not subject to routine checks. The potential impact of failure of these basins was assessed and is discussed in more detail in Section 3.2.4.

A Digital Elevation Model (DEM) for the study area is shown in **Figure 3**. The DEM shows that ground surface elevations vary from over 70 mAHD to less than 1 mAHD along the Tuggerah Lake foreshore.

2.2 Past Studies

The most recent flood study for the area is the *‘Killarney Vale / Long Jetty Catchments Overland Flood Study’* (Catchment Simulation Solutions, 2014). This study provides the most contemporary description of flood behaviour across the Killarney Vale and Long Jetty catchments. The outcomes from this study are discussed in more detail in Section 3.2.

A number of other studies have been completed across the area to assist in better understanding the existing flooding problem and evaluate options for better managing the flood risk. A summary of these studies is provided below.

2.2.1 Saltwater Creek Stormwater Drainage Review (May, 1981)

The *‘Saltwater Creek Stormwater Review’* was prepared by Willing & Partners Pty Ltd for the Shire of Wyong (now part of Central Coast Council). The study was prepared following a significant flood that occurred within the Saltwater Creek catchment on the 6th February 1981, which caused inundation of retirement villages on the western floodplain of Saltwater Creek between Rushby and Yakalla Streets. The study aimed to quantify the performance of the existing drainage system and identify potential options that could be implemented to improve the performance of the drainage system. As shown in **Figure 1**, Saltwater Creek is one of the major watercourses located within the Killarney Vale catchment.

The study included a significant amount of information on the February 1981 flood, which was considered to be in excess of a 1% AEP event. This included rainfall information as well as indicative flood extents between Bloomfield Street, Long Jetty and Malana Avenue, Bateau Bay.

The report determined that major components of the stormwater system (e.g., detention basins) typically had a 50 year ARI (i.e., 2% AEP) capacity. During events in excess of the 2% AEP flood, inundation of a number of properties was predicted, including the Nareen Gardens and Elderslee Retirement Villages. To provide additional protection for floods in excess of the 2% AEP flood, the report recommended a number of upgrades to the existing stormwater system. The majority of these recommendations have since been implemented (refer following sections).

2.2.2 Saltwater Creek –Basin C and Associated Works (March, 1987)

The *‘Saltwater Creek – Basin C and Associated Works’* report was prepared by Willing & Partners Pty Ltd for the former Wyong Shire Council. The study was commissioned following the *‘Saltwater Creek Stormwater Review’* (Willing & Partners Pty Ltd, 1981) to provide a detailed investigation into drainage augmentation options that could be implemented between Yakalla Street and Tuggerah Lake to help alleviate flooding/drainage problems across the downstream sections of the Saltwater Creek catchment.

The report includes some information for a flood that occurred in November 1984. However, the report notes that the 1984 event was only a small flood (approximately equal to a 20% AEP flood).

The report notes that flood levels along the downstream reach of Saltwater Creek are influenced by the prevailing water level within Tuggerah Lake at the time of the flood. However, the report goes on to say that the available information suggests that there is little correlation between elevated Tuggerah Lake levels and short duration storms typical of those that produce flooding across the Saltwater Creek catchment. That is, elevated water levels in Tuggerah Lake typically occur as a result of longer storm durations (i.e., ~2-3 days) while flooding along Saltwater Creek typically occurs as a result of short duration rainfall bursts (i.e., ~1-2 hours).

The report recommended construction of a new basin (referred to as "Basin C") between Yakalla Street and Shelley Beach Road, Bateau Bay. This concept design was refined during subsequent investigations (refer following section) and is now constructed.

2.2.3 Saltwater Creek Flood Mitigation Work – Design Report (March 1990)

The '*Saltwater Creek Flood Mitigation Work – Design Report*' was prepared by Willing & Partners Pty Ltd. The study was commissioned following on from previous studies to document the hydraulic and civil engineering design to support:

- Amplification of the existing detention basin south of Yakalla Street, Bateau Bay; (Basin B)
- Construction of a new detention basin between Yakalla Street and Shelley Beach Road, Bateau Bay (Basin C);
- Amplification of the existing culvert beneath Shelley Beach Road;

The report notes that Basin C would fully contain the 1% AEP flood (although there is only 0.01 metres of "freeboard" between the peak 1% AEP flood level and the spillway elevation). Basin B was predicted to "spill" during the 1% AEP flood, however, this volume of water was considered to be negligible and would not adversely impact on downstream properties.

2.2.4 Tuggerah Lakes Floodplain Risk Management Study – Public Exhibition Draft (November, 2010)

The *'Tuggerah Lakes Floodplain Risk Management Study'* was prepared by WMAwater for the former Wyong Shire Council. The study was prepared to examine a range of measures that could be potentially implemented to reduce the impact of flooding across the floodplain of the Tuggerah Lakes system (i.e., Tuggerah Lake, Budgewoi Lane and Lake Munmorah).

The study was mainly concerned with land that is located below 3 mAHD. That is, it did not consider flooding along each of the major tributary inflows to the lake system, including the Killarney Vale and Long Jetty catchments. Nevertheless, it does provide useful information regarding flooding mechanisms across Tuggerah Lake. As shown in **Figure 1**, the Killarney Vale and Long Jetty catchments drain into Tuggerah Lake. Accordingly, the prevailing water levels in Tuggerah Lake can influence flood behaviour along the downstream reaches of both catchments.

The study notes that Tuggerah Lake discharges to the Pacific Ocean across a sandy beach berm at The Entrance, which is intermittently open and closed. The severity of flooding across the lake system is strongly influenced by the level of the beach berm and whether there are elevated ocean levels at the time of a flood (elevated ocean levels may prevent the egress of floodwaters from the lake). The report also notes that rainfall over a period of 2 to 5 days is typically required to elevate lake levels significantly.

The study notes that the non-flood water level within the lake (i.e., lake water level when there is no catchment runoff) is typically between 0.2 and 0.4 mAHD with no apparent tidal fluctuation.

The study provides an overview of previous flooding investigations that have been completed for the lake system. This includes the '*Tuggerah Lakes Flood Study*' (Lawson and Treloar, 1994), which provides design flood levels for Tuggerah Lake that were prepared based on frequency analysis and hydrologic/hydraulic computer modelling (refer **Table 2**). The design flood levels listed in **Table 2** are based on an entrance breach model that was calibrated against historic floods.

Table 2 Summary of peak design flood levels for Tuggerah Lake taken from "Tuggerah Lakes Flood Study"

Location	Peak Lake Water Level (mAHD)				
	50% AEP	20% AEP	5% AEP	1% AEP	Maximum Probable Flood
Tuggerah Lake	0.91	1.36	1.80	2.23	2.70

The study determined that up to 1,300 building fronting the lake foreshore would be potentially inundated during a 1% AEP flood and would result in over $40 million of damages. The average annual damage cost was determined to be $2.2 million (WMAwater, 2014).

The study notes that "structural" mitigation options were largely ineffective. Structural options that were explored included:

- Levees, flood gates and pumps
- Dams/flood detention basins
- Entrance management/dredging
- Enlarging the Entrance channel

Therefore, the plan focused on property and emergency response measures to better manage the existing flood risk. The options that were put forward in the draft floodplain risk management plan are summarised in **Table 3**.

Table 3 Flood risk management measures recommended as part of the draft Tuggerah Lake Floodplain Risk Management Plan

High Priority	Medium Priority	Low Priority
Adaptation planning for the foreshore suburbs	Review Tuggerah Lakes Flood Study and Floodplain Risk Management Plan	Assess and manage the risk of electrocution during floods
Flood emergency management planning		Investigate opportunities for house raising
Development of management plan for vulnerable water and sewer assets		Develop specific flood related controls for existing and future tourist parks
Formalise an entrance management strategy to manage flooding		
Develop asset management procedure for the Wilfred Barrett Drive levee		
Update Section 149(2) planning certificates		
Address and manage local frequent flooding issues		
Maintenance of water level and rainfall gauges		
Undertake transfer of all relevant flood related information to the community, Insurance Council of Australia and the NSW SES		

As discussed, the current study is focussed on the more elevated sections of the catchment located away from the lake. Therefore, the options summarised in **Table 3** are still considered to be the most appropriate options for managing the flood risk around the lake foreshore. However, due to the differing characteristics of the Tuggerah Lake catchment relative to the Long Jetty and Killarney Vale catchments, these options may not afford benefits across Long Jetty and Killarney Vale. Therefore, it is important that the Long Jetty and Killarney Vale catchments are independently investigated, which is the focus of the current study.

2.3 Local Environment

2.3.1 Vegetation

As discussed, the Killarney Vale and Long Jetty catchments are highly developed and minimal native vegetation remains. Nevertheless, there are some small sections of each catchment that are included in Council's vegetation mapping, which are shown on **Figure 4**.

As shown in **Figure 4**, the vegetation is typically concentrated along the Tuggerah Lake foreshore as well as areas adjoining Saltwater Creek as well as an unnamed watercourse located on the western side of The Entrance Road. However, isolated "pockets" of vegetation are also scattered elsewhere across the study area. The vegetation communities occupy 0.8 km^2 of the 8.8 km^2 study area (i.e., 9%).

The potential for implementation of structural mitigation measures in areas with vegetation coverage will be limited as there is potential for adverse impacts on native flora and fauna in these areas.

2.3.2 Acid Sulphate Soils

Acid sulphate risk mapping is presented in **Figure 4**. It shows that here is a high probability of acid sulphate soils across areas adjoining Tuggerah Lake (typically areas located below 2 mAHD). Across most of the elevated sections of each catchment, the potential for acid sulphate soils is low.

2.3.3 Heritage

Several locations across Long Jetty are currently protected through heritage listing under the former Wyong Shire Council Local Environmental Plan 2013. The location of each heritage item is shown in **Figure 4**.

In general, the heritage status applies to isolated residential, commercial and special use buildings (e.g., hotels, schools). This heritage status limits the extent of major works that may damage, disturb or otherwise inhibit items of significant heritage.

A review of Aboriginal heritage sites was also completed. The location of these heritage sites is also shown in **Figure 4**. This shows that there are several Aboriginal heritage sites located in proximity to the study area. However, there are no sites falling within the study area.

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 Killarney Vale and Long Jetty that was collected as part the 2016 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:

- The majority of residential properties in Killarney Vale (i.e., >90%) are "standalone" houses. Although the majority of residential properties in Long Jetty are also standalone dwellings, Long Jetty also includes a significant number of villa/townhouse style dwellings.
- The majority of households only speak English at home. However, there are a limited number of households that also speak Spanish, Italian and Greek.
- Roughly 76% of households have an internet connection.
- The median age of residents within the study area is around 40.
- Approximately 42% of the population in Long Jetty rents their place of residence, which is higher that the state average of 31%. Only 26% of the population in Killarney Vale rents. This indicates that there may be a relatively high population turnover in Long Jetty and, as a result, a lower than average level of flood exposure and awareness.

- Most households have at least 1 motor vehicle. However, 11% of properties in Long Jetty and 6% of properties in Killarney Vale do not have access to a motor vehicle.
- Approximately 40% of the population would be considered less mobile (e.g., the elderly or children under the age of 15).

Table 4 Summary of Demographics for Long Jetty and Killarney Vale

Statistic[#]				Long Jetty	Killarney Vale
Population Statistics	Age	Median Age		43	39
		<15 years of age		18%	20%
		>65 years of age		23%	19%
		Proportion of population that volunteers		15%	14%
	Education	Year 12 or equivalent		12%	12%
		Year 10 or equivalent		18%	18%
		Did not Complete Year 10		12%	11%
Dwelling Statistics	Motor Vehicles	Dwellings with no vehicles		11%	6%
		Dwellings with ≥ 1 vehicle		84%	90%
		Average persons per dwelling		2.2	2.6
	Language spoken at home	Speaks English only		88%	90%
		Other	Spanish	0.7%	0.3%
			Italian	0.5%	0.3%
			Greek	0.4%	0.2%
		Proportion of renters		42%	26%
	Dwelling Type	Separate house		53%	91%
		Semi-detached, row or terrace house, townhouse		39%	9%
		Flat, unit or apartment:		6%	0%
		Other dwelling (cabin, caravan):		1%	0%
Income		Median total household income ($/weekly)		$972	$1,222
		Median Rent ($/weekly)		$315	$350
Internet Statistics		No Internet connection		23%	17%
		Access to Internet connection		72%	80%
		Not Stated		4%	3%

2.5 Community Consultation

2.5.1 Overview

Central Coast Council recognises that the community is an important part in the development of the floodplain risk management study and plan for the Killarney Vale and Long Jetty catchments. Separate consultation activities were complete during the flood study and the floodplain risk management study recognising the different focus of each study:

- The consultation during the flood study aimed to collect information about the community's past flooding experience, with a particular focus on gathering information that could be used to calibrate the computer flood model;
- The consultation during the floodplain risk management study was targeted at obtaining feedback from the community regarding the best way to manage the flood risk as well as how they would likely respond during a future flood.

A summary of the outcomes of each phase of the consultation is provided below.

2.5.2 Flood Study

A community information brochure and questionnaire were prepared and distributed to all households and businesses within the Killarney Vale and Long Jetty catchments.

The questionnaire sought information from the community regarding whether they had experienced flooding, the nature of flood behaviour, if roads and houses were inundated and what was the major cause of flooding. A total of 585 questionnaire responses were received.

The following information was gleaned from the responses to the questionnaire:

- The majority of respondents have lived in or around the catchment for around 20 years. Accordingly, most respondents experienced the 2007 and 2010 floods, however, were not living in the catchment during the 1981 flood (i.e., the largest flood on record).

- Approximately one quarter of respondents have experienced some form of disruption as a result of flooding in the study area. This includes:
    - 73 respondents have experienced traffic disruptions;
    - 154 respondents have had their front or back yard inundated; and
    - 24 respondents have had their house or garage inundated.

- The following streets/areas were identified by several respondents as being particularly susceptible to flooding problems:
    - Shelley Beach Golf Course / Grandview Street, Shelley Beach
    - Tuggerah Lake foreshore
    - Brooke Avenue/Hume Boulevard, Killarney Vale
    - Tasman Ave/Kathleen White Crescent, Killarney Vale
    - Sierra Ave, Bateau Bay
    - Neale St/McLachlan Ave, Long Jetty

- Several respondents noted that they have purchased pumps to help alleviate flooding/ponding of water across their yards and prevent inundation of their home/garage.

- Those respondents living across lower sections of the study area indicate that flooding is predominately caused by elevated water levels within Tuggerah Lake. Those respondents living across the more elevated sections of the catchment believe flooding is exacerbated by:
  - lack of routine maintenance / blockage of stormwater pipes and culverts
  - Inadequate stormwater system
  - Lack of kerb and gutter

2.5.3 Floodplain Risk Management Study

Consultation with the community was also completed at various stages throughout the preparation of the floodplain risk management study. A questionnaire was distributed to 1,060 households and businesses during the initial stage of the project in an effort to understand the types of flooding impacts that the community has experienced, how people would respond during future floods and what key objectives potential flood risk management measures should focus on. A copy of the questionnaire is included in **Appendix A**.

The questionnaire was also included on an interactive website. The website provided the community with an opportunity to explore the advantages and disadvantages of potential flood risk management options and make a more informed decision on what options may be appropriate for implementation as part of the study:
http://www.floodengage.com/killarneyvalelongjetty/

During the course of the study (up to April 2019), the website was visited over 400 times.

A total of 132 questionnaire responses were received. When combined with the flood study (i.e., 585 responses), a total of 717 questionnaire responses were received over the course of the project.

The responses to the questionnaire are included in **Appendix A**. However, a summary of the key outcomes of the consultation is provided below:

- Flood Impacts:
  - 67% of the questionnaire respondents had been impacted by flooding (the location of properties that have experienced flooding problems are shown in **Figure A1** in **Appendix A**).
  - The most common reported impact was roadways being cut by water followed by flooding of garages and sheds. Three respondents reported above floor inundation of their house.
- Flood Awareness:
  - 36% of respondents did not know whether their property could be potentially flooded or not.
  - 43% of respondents acknowledged that their home or business could be flooded.
- Evacuation:
  - During a future flood, 54% of respondents said that they would remain at home. Only 15% said they would evacuate to an official evacuation centre.

  - The primary reason for people choosing to stay at home was concern for the security of their property should they evacuate.
- Flood Risk Management Options:
  - The following factors/goals were considered to be the most important by the community when developing a potential list of flood risk management options:
    - Provides safety to the community during floods
    - Reduced flood damages to the community
    - Raises community awareness and understanding of the local flood risk
    - Improved community access and recreational use
- The interactive website outputs indicate that the following potential flood risk management options were the most favoured by the community:
  - Local Flood Policies and Development Controls
  - Voluntary Purchase of Properties
  - Local Flood Plan Updates
  - Local Flood Warning / Flood Forecasting System
  - Upper Storey Flood Free Refuges
- The interactive website outputs suggested the following potential flood risk management options were the least favoured by the community:
  - Rainwater Tanks
  - Increased Infiltration Capacity
  - Earthen Levee
  - Concrete Lined Channels
  - Channel Realignment

3 DEFINING THE EXISTING FLOOD RISK

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. The former Wyong Shire Council commissioned the *'Killarney Vale / Long Jetty Catchments Flood Study'* (Catchment Simulation Solutions, 2014) to fulfil this requirement. Further information on the flood study and the associated outputs that were used to describe the existing flood risk are provided in the following sections.

Once existing flood behaviour is defined, it was 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 a flood damage assessment was also prepared and is documented in the following sections.

3.2 Existing Flood Behaviour

3.2.1 Overview

The former Wyong Shire Council commissioned the *'Killarney Vale / Long Jetty Catchments Flood Study'* (Catchment Simulation Solutions, 2014) to describe existing flood behaviour across the Killarney Vale and Long Jetty catchments. The flood study utilised a direct rainfall TUFLOW model to describe the transformation of rainfall into runoff and how that runoff would be distributed across the catchment. The model was used to simulate a range of historic and design floods and produce information on key flooding characteristics including floodwater depths, levels and velocities. In general, the flood study determined that relatively short, high intensity rainfall bursts (i.e., less than 3 hours in duration) generate the "worst case" flooding across the catchment.

It is considered that the information presented in the *'Killarney Vale / Long Jetty Catchments Flood Study'* provides the best contemporary description of flood behaviour for the study area and provides a suitable basis for establishing the existing flood risk.

The results from the flood study were used to prepare a series of maps to define the nature and extent of the existing flooding problem. A summary of the maps that were prepared are provided in the following sections.

3.2.2 Presentation of Flood Modelling Results

The adopted modelling approach involved applying rainfall directly to each cell in the computer model and routing the rainfall excess based on the physical characteristics of the catchment (i.e., topography, stormwater system, culverts). Once the rain falling on each grid cell exceeds the rainfall losses, each cell will be "wet". However, water depths across the majority of each catchment will likely be very shallow and would not present a significant flooding problem. Therefore, it was necessary for the results of the computer simulations to be "filtered" to distinguish between areas of significant inundation depth/flood hazard and those areas subject to negligible inundation.

Based upon discussions with Council as well as flood mapping being completed across other nearby catchments, the following criteria were selected to define areas of significant inundation:

- Depth > 0.1 metres; OR
- Depth > 0.05m AND Velocity-Depth Product (VxD) > 0.025m^2/s; OR
- Velocity > 2m/s

The criteria were combined to form a "filtered" flood extent for each design event. However, it was noted that this approach produced a number of isolated "puddles" across the catchments that did not fall within an obvious overland flow path. Therefore, an additional criterion was applied whereby "puddles" with an area of less than 100m^2 were also removed from the mapping.

The above filter criteria were applied to all flood mapping that is presented in the following sections.

It is to be noted that this study does not examine flooding as a result of elevated water levels in Tuggerah Lakes as this was already assessed as part of the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'* (WMAwater, 2014). Nevertheless, design inundation extents for Tuggerah Lake are included on the various flood maps that are documented in the following sections. The inundation extents are based on the peak design Tuggerah Lake water levels documented in **Table 5**. For further information on flood behaviour across Tuggerah Lake, please refer to the *'Tuggerah Lakes Floodplain Risk Management Study and Plan'*.

Table 5 Summary of peak design flood levels for Tuggerah Lake (WMAwater, 2014)

Location	Peak Lake Water Level (mAHD)			
	20% AEP	5% AEP	1% AEP	Maximum Probable Flood
Tuggerah Lake	1.36	1.80	2.23	2.70

3.2.3 Floodwater Depths and Velocities

A range of design floods were simulated as part of the flood study. This included the 20%, 5% 1% events as well as the Probable Maximum Flood (PMF).

Peak floodwater depths were extracted from the results of the 20% AEP, 5% AEP, 1% AEP and PMF simulations and are presented in **Figures 5** to **8**. Flow velocity vectors (showing the speed and direction of floodwater movement), were also extracted and are also presented in **Figures 5** to **8**.

Figures 5 to **8** indicates that during events up to and including the PMF, floodwaters are generally contained near existing creeks/drainage channels. However, more extensive inundation extents are predicted across designated flood detention areas as well as across low lying areas adjoining Tuggerah Lake. This confirms that inundation of the study area can occur because of local catchment runoff as well as elevated water levels in Tuggerah Lake. However, flooding from both the local catchment and Tuggerah Lake is unlikely to occur at the same time as local catchment flooding typically occurs because of relatively short duration rainfall bursts (i.e., less than 3 hours) while flooding of Tuggerah Lake flooding most frequently occurs due to extended rainfall events (i.e., > 1 day).

Inundation from local catchment runoff can occur because of creeks/channels overtopping their banks as well as the capacity of the stormwater system being exceeded. Flooding can also be exacerbated when blockage of stormwater inlet and bridges/culverts occurs.

Significant inundation is predicted across the following areas at the peak of the 1% AEP flood:

- Tuggerah Lake foreshore;
- Hume Boulevard (between Macarthur St and Cunningham Rd) and Wyong Road (between Davidson Ave and Boorana Cl)
- Ferndale St (from Shaw St to open channel on eastern western side of Opal aged care facility
- Wyong Road (between Tasman Ave and The Entrance Road)
- McLean St, Graham St, GlenBook St and The Entrance Road (adjoining Saltwater Creek)
- Overland flow path running parallel with Yakalla St extending from Shelley beach Golf Club to Salt Water Creek
- Overland flow path between Sabrina Ave and Fishermens Bend (north of Rays Road)
- Localised depression between Bonnnieview St and Captain Cook Cres.
- Overland flowpath between Stella St and Elsiemer St
- Major overland flow path that originates near Rodin Drive and drains towards The Entrance Road/Gosford Ave roundabout and continues to drain east along open channel and into Tuggerah Lake
- Overland flow path running parallel to Ashton Ave from Oakland Ave to Tuggerah Pde

In addition to the property inundation summarised above, several roadways would be inundated to a depth that would prevent vehicular access. Further information on the impact of flooding on transportation links is provided in Section 3.3.2.

3.2.4 Performance of Flood Detention Basins

Five flood detention basins are located within the Killarney Vale catchment. (refer **Figure 2**). The results documented in the flood study for each detention basins were reviewed and this determined that:

- the basins typically reduce peak downstream discharges during all floods up to and including the PMF. The only exception is the Eastern Road Basin, which only provides a significant reduction in downstream discharges during events less than the 5% AEP flood.
- Basin C and the Eastern Road Basin are predicted to overtop in events as frequent as the 20% AEP event.
- the Bay Village Basin is predicted to overtop, and Basin B is predicted to overtop in the 1% AEP flood.
- During the PMF, all basins are predicted to overtop.

It should be recognised that the results outlined above are based upon partial blockage of the basin outlets, which will provide less outlet capacity and, consequently, higher design stages within each basin.

Overall, except for the Eastern Road Basin, the detention basins within the study area offer a tangible reduction in downstream discharges. However, each basin could be potentially modified to further assist in reducing downstream discharges during floods.

Impact of Detention Basin Failure

As discussed above, there are five flood detention basins located within the study area. Although the basins are not designed to permanently "store", if failure of any of the basins was to occur when water is stored behind the basin wall, it has the potential to cause a sudden release of water. This may adversely impact on people, properties and the environment in areas downstream of each basin.

To gain an understanding of the impact that failure of the basins may have across downstream properties, an additional basins failure simulation was completed. The basin failure simulation was completed by simulating an additional 1% AEP flood, however, the wall of each basin was dynamically modified to reflect the progressive failure of the downstream wall of each basin. It was assumed that the most upstream basin along each drainage line failed at the time of peak basin stage. The arrival of the "flood wave" from the upstream basin triggered the failure of the next downstream basin and so on. It was assumed that the breach originated in the centre of the spillway/location of first overtopping and propagated to form a trapezoidal shape, as shown in **Plate 4.**

The basin failure parameters (i.e., time and shape of the breach) were defined based upon recommendations in Von Thun and Gillette (1990). The adopted failure parameters are summarised in **Table 6** and **Plate 5.**

Flood level difference mapping was prepared to show the magnitude and extent of changes in 1% AEP flood levels associated with the basin failure. The difference mapping is shown in **Plate 6**.

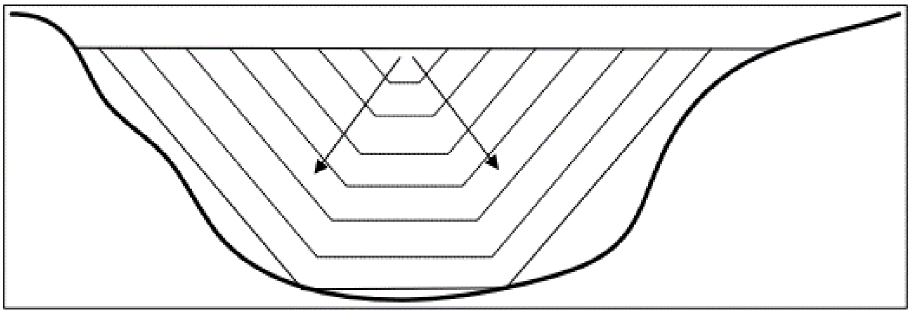


Plate 4 Adopted basin failure breach propagation

Table 6 Comparison of Basin Breach Parameters

Breach Parameter		Basin A	Basin B	Basin C	Eastern Rd Basin	Bay Village Basin
W_b (metres)	Refer **Plate 5**	13.6	11.7	11.1	9.5	12.0
B_t (metres)		23.6	19.1	17.9	13.9	19.9
H_b (metres)		5.0	3.7	3.4	2.2	4.0
Side Slope		1H:1V	1H:1V	1H:1V	1H:1V	1H:1V
Breach Development Time (minutes)		21	19	19	17	20

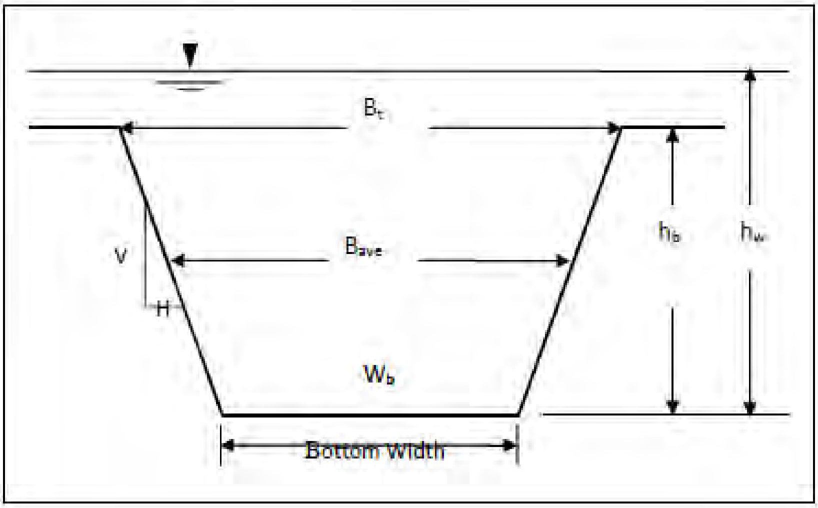


Plate 5 Key basin failure parameters. The trapezoidal shape reflects the ultimate breach shape

As shown in **Plate 6**, failure of the detention basins is predicted to increase peak flood levels downstream of each basin. More specifically, the following increases are predicted:

- Basin A: Downstream properties experience increases of over 0.15 metres;
- Basin B: Downstream properties experience increases of over 0.5 metres;
- Basin C: Downstream properties experience increases of up to 0.7 metres;
- Eastern Road Basin: Downstream properties experience increases of less than 0.1 metres;
- Bay Village Basin: Downstream properties experience increases of up to 0.3 metres.

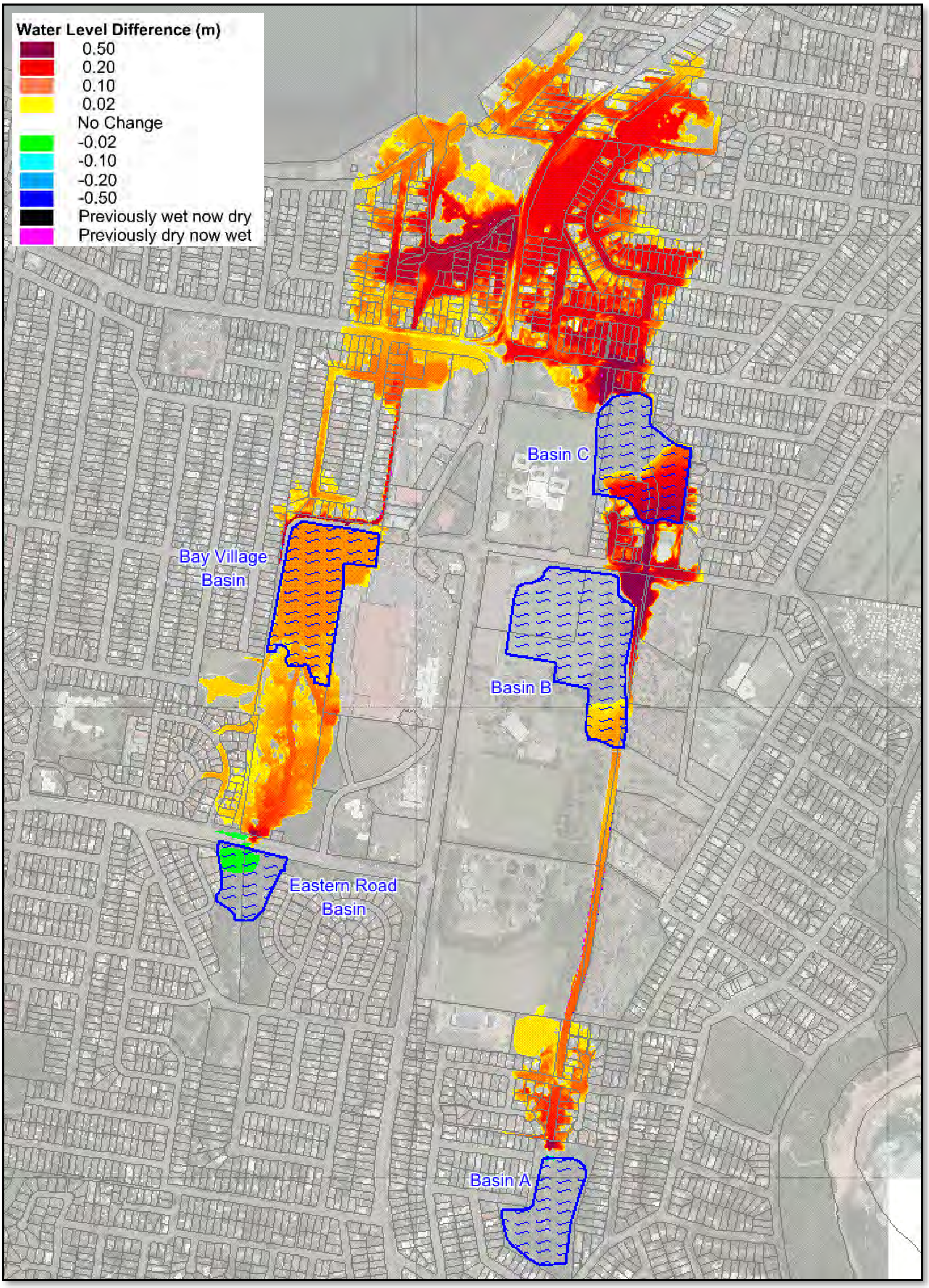


Plate 6 Flood Level Difference Map for Basin Failure Scenario

As shown in **Plate 6** a significant increase in flood level is also predicted downstream of Wyong Road where the two tributaries meet. Increases of over 0.4 metres are anticipated in this area.

The flood level increases are sufficient to increase the flood hazard across downstream properties. The areas of highest flood hazard are typically contained to the open channels and roadways. However, the H5 and H6 hazard categorisation across these roadways indicates it would not be safe for people and failure of the basins would increase the risk to life. Fortunately, the many buildings located downstream of the basins serve to impede the movement of water. Therefore, the 1% AEP hazard is more commonly contained below H4 across downstream residential properties.

Accordingly, failure of the detention basins has the potential to increase the severity of flooding downstream of each basin. Although the flood level increases are typically less than 0.3 metres, there are some downstream areas where the flood level increases are predicted to exceed 0.4 metres.

3.2.5 Design Rainfall Depths and Gauge Heights

Design rainfall depths for the Killarney Vale and Long Jetty catchments are provided in **Table 7**. This information can be potentially used by emergency services to determine the quantity of rainfall over different time periods that would produce floods of differing severities.

The outcomes of the *'Killarney Vale/Long Jetty Catchments Flood Study'* indicate that rainfall over a 1 to 3 hour periods typically produced the worst case flooding across the study area(highlighted in yellow in **Table 7**).

Table 7 Design Rainfall Depths

DURATION	Average Rainfall Intensity (mm/hr)			
	20% AEP	5% AEP	1% AEP	PMP
20 minutes	31	40	51	200
30 minutes	38	49	64	230
1 hour	52	68	89	340
1.5 hour	61	80	105	431
2 hour	68	89	116	500
3 hour	78	102	134	609
6 hour	98	128	169	810
12 hour	126	166	217	N/A
24 hour	166	220	290	N/A
48 hour	218	293	393	N/A
72 hour	247	333	449	N/A

NOTE: N/A indicates a design rainfall is not available for the nominated storm duration

3.2.6 Performance of Stormwater System

The TUFLOW modelling completed as part of the *'Killarney Vale / Long Jetty Catchments Flood Study'* (Catchment Simulation Solutions, 2014) also provided information describing the amount of water flowing into each stormwater pit and through each stormwater pipe. This includes information describing which pipes are flowing completely full during each design flood. This information can be used to provide an assessment of the capacity of each pit and pipe in the stormwater system. In doing so, it allows identification of where stormwater capacity constraints may exist across the catchments.

The pipe flow results of all design flood simulations were interrogated to determine the capacity of each stormwater pipe in terms of a nominal return period (i.e., AEP). The capacity of the pipe was defined as the largest design event whereby the pipe was not flowing completely full. For example, if a particular stormwater pipe was flowing 95% full during the 10% AEP event and 100% full during the 5% AEP event, the pipe capacity would be defined as "10% AEP".

A nominal return period was also calculated for each stormwater pit based on one of the following "failure" criteria:

- AEP at which the pit begins to surcharge;
- AEP at which the water depth at the pit exceeds 0.2 metres;

The resulting stormwater capacity maps are presented in **Figure 9**. As shown in **Figure 9**, the pit and pipe capacities are colour coded based on the nominal capacity that was calculated. Furthermore, different symbols have been applied to each pit to define whether the pit first "fails" via ponding depth or surcharge.

The information presented in **Figure 9** shows that a significant proportion of the stormwater system has a nominal capacity less than or equal to the 20% AEP flood. Accordingly, notable overland flooding could be expected to occur, on average, once every five years. In general, the areas with significant inundation depths during the 1% AEP flood (refer discussion in Section 3.2.3) coincide with areas of limited stormwater system capacity.

However, it should be noted that this outcome is not unusual as stormwater systems are typically not designed to convey large floods such as the 1% AEP event (i.e., it is generally not economically justifiable to design a stormwater system to cater for an event that has only a 1% chance of occurring). Council currently has set the following design standards for stormwater/drainage systems:

- Residential (low density) – 20% AEP;
- Residential (medium & high density), commercial and industrial – 5% AEP;

In addition to the standards set out above, Council requires that overland flow paths be provided and sized to carry flows in excess of the capacity of the stormwater system up to the 1% AEP event.

A review of the flood mapping and stormwater capacity mapping indicates that Council's design standards appear to be met across the majority of the study area. However, there are some areas that do not meet this standard. The capacity mapping indicates that it is lack of pipe capacity rather than lack of pit capacity that is the major limitation in these areas (i.e., the pipes are predicted to fail before the pits).

It should be noted that the drainage assessment assumes partial blockage of all stormwater pits, which may impact on the outcomes of the capacity assessment. Nevertheless, it is unlikely that removal of all blockage would significantly increase the capacity of the drainage system. Therefore, it is considered that the pipe capacity mapping provides a reasonable understanding of the stormwater capacity constraints across the study area.

3.2.7 Flood Hazard Categories

A key component of a flood risk management study involves identifying the potential flood risk across different sections of the study area. One of the major inputs to flood risk is identifying the potential consequences of flooding on people, buildings and vehicles. In this regard, flood hazard mapping was prepared to describe the potential for floodwaters to cause damage to property or loss of life / injury (Australian Government, 2014).

It is noted that flood precinct definitions specified by Council within the *Wyong Development Control Plan 2013* (Wyong DCP 2013) adopt 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 the Australian Government's *"Technical Flood Risk Management Guideline: Flood Hazard"* (2014). 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 7** and are also described in **Table 8**.

As shown in **Plate 7**, the hazard curves assess the potential vulnerability of people, cars and structures based upon the depth and velocity of floodwaters at a particular location. Therefore, peak depth, velocity and velocity-depth product outputs generated by the TUFLOW model were used to map the variation in flood hazard across the Killarney Vale and Long Jetty catchments based on the hazard criteria shown in **Plate 7** for the 1% AEP flood as well as the PMF. The resulting hazard category maps are shown in **Figures 10** and **11**.

Figure 10 indicates that during the 1% AEP flood, the hazard categories across most urban areas is predicted to remain below H4 (although it is noted that the hazard within the main waterways reaches H5 and sometime H6). A hazard designation of less than H4 indicates that able bodied adults would typically be able to wade through most overland flooding areas. However, H3 areas would not be safe for the elderly or children, and cars would likely not be able to drive through H2 and H3 areas.

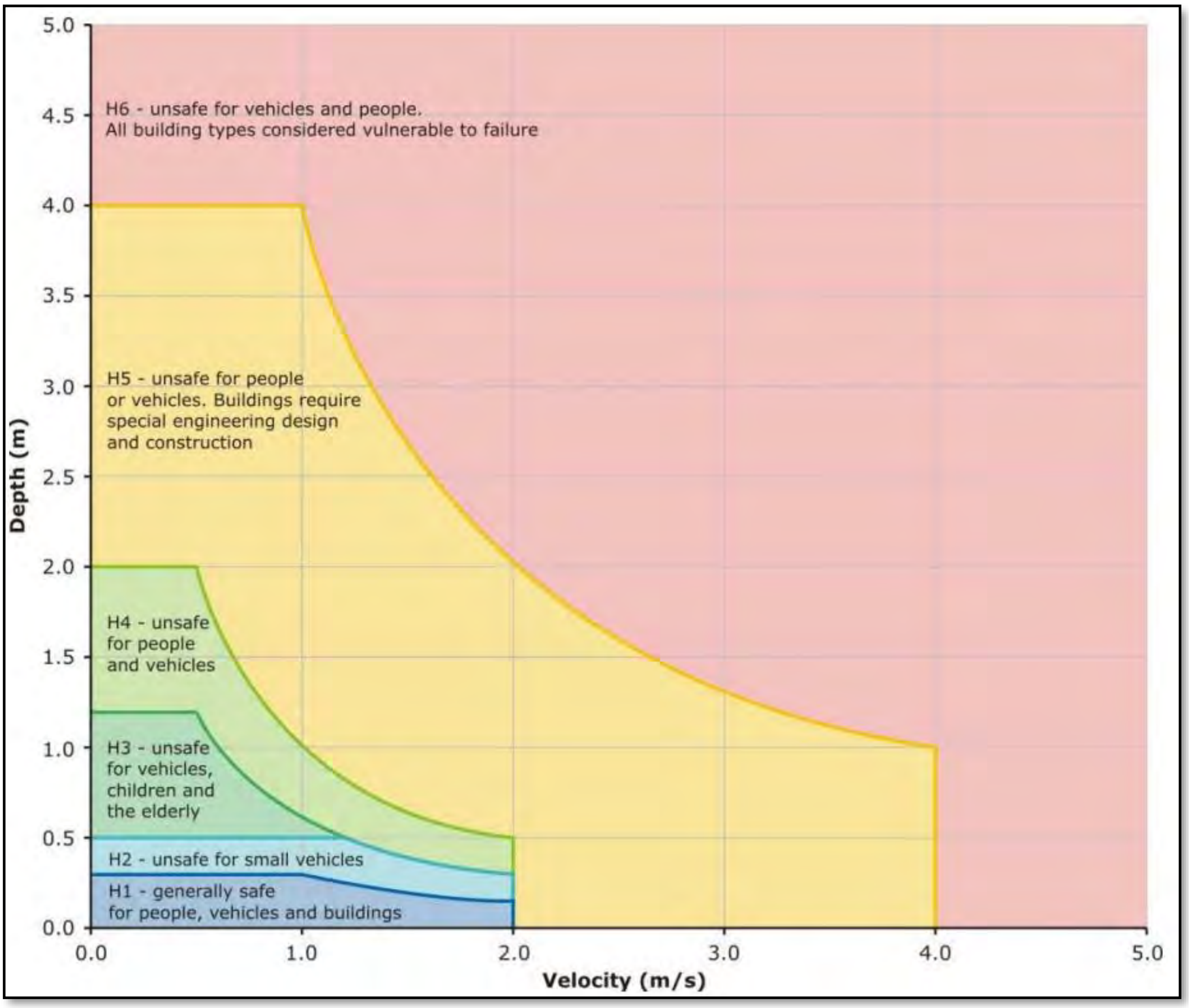


Plate 7 Flood hazard vulnerability curves (Australian Government, 2014)

Table 8 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.

Figure 11 shows that during the PMF more significant inundation is predicted. However, the hazard categories are generally not predicted to exceed H4 across most of the urban sections of the study area. The lack of significant areas of H5 and H6 hazard across the urban areas indicates that structural damage to properties is unlikely to occur during even the largest of floods and there may be opportunities for people to safely shelter inside buildings during large floods.

Nevertheless, the following allotments are predicted to be exposed to a PMF hazard of H5 or H6:

- The Reef Resort (near the intersection of The Entrance Road and Gosford Avenue)
- Properties between Duncan St and Tuggerah Pde (north of Ashton Ave)
- A selection of properties located downstream of Basin C (including properties fronting Shelley Beach Road, Kirrang St, Bloomfield St and Bonniefield Ave)

The H5/H6 categorisation indicates that the integrity of these buildings cannot be guaranteed during a PMF if the building was not specifically designed to withstanding the hydrodynamic forces of the floodwaters. Therefore, safe on-site refuge may not be feasible within these properties.

A number of roadways would also serve as major flow paths during the PMF. Accordingly, these areas would be unsafe for vehicles and pedestrians.

3.2.8 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 8** (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.

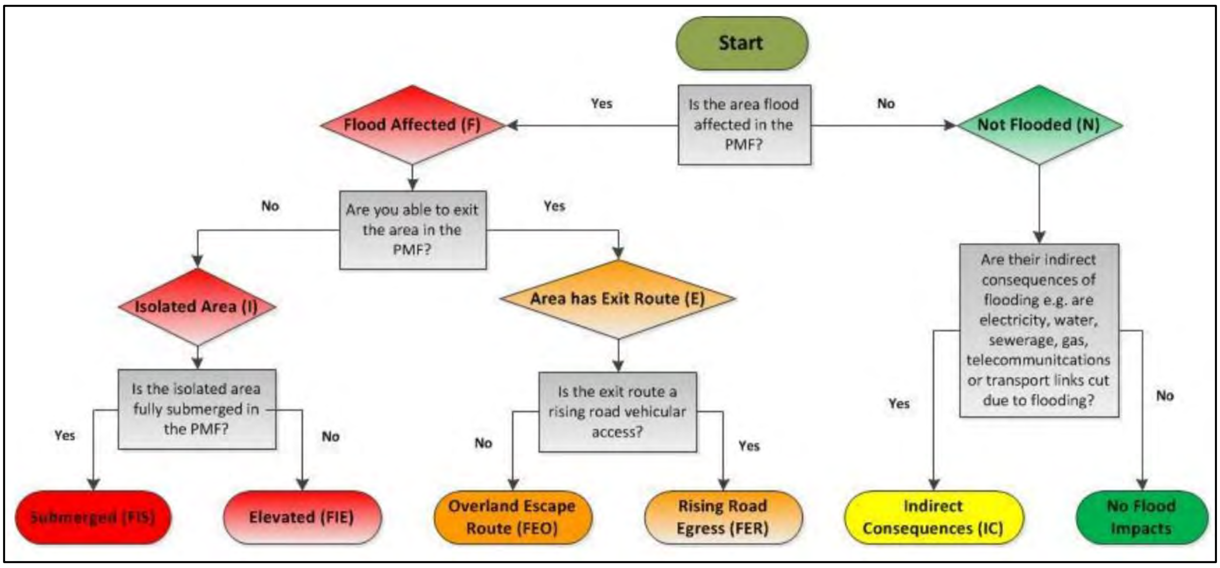


Plate 8 Flow Chart for Determining Flood Emergency Response Classifications (AEMI, 2014).

Each allotment within the Killarney Vale and Long Jetty catchments was classified based upon the ERP flow chart 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); and,
- whether evacuation routes continuously rise out of the floodplain;

The resulting ERP classifications for the 1% AEP flood as well as the PMF are provided in **Figures 12** and **13**. 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 3.3.2.

Figure 12 shows that during the 1% AEP flood, the most common ERP classification is "Rising Road Egress", which indicates that evacuation route grade up and out of the floodwaters. However, there are some "flooded isolated submerged" areas (i.e., low flood islands), which indicates that evacuation routes are likely to be cut.

Figure 13 shows that during the PMF, the number of "flooded isolated submerged" areas increase significantly, particularly, for areas adjoining Saltwater Creek. Accordingly, if a particularly large flood was to occur, there is potential for a very large number of lots to become isolated. The shear number of these "flooded isolated submerged" lots during the PMF (683 lots) and the limited warning times means that it is unlikely emergency services will be able to offer assistance.

3.2.9 Hydraulic Categories

Unlike provisional hazard categories, the *'Floodplain Development Manual'* does not provide explicit 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.

However, the *'Floodplain Development Manual'* does provide qualitative guidelines to assist in the delineation of hydraulic categories. The *"Floodway Definition"* guideline (Department of Environment and Climate Change, 2007) also provides additional guidance for the definition of floodway extents. This information was used as the basis for developing qualitative criteria to define the hydraulic categories as part of the flood study to define hydraulic categories. The adopted criteria are summarised in **Table 9** and the resulting hydraulic category maps for the 1% AEP flood and PMF are shown in **Figures 14** and **15**.

It should be noted that there is negligible flood fringe shown in **Figures 14** and **15**. This is associated with the "filtering" that was completed to remove model results from those areas subject to negligible floodwater depths. Filling of these areas is unlikely to produce a significant impact on existing flood behaviour. Therefore, it is considered that those areas not subject to any hydraulic category in **Figures 14** and **15** could also be considered flood fringe.

As noted in **Table 9**, floodways are areas that should be kept free of flow obstructions to ensure flood behaviour is not adversely impacted. However, **Figure 15** shows some floodway areas extending through multiple properties. Accordingly, there are likely to be multiple obstructions to flow within the floodway area including buildings and solid fencing. It is recommended that opportunities to remove significant flow impediments within the floodway areas be explored. This may be possible through DCP modifications, which are discussed in more detail in Section

3.2.10 Australian Rainfall & Runoff 2016

The *'Killarney Vale / Long Jetty Catchments Flood Study'* (Catchment Simulation Solutions, 2014) derived design flood estimates based upon hydrologic procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987) (referred to herein as ARR1987). Since publication of this study, a revised version of Australian Rainfall and Runoff has been released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, additional investigations were completed to confirm the impact that the revised hydrologic procedures may have on design flood behaviour across the Smithfield West catchment and determine the most appropriate hydrologic procedures to carry forward into the Killarney Vale / Long Jetty Floodplain Risk Management Study.

Table 9 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Floodplain Development Manual Definition	Adopted Criteria*
Floodway	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels and drainage depressions • they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	Depth >= 0.5m, and Velocity >= 0.8, and VxD product >= 0.2, OR Hand delineation based upon areas where the majority of flow is conveyed. This was based on visual interpretation of velocity, depth and flow outputs
Flood Storage	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • if the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.	Areas that are not floodway and where the depth of inundation is greater than 0.15 metres
Flood Fringe	• the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. • development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	Areas that are not floodway where the depth of inundation is less than 0.15 meters

NOTE: * The criteria adopted for the definition of hydraulic categories is specific to this study area and may not be appropriate across other areas

The outcomes of the ARR2016 analysis is summarised in **Appendix B** and determined that the revised hydrologic procedures summarised in ARR2016 would produce slightly higher peak flood level estimates across some areas relative to ARR1987, but slightly lower flood levels across other areas. In general, the differences in flood levels are minor (i.e., less than 0.1 metres). Therefore, the revised ARR2016 approaches don't appear to afford a sufficient difference to warrant a revised hydrologic approach as part of the Killarney Vale / Long Jetty Floodplain Risk Management Study. Therefore, the ARR1987 hydrology was retained for the current study.

3.3 Impacts of Flooding

3.3.1 Impact of Flooding on Key and Vulnerable Facilities

The Killarney Vale and Long Jetty catchments are 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., evacuation centres). Therefore, it is important to understand the potential vulnerability of these facilities during a range of floods.

A list of vulnerable facilities within the Killarney Vale and Long Jetty catchments are discussed below and are also summarised in **Table 10**. **Table 10** 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.

- **Fire Stations**:
  - *The Entrance Fire and Rescue* (24 Boondilla Road, The Entrance): not predicted to be directly impacted by floodwaters during any of the design events.
  - *Bateau Bay Fire and Rescue* (1 Community Road, Bateau Bay): not predicted to be directly impacted by floodwaters during any of the design events.
- **The Entrance Police Station** (12/14 Dening Street, The Entrance): not predicted to be directly impacted by floodwaters during any of the design events.
- **Evacuation Centres**:
  - *Diggers @ The Entrance* (315 The Entrance Road, Long Jetty): Serves as the primary evacuation centre in the study area during floods. The site is not predicted to be inundated during the 1% AEP or PMF events. However, The Entrance Road is predicted to be cut to the north and south of the site. Therefore, travel from other sections of the study area to the site may not be possible during large floods.
  - *Bateau Bay Bowling Club* (5 Bias Ave, Bateau Bay): Serves as a local evacuation centre in the study area during floods. The car park is predicted to be inundated during the 1% AEP and PMF events. Therefore, evacuation to/from the site may not be possible during large floods.
  - *The Entrance Leagues Club* (3 Bay Village Road, Bateau Bay): Serves as an evacuation centre. The site itself is not directly affected during the PMF Floods however nearby roads such as Bay Village Rd and Eastern Rd are cut during the PMF and 1% AEP. Therefore, travel to the site may not be possible during large floods.
  - *Shelly Beach Golf Club* (Shelly Beach Road, Shelly Beach): Serves as another evacuation centre. The site is not predicted to be inundated during the 1% AEP or PMF events however both Shelly Beach Rd and Bonnieview St are cut during the PMF and 1% AEP. Therefore, travel to the site may not be possible.
- **Caravan Parks**:
  - *Lakeview Tourist Park* (491 The Entrance Road, Long Jetty): The caravan park is expected to be inundated during the 1% AEP as well as the PMF event. However, roads entering the site are expected to be cut in events as common as the 20% AEP event. As a result, vehicular access may not be possible during larger events.

  - *Paradise Park Cabins* (137 Tuggerah Parade, Long Jetty): The site is expected to be inundated in events as common as the 20% AEP event. Additionally, both Shelly beach Road, Tuggerah Parade and Pacific St are cut during the 20% AEP. Therefore, evacuation from the site may not be possible during large floods.
- **Bateau Bay Ambulance Station** (2 Community Road, Bateau Bay): not predicted to be directly impacted by floodwaters during any of the design events.
- **Hospitals**: There are no hospitals located within the catchment;

Table 10 Impact of Flooding on Key and Vulnerable Facilities

Key Infrastructure		1% AEP Flood		PMF	
		Property Flooded?	Access Cut?	Property Flooded?	Access Cut?
Fire Stations	*The Entrance Fire and Rescue* (24 Boondilla Rd, The Entrance)				
	Bateau Bay Fire and Rescue (1 Community Rd, Bateau Bay)				
Police Stations	*The Entrance Police Station* (12/14 Dening St, The Entrance)				
Evacuation Centre	*Diggers @ The Entrance (315 The Entrance Road, Long Jetty)*				
	Bateau Bay Bowling Club (5 Bias Ave, Bateau Bay)	☑	☑	☑	☑
	The Entrance Leagues Club (3 Bay Village Road, Bateau Bay)		☑		☑
	Shelly Beach Golf Club (Shelly Beach Road, Shelly Beach)		☑		☑
Caravan Parks	*Lakeview Tourist Park (491 The Entrance Road, Long Jetty)*	☑	☑	☑	☑
	Paradise Park Cabins (137 Tuggerah Parade, Long Jetty)	☑	☑	☑	☑
Ambulance Stations	*Bateau Bay Ambulance Station* (2 Community Rd, Bateau Bay)		☑		☑
Hospitals		There are no hospitals located within the study area			
Schools	*The Entrance Public School* (80 Oakland Ave, The Entrance)				
	Our Lady of the Rosary Catholic School (Cnr The Entrance Rd and Shelley Beach Rd, Shelley Beach)		☑	☑	☑
	Tuggerah Lakes Secondary College (Cnr The Entrance Rd and Yakalla St, Long Jetty)			☑	☑
	Brooke Avenue Public School (Brooke Ave, Killarney Vale)			☑	☑

Key Infrastructure		1% AEP Flood		PMF	
		Property Flooded?	Access Cut?	Property Flooded?	Access Cut?
Aged Care Facilities	*Opal Aged Care* (1 Daniel Close, Killarney Vale)	☑	☑	☑	☑
	Bupa Care Services (17 Bias Ave, Bateau Bay)	☑		☑	
	Elderslee Retirement Village (15 Bias Ave, Bateau Bay)			☑	
	Karagi Court Retirement Village (2 Pheasant Ave, Bateau Bay)			☑	
	Australian Unity Kiah Lodge Aged Care Facility (15 Anne Findlay Place, Bateau Bay)	☑		☑	☑
	Nareen Gardens Aged Care Facility (5 Yakalla St, Bateau Bay)	☑		☑	☑
	Nareen Gardens Self Care Units (68 Bias Ave, Bateau Bay)			☑	
	Reynolds Court Retirement Village (7 Bias Ave, Bateau Bay)	☑		☑	☑

- **Schools**:
  - o *The Entrance Public School* (80 Oakland Ave, The Entrance): not predicted to be directly impacted by floodwaters during any of the design events.
  - o *Our Lady of the Rosary Catholic School* (Cnr The Entrance Road and Shelley Beach Road, Shelley Beach): not predicted to be directly impacted by floodwaters up to and including the 1% AEP event. However, inundation of some school property adjacent to the drainage canal (outflow canal of Basin B) is predicted during larger floods and roadway access along Shelley Beach Road will also be affected. During the PMF, a significant proportion of the school property will be flood affected, including multiple buildings, and adjoining roadways.
  - o *Tuggerah Lakes Secondary College - The Entrance Campus* (Cnr The Entrance Road and Yakalla St, Long Jetty): not predicted to be directly impacted by floodwaters during any of the design events, however the school is adjacent to Basic C, and portions of the playing fields may be impacted.
  - o *Brooke Avenue Public School* (Brooke Avenue, Killarney Vale): Some flooding is expected from build-up along the structures in events up to and including the PMF event, however depths and velocities are minor.
- **Aged Care Facilities**:
  - o *Opal Aged Care* (1 Daniel Close, Killarney Vale): The south-western wing of the nursing home is expected to be impacted by flooding in events as common as the 5% AEP event, and the main access roadway (Daniel Close) is predicted to be exposed to significant flow depths (>0.5m depth) during all design events. As a result, Benalla Cl and Malaleuca St may need to be used for access during floods. In

events greater than the 1% AEP, vehicular access to the nursing home will not be possible.

- o *Bupa Care Services* (17 Bias Avenue, Bateau Bay): Very limited, shallow inundation is predicted across part sections of the site during the 1% AEP flood (evacuation would not be cut). Property is predicted to be subject to more significant inundation during the PMF, although the flood hazard across most of the site is not predicted to exceed H2. Evacuation via Bias Ave should still be possible during the PMF;
- o *Elderslee Retirement Village* (15 Bias Avenue, Bateau Bay): Shallow inundation is predicted across limited sections of the site during the 1% AEP flood (evacuation would not be cut. More significant inundation is predicted during the PMF, although the flood hazard across most of the site is not predicted to exceed H2 (a small section of H3 hazard is predicted immediately adjacent to the western site boundary). Evacuation via Bias Ave should still be possible during the PMF;
- o *Karagi Court Retirement Village* (2 Pheasant Avenue, Bateau Bay): Property is predicted to be subject to shallow inundation at the peak of the 1% AEP flood and PMF (i.e., H1 hazard only). Evacuation via Pheasant Ave or Yakalla St should be possible during the 1% AEP flood and PMF;
- o *Australian Unity Kiah Lodge Aged Care Facility* (15 Anne Findlay Place, Bateau Bay) Subject to shallow inundation during the 1% AEP flood (however, access would not be cut). More significant inundation during the PMF (including some areas of H4 hazard). Evacuation would also be cut during the PMF, so emergency access may not be available;
- o *Nareen Gardens Aged Care Facility* (5 Yakalla Street, Bateau Bay): Shallow inundation is predicted during the 1% AEP flood (H1 hazard), but evacuation via Yakalla Road would be possible. More significant inundation is predicted during the PMF, although most of the site is exposed to a hazard classification of H3 or below. Vehicular access would likely be cut during the PMF;
- o *Nareen Gardens Self Care Units* (68 Bias Avenue, Bateau Bay)
  Not predicted to be directly impacted by floodwaters during any of the design events up to the 0.4% AEP. However, these properties back onto Saltwater Creek, and hence a high hazard floodway exists in this area.
- o *Reynolds Court Retirement Village* (7 Bias Avenue, Bateau Bay); on-site roadway area impacted in all events greater than the 20% AEP, and some inundation is predicted around buildings during the PMF. Evacuation is likely to remain open via Bias Ave towards Bateau Bay Road.

The assessment summarised in **Table 10** indicates that the majority of vulnerable and key facilities within the study area would not be significantly impacted during the 1% AEP flood. However, more significant impacts are anticipated during the PMF.

As outlined above, the most significantly impacted vulnerable facility is the Opal Aged Care facility, where access will be cut and the property will be inundated during the 1% AEP flood. Therefore, it may not be possible for emergency service vehicles (ambulances) to access this property during floods.

3.3.2 Transportation Impacts

There are a several major roadways within the Long Jetty and Killarney Vale catchments which may be required for evacuation or emergency services access during floods. It is important to understand 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 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 12** and **13**. The overtopping locations shown in **Figures 12** and **13** 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. Additional roadway inundation information is also included in **Appendix E**.

There are two major roadways located within the Killarney Vale and Long Jetty catchments which may be required for evacuation or emergency services access during floods. The outcomes of the transportation impact assessment indicate that:

- Wyong Road: The roadway remains relatively flood free for all events up to the 1% AEP flood, where a maximum depth of 0.35 m is expected along some isolated areas of the roadway shoulder; however, vehicular passage should be possible along the northern carriageway. During the PMF, Wyong Road is expected to be inundated with up to 0.7m of floodwaters near Hume Boulevard, Brooke Avenue and Kathleen White Crescent, and vehicular access would be cut at all locations. In general, the roadway would be cut for at least 30 minutes during a PMF.
- The Entrance Road: The Entrance Road experiences up to 0.6m depth in the 1% AEP flood between Graham Street and Lake Street, Long Jetty (encompassing the Saltwater Creek Bridge), and depths of up to 1.3m are experienced between Anzac Rd and Gosford Ave. The depths at each of these locations increase to over 1.9m and 2.2m respectively during the PMF. Accordingly, access would be prevented along The Entrance Road during significant floods within the Killarney Vale and Long Jetty catchments. The roadways would be cut for a minimum of 30 minutes during large floods.

Figures 12 and **13** shows that multiple other roadways within the study area would also be cut during a 1% AEP flood or PMF. In general, the roadways would be cut in as little as 15 minutes after the initial onset of rainfall and would remain cut for between 30 and 60 minutes. Some roadway “sag” points” would remain inundated for well over 1 hour.

Overall, the outcomes of the transportation impact assessment shows that very little warning time would be available during most floods in the Long Jetty and Killarney Vale catchments. This indicates that minimal time would be available for emergency services to mobilise resources and evacuate people from the study area during future floods. Fortunately, most roadways would not be cut for a significant amount of time (i.e., less than 1 hour at most locations). However, the short warning times means that there is a high probability of people becoming isolated.

It should be noted that the degree of blockage can significantly impact flood levels near bridge and culvert crossings. Accordingly, roadway crossings may be cut more frequently if structures become partially or fully blocked during a flood. Conversely, the level of service may improve if the structures remain free from blockage.

3.3.3 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 Killarney Vale and Long Jetty catchments. 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 11**. The number of properties subject to property damage (even if above floor flooding is not predicted) are also provided in **Table 11**. This includes damage to external items such as fences, sheds and garages.

Table 11 Number of Properties Subject to Above Floor Inundation and Property Damage

Flood Event	Residential		Commercial/ Industrial		Total Number	
	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation	Damaged	Above Floor Inundation
20% AEP	171	1	8	8	179	9
5% AEP	314	12	10	10	324	22
1% AEP	450	26	11	11	461	37
0.4% AEP	517	52	18	18	535	70
PMF	1584	331	37	37	1621	368

Table 11 shows that above floor inundation is predicted to occur across both residential and commercial/industrial properties as frequently as the 20% AEP flood with 1 residential property and 8 commercial/Industrial properties impacted. During the 1% AEP event, 450 residential properties are predicted to suffer flood damage (26 of which are predicted to be inundated above floor level). Additional information on property impacts during each design flood is provided in **Appendix F**.

The final flood damage estimates for each design flood is summarised in **Table 12** for existing topographic and development conditions. It indicates that if a 1% AEP flood was to occur, over $2.3 million worth of damage could be expected. Over half of that damage cost would be incurred across residential properties.

Table 12 Summary of Flood Damages for Existing Conditions

Flood Damage Component	Flood Damages (2017 dollars)				
	20% AEP	5% AEP	1% AEP	0.4% AEP	PMF
Residential	$177,313	$718,904	$1,308,167	$2,553,723	$18,083,083
Commercial.	$303,505	$566,326	$715,768	$863,723	$2,088,184
Industrial	$0	$4,783	$10,351	$15,640	$43,099
Infrastructure	$72,123	$193,502	$305,143	$514,963	$3,032,155
TOTAL	$552,941	$1,483,515	$2,339,429	$3,948,049	$23,246,521

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 Killarney Vale and Long Jetty catchments was determined to be **$291,000**. 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 $291,000 per annum (on average).

3.4 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. The interim climate change factors published in Australian Rainfall and Runoff (Geoscience Australia, 2016) indicates that a 18.6% increase is the most conservative estimate of likely increases in rainfall for the year 2090 (refer **Plate 14**).

Interim Climate Change Factors

Values are of the format temperature increase in degrees Celcius (% increase in rainfall)

	RCP 4.5	RCP6	RCP 8.5
2030	0.892 (4.5%)	0.775 (3.9%)	0.979 (4.9%)
2040	1.121 (5.6%)	1.002 (5.0%)	1.351 (6.8%)
2050	1.334 (6.7%)	1.28 (6.4%)	1.765 (8.8%)
2060	1.522 (7.6%)	1.527 (7.6%)	2.23 (11.2%)
2070	1.659 (8.3%)	1.745 (8.7%)	2.741 (13.7%)
2080	1.78 (8.9%)	1.999 (10.0%)	3.249 (16.2%)
2090	1.825 (9.1%)	2.271 (11.4%)	3.727 (18.6%)

Plate 9 Adopted rainfall intensity increase for climate change simulation (Geoscience Australia, 2017)

Although it was acknowledged that sea level rise could impact on Tuggerah Lake water levels, the focus of the current study is on the more elevated sections of the catchments located away from the lake (and, therefore, Tuggerah Lake water level increases will have less of an impact). As a result, no specific allowance for sea level rise was included in the climate change simulations.

Peak 1% AEP inundation extents were extracted from the results of the climate change simulations and are presented in **Figure 16**. The inundation extents for 'existing' conditions are superimposed for comparison.

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 the climate change simulation and are presented in **Table 13**.

Table 13 Predicted Climate Change Impacts

Metric	Existing	Climate Change 18.4% Increase in Rainfall
Inundated Area (km^2)	1.8	**2.5** (35% increase)
Buildings Flooded Above Floor Level	37	**55** (49% increase)
Flood Damage ($ millions)	2.34	**3.29** (40% increase)

As shown in **Figure 16**, climate change has the potential to cause increases to existing inundation extents. However, the changes in inundation extents are relatively minor across most sections of the catchment.

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 50% during the 18.4% increase in rainfall scenario. This is predicted to increase the damage costs incurred during a 1% AEP flood by about 40%.

Accordingly, climate change does have the potential to increase the existing flood risk and the potential financial impacts of future floods.

3.5 Summary of Flooding "Trouble Spots"

The information presented in this section indicates that parts of the Killarney Vale and Long Jetty catchments are predicted to be exposed to inundation during relatively frequent floods. In particular, the following areas are likely to experience significant property damage, risk to life and/or evacuation difficulties during floods within the catchments:

- Hume Boulevarde and Wyong Road near Macarthur Street, Killarney Vale;
- Davidson Avenue at Ferndale Street, Killarney Vale;
- Wyong Road near Kathleen White Crescent, Killarney Vale;
- Grandview Street, Shelly Beach;
- The Entrance Road at Norfolk Street, Long Jetty

Furthermore, a number of major roads are predicted to be cut by floodwaters in events as frequent as the 20% AEP flood. This will likely have negative impacts on emergency response during floods and may pose a risk to any motorists that attempt to drive through the floodwaters. If a PMF was to occur, there is potential for structural failure of some buildings. Due to the limited amount of warning time available, there may not be an opportunity to evacuate from these buildings before the peak of the flood arrives.

4 Existing Planning Information

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 following sections discuss existing planning legislation and policies that affect the development of land within the Central Coast Council Local Government Area.

4.1 National Provisions

4.1.1 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 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 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.

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), 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*. Certain development on the floodplain is also required to satisfy the requirements of the BCA under *Wyong Development Control Plan 2013* (currently being revised). The Building Circular also indicates that following development approval, an application for a construction certificate (CC) will require assessment of compliance with the BCA.

4.2 State Provisions

4.2.1 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 9.1 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 the then Section 117 (now Section 9.1) 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.

The question as to whether flood behaviour in the Killarney Vale/Long Jetty local catchments commends the imposition of flood related development controls above the residential flood planning level is considered in Section 4.2.3.

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. (Note that previously this clause was Section 149).

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 lot that is a flood control lot is a prescribed matter for the purpose of a certificate 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.

4.2.2 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 this '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 industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing)*'. 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 3.5 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)[1], flood affectation, access, and car parking (see **Plate 10**).

(2) If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:
 (a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,
 (b) any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,
 (c) any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),
 (d) the development must not result in increased flooding elsewhere in the floodplain,
 (e) the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,
 (f) vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,
 (g) the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.

Plate 10 Extract from 'Codes' SEPP 2008 Clause 3.5(2)
Note: version dated 22 December 2017

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.

In order to facilitate the process of applying for complying development, the preparation and sharing of the following spatial information is advantageous:

- land that is a flood control lot. This will reflect the standards set in the LEP and DCP, which shape the flood planning area. Draft mapping of the flood planning area was provided in the Killarney Vale/Long Jetty Catchments Overland Flood Study (Catchment Simulation Solutions, 2014) and was refined as part of the current study (refer Section 4.3.1). Especially for rainfall-on-the-grid models such as that employed for this study area, some 'artistry' may be required to define mapping outputs suitable for use by planners (Gear et al., 2016);
- land where Council is confident a Complying Development Certificate (CDC) could be issued, that is, where the land in a flood control lot is not a flood storage area, floodway area, flow path, high hazard area or high risk area. This mapping may also require some 'artistry', since what constitutes a 'flow path' in overland flow catchments may not be obvious (Gear et al., 2016). Hydraulic function mapping and hazard mapping in the Killarney Vale/Long Jetty local catchments has been developed as part of the current

[1] Clause 3.5(2)(c) implies that an on-site refuge can function as a refuge under clause 3.5(2)(e) for the purposes of the SEPP.

study. Nonetheless, here too careful consideration is required. Defining flood storage areas as areas where the depth of inundation is greater than 0.15 m (and is not a floodway) could set too conservative a trigger for requiring formal development approval. What constitutes 'high hazard' is not clear. If based on the NSW Floodplain Development Manual, this could mean a high hydraulic hazard (depth > 1.0 m, or velocity > 2.0 m/s, or depth-velocity product > 0.7 m^2/s) or high 'true' hazard. The hydraulic hazard categories adopted for the new national guideline are different and what specifies a 'high' hazard is not explicitly defined. Consideration of 'risk' implies that other factors such as available warning time and evacuation constraints are important considerations in mapping where CDCs could be issued.

4.2.3 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.

At the time of preparation of this report, the NSW Floodplain Development Manual is being updated.

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 (now Section 9.1) Direction 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 4.15 (previously Section 79C) of the EP&A Act.

The Guideline states that councils should not include a notation for residential development on Section 10.7 (previously 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 10.7(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 above the default FPL.

In considering whether a case for 'exceptional circumstances' should be made for the Killarney Vale/Long Jetty overland flow catchments, consideration is given to how differently floods behave in the probable maximum flood (PMF) compared to the 'planning flood' (i.e., the 1% AEP flood). One measure is the flood height range between the 1% AEP flood and the PMF, which is shown in **Plate 11** as a flood level "difference map". **Plate 11** shows that for most of the catchment, the difference is less than 0.5 metres (refer blue and aqua colours). Residential areas where the flood height range exceeds 0.5 m include:

- Ferndale St, Killarney Vale (west of Opal Aged Care facility) – increases up to 0.6m.
- Nareen Gardens Aged Care, Yakalla Street, Bateau Bay, adjacent to Basin B – up to about 0.7 m
- Parts of Laird Close, Marquis Close and Viscount Close, Shelly Beach downstream of Basin B – up to about 0.8 m
- Properties between Basin C and Shelly Beach Road, including Kirrang Street, Shelly Beach – up to about 1.0 m
- Some more extensive areas in the lower part of Saltwater Creek catchment including 0.8 metres in Glenbrook St and about 1.1 m in Graham Street, Long Jetty.
- The Reef Resort (near the intersection of The Entrance Road and Gosford Avenue) – up to 1.2 m

From this inspection, the maximum flood height range is about 1.2 metres, though such areas tend to be very localised and may reflect modelling protocols employed around fences and buildings. A significant difference in flood level was also noted on the eastern side of the Bateau Bay shopping Centre. However, none of the local drainage system for this area is included in the flood model so the reported flood level differences are likely to be exaggerated.

Another consideration is whether residentially zoned land is affected by flooding depths and velocities that could pose a substantial threat to life (H4) and buildings (H5–H6) in the PMF. Very few residential properties are subject to these conditions (refer **Figure 11**).

Given the relatively modest flood height range between the 1% AEP and PMF levels, and the few residential properties subject to overland flow that reach a threshold of high hazard, it is judged that flood behaviour in the Killarney Vale/Long Jetty overland flow catchments does not reach the threshold required for an application of 'exceptional circumstances'.

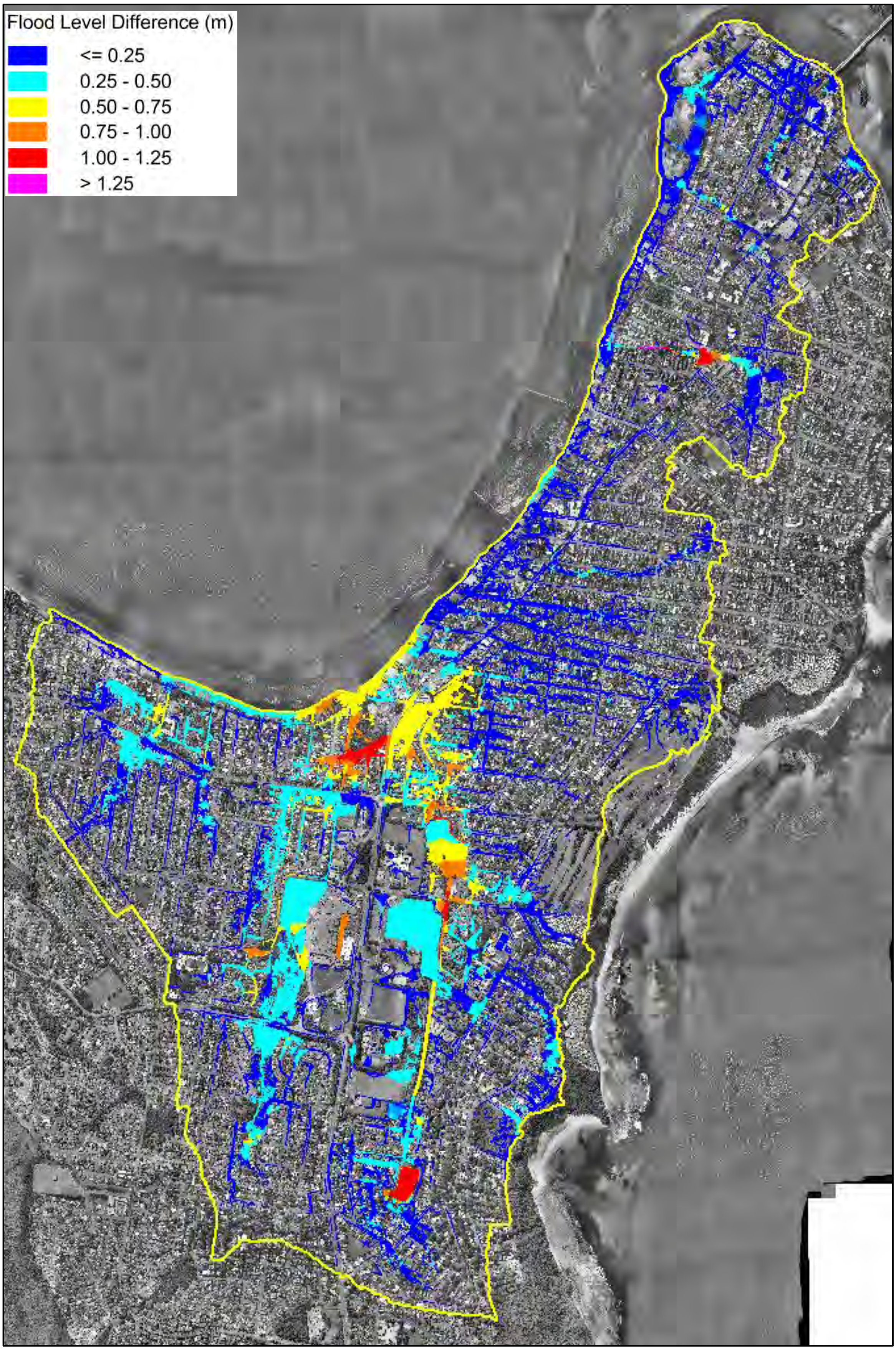


Plate 11 Difference between PMF and 1% AEP Flood Water Levels

4.3 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. This section briefly describes and reviews the flood-related controls within the existing Wyong Shire policies, with a view to flood behaviour in the Killarney Vale and Long Jetty catchments study area.

4.3.1 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.

Flood planning and floodplain risk management are addressed in clauses 7.2 and 7.3. These are reproduced in **Plate 12**. Clause 7.2 relates to land at or below the flood planning level (FPL), sometimes called the 'flood planning area'. Clause 7.3 relates to land between the FPL and the PMF. The 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'.

The appropriateness of the existing Wyong LEP 2013 for managing flood risk in the Killarney Vale/Long Jetty local catchments is considered under the following headings:

- Flood planning area definition
- Compatibility of existing land use zones with flood hazard
- Evacuation challenges

Flood planning area definition

Flood Planning Levels (FPLs) and the Flood Planning Area (FPA) are important tools in the management of flood risk. The FPA is used to define the area where flood-related development controls apply. For those areas contained within the FPA, the FPLs are frequently used to establish the elevation of critical components of a development, such as minimum floor levels.

The FPL is typically derived by adding a freeboard to a specific design flood. This specific design flood is frequently referred to as the "planning" flood. The freeboard is intended to account for any uncertainties in the derivation of the planning flood level.

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.

Plate 12 Extract from Wyong LEP 2013 Clauses 7.2 and 7.3

Note: version dated 1 September 2017

The adoption of the 1% AEP flood for setting the flood planning level (FPL) is considered appropriate for the Killarney Vale/Long Jetty local catchments. A more frequent design flood would expose communities to too great a risk, while a rarer event is not considered warranted given the modest flood height range between the 1% AEP flood and the PMF across most of the catchment (see **Section 4.2.3**).

Traditionally a 0.5 metre freeboard has been added to the planning flood to define the FPL and this FPL has been extended laterally until it encounters higher ground to define the FPA. While this approach is suitable for areas bound by higher ground (e.g., lakes, creek, rivers), it is not necessarily appropriate for urban catchments where the FPL may not be contained by higher ground (refer **Plate 13**).

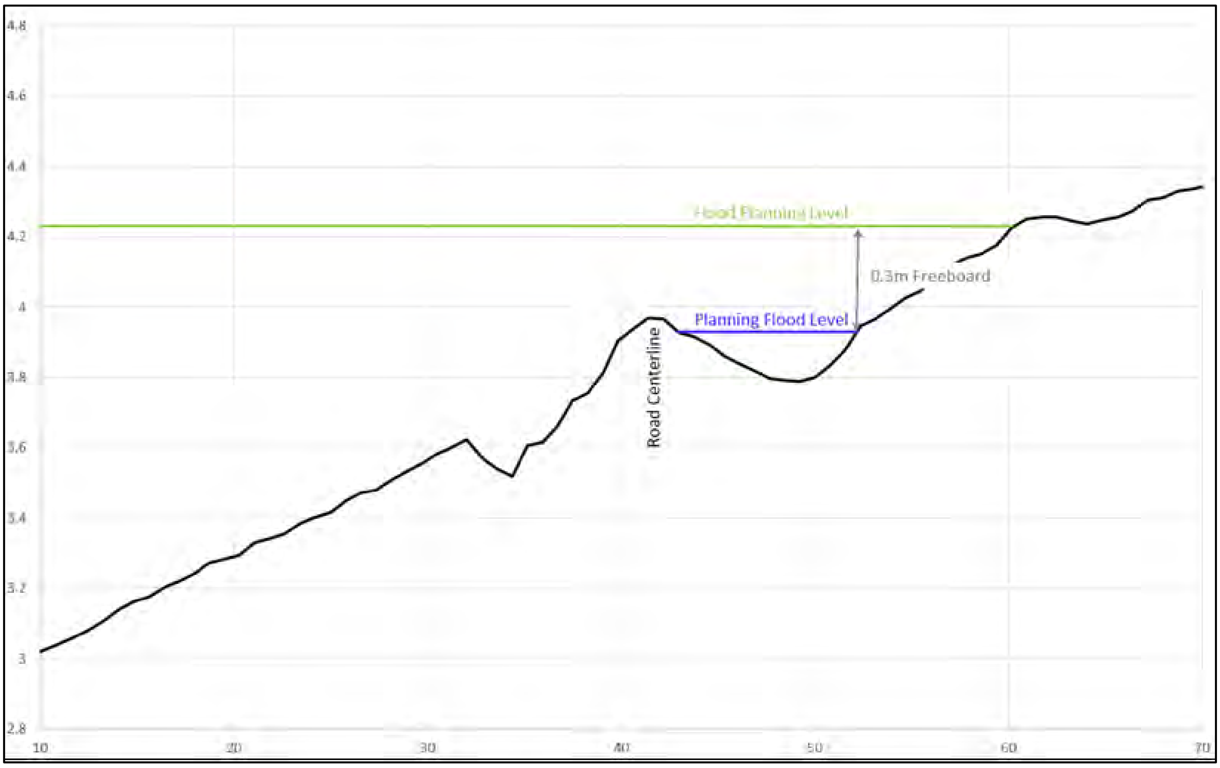


Plate 13 Example of inappropriate FPL/FPA in urban catchment

There is currently no industry standard for defining the FPA and FPL in an urban catchment. It is also noted that although the FPA has historically been defined based upon the FPL, this is not a requirement.

In recognition of the challenges involved in mapping the FPA in an urban catchment, studies for other nearby catchments (e.g., *'Tuggerah Lakes Southern Catchments Flood Study'* WMAwater, 2018) have defined the FPA by incorporating a rainfall intensity increase to the 1% AEP event and using the inundation extent from this simulation to define the FPA. The rainfall intensity increase serves as a factor or safety (i.e., freeboard), thereby incorporating an allowance for uncertainty while ensuring a hydraulically realistic FPA is provided. For this study, a similar approach was adopted whereby the FPA was defined by re-simulating the 1% AEP flood with a 30% increase in rainfall to account for uncertainties. The resulting FPA is shown in **Figure 17**.

As discussed, a 0.5 metres freeboard has traditionally been added to the 1% AEP flood level to define the FPL. However, the addition of a 0.5 metre freeboard may not be appropriate for the entire Local Government Area. An analysis of modelling sensitivities and uncertainties for the Killarney Vale/Long Jetty local catchments was undertaken as part of the '*Killarney Vale/Long Jetty Catchments Overland Flood Study*' (Catchment Simulation Solutions, 2014). This considered variations in rainfall intensities, initial/continuing losses, hydraulic roughness, stormwater/culvert blockage, fence blockage and lake level. Statistical analysis concluded that a "worst case" confidence limit of 0.3 metres was considered to be appropriate across the majority of the study area. Accordingly, it was argued that a 0.3 metre freeboard would suitably account for any modelling uncertainty, particularly across those areas subject to relatively shallow depths of inundation.

However, as noted in Section 3.2.4, the outcomes of a detention basin failure assessment, determined that failure of one or more of the five detention basins in the study area could expose properties downstream of each basin to an increase in 1% AEP flood levels of more than 0.3 metres. As a result, application of a 0.5 metres freeboard is considered more appropriate across these properties. Furthermore, the '*Tuggerah Lakes Floodplain Risk Management Study'* (WMAwater, 2010), applied a 0.5 metre freeboard to those areas subject to Tuggerah Lake flooding. Accordingly, to ensure consistency with this past study and account for the potential impacts of basin failure, a 0.5 metre freeboard is considered appropriate across some areas of the catchment.

Although application of a constant 0.5 metre freeboard could be implemented, Council considered that to impose a higher freeboard across the entire study area for the sake of a few properties subject to higher flood levels in the event of basin failure could not be justified. As a result, it is considered appropriate to adopt a variable freeboard (i.e., 0.3 metre freeboard across the majority of the study area and 0.5 metre freeboard across localised areas and the Tuggerah Lake foreshore) as part of the FPL definition. Those lots where a 0.3 metre and 0.5 metre freeboard are considered appropriate is shown in **Appendix G**.

However, the model LEP clause taken up in Wyong LEP 2013 – stipulating only a 0.5 metres freeboard – does not allow this flexibility. As Central Coast Council consolidates the Wyong and Gosford LEPs into a single instrument, and as it considers the diversity of flood mechanisms across the LGA, it is possible that even more flexibility will be considered appropriate to define flood planning areas. It is therefore recommended that Council seek to amend the definition of flood planning level to cater for flexible requirements. For example:

> *'Flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard, or other freeboard determined by an adopted floodplain risk management plan*.'

Or, to allow even more flexibility:

> *'Flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard, or other freeboard as determined in relevant studies and plans.'*

Compatibility of existing land use zones with flood hazard

An assessment of the compatibility of the existing land use zoning (under Wyong LEP 2013) with the flood hazard was undertaken by comparing land use zones (refer **Figure 18**) with the flood precincts used for Wyong DCP 2013. Under the DCP, precinct 1 corresponds to land between the flood planning level (FPL) and the PMF, precinct 2 corresponds to land below the FPL that is flood fringe and low hazard, precinct 3 corresponds to land below the FPL that is flood storage and low hazard, and precincts 4/5 corresponds to high hazard (mapped as H4–H6 based on the national guideline) or floodway. The results are presented in **Plate 14** and a summary for combined residential uses is presented in **Table 14**.

Table 14 Areas zoned residential by flood precinct

	Flood Precinct 1	Flood Precinct 2	Flood Precinct 3	Flood Precincts 4/5
Area (hectares) zoned residential	172	64	38	4
% zoned residential out of total area in each flood precinct	72%	70%	43%	25%

Of most interest is land zoned residential within flood precincts 4 or 5. This occupies only about four hectares in the Killarney Vale/Long Jetty local catchment in total. An inspection of these areas indicates that a sizeable proportion of these four hectares is located in road corridors. One flowpath however stands out as flowing through residential lots, though mostly affecting only a portion of backyards. This is the flowpath that commences near Rhodin Drive and flows in a westerly direction to Tuggerah Lake. Two lots are substantially affected by flood precincts 4 and/or 5 (one lot in Gosford Avenue, The Entrance and one lot in Tuggerah Parade, Long Jetty). In the 1% AEP event, the hydraulic hazard at the two dwelling locations is H4 and H5, respectively.

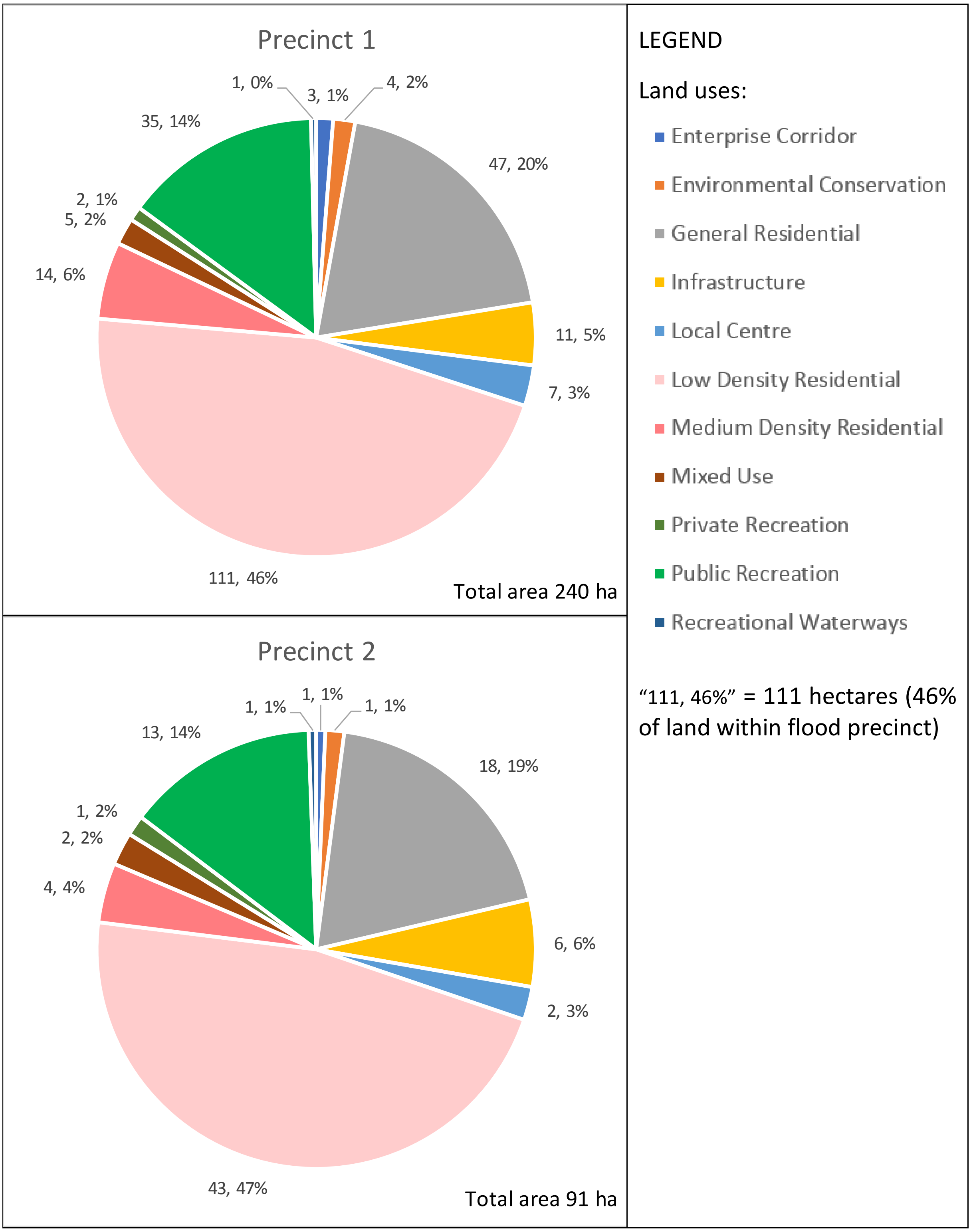
Apart from the locations noted above, the LEP zoning appears to be broadly appropriate. That is, there is no obvious need for modification to the current LEP zones. Nevertheless, intensification of land uses below the flood planning level (in particular, those locations highlighted above), should be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

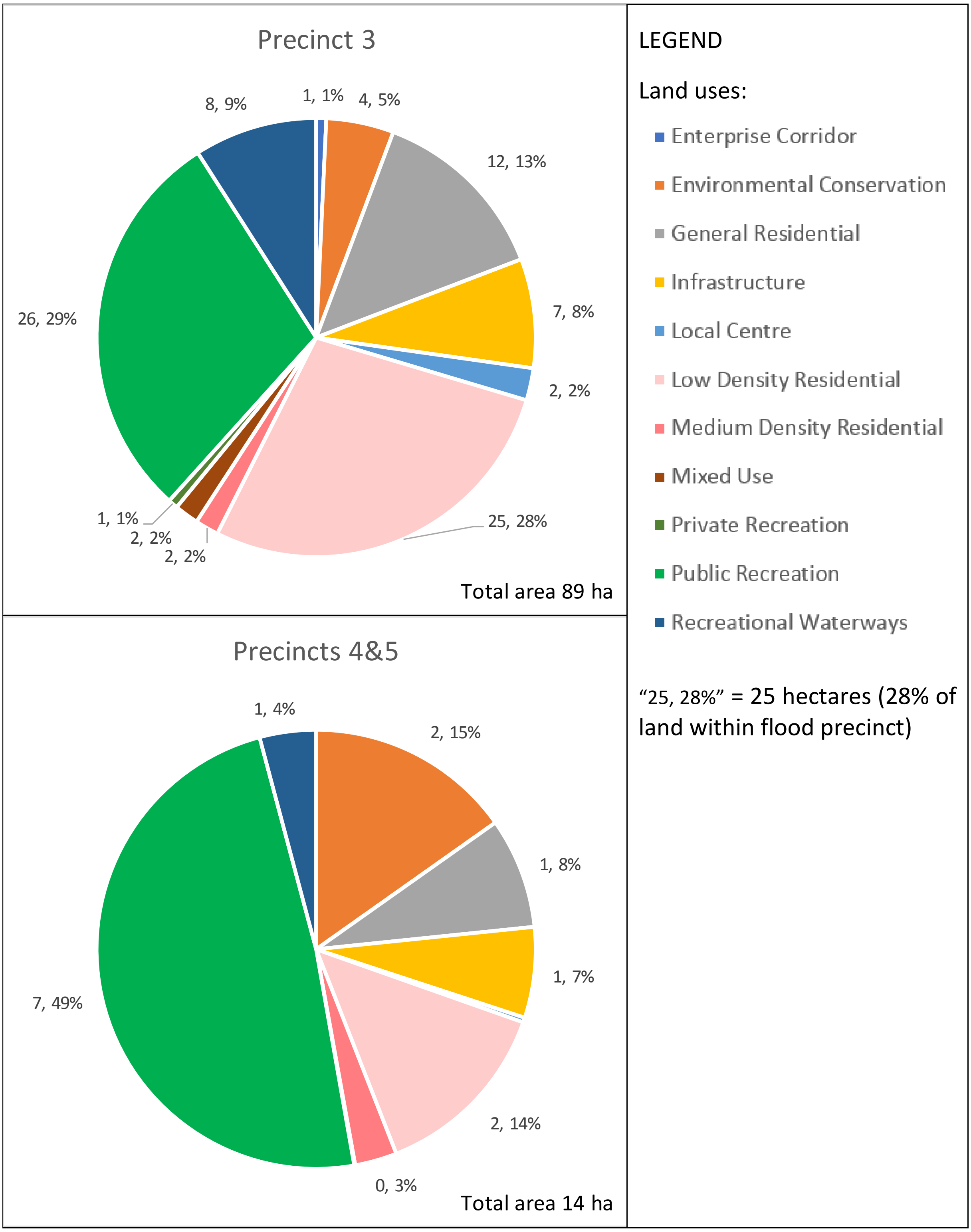
Evacuation challenges

Flood modelling undertaken for the Flood Study and this Floodplain Risk Management Study identifies a number of features of flood behaviour that indicate evacuation in advance of, or during, a flood is likely to be impractical, and that on-site refuge may be an acceptable or safer emergency response:

- The worst flooding in these local catchments results from short storms – the 30 minute storm across the upstream sections and the 2 hour storm along major waterways
- Roads may be cut less than 30 minutes after the commencement of a storm. As a result, there is unlikely to be sufficient time to evacuate from parts of the catchments before roadways are inundated
- Roadways may be impassable for approximately 30 minutes to 2 hours, which means a relatively short period of isolation
- Depths of inundation across most of the study area are typically shallow and the flood hazard indicates that most buildings are unlikely to suffer structural damage

Plate 14 Area within Wyong DCP 2013 flood precincts by Wyong LEP 2013 land use





Clause 7.3 of Wyong LEP is focussed on the evacuation of land subject to flooding in events exceeding the flood planning level. If this clause is strictly applied, any development application for the listed land uses in the Killarney Vale/Long Jetty local catchments is likely to fail because the very fast-rising inundation prevents safe evacuation. Council may wish to seek approval to amend this clause to provide Council with discretion to be assured of safe evacuation *or* safe on-site refuge above the PMF.

4.3.2 Wyong Development Control Plan 2013

Supporting Wyong LEP 2013 is the *Wyong Development Control Plan 2013* (Wyong DCP 2013), which at the time of writing continues to set the design and construction standards that apply when carrying out development within the former Wyong LGA.

A detailed review of the Wyong DCP was provided as part of the '*Wyong River Floodplain Risk Management Study & Plan'* (Catchment Simulation Solutions, 2018). This section discusses controls that may be appropriate to manage overland flow inundation risks in the Killarney Vale/Long Jetty local catchments, for consideration for inclusion in the floodplain risk management chapter of a new Central Coast DCP currently under development.

Floor level

As noted in Section 4.3.1, a freeboard of 0.3m rather than the normal 0.5m is considered appropriate for setting the flood planning level (FPL) across the majority of the study area. The FPL, in turn, sets minimum habitable floor levels for new dwellings.

Historically, concessions to floor level controls were sometimes permitted for commercial or industrial land uses, reasoning that businesses have capacity to tolerate more risk (including through insurance). Recent floods however have shown that flooding can cause severe damage to modern equipment and to livelihoods that depend on that business. Council may wish to consult with its business communities as it confirms an appropriate minimum habitable floor level for commercial and industrial uses.

Sensitive uses and critical infrastructure typically have the PMF level as the minimum habitable floor level, which is considered appropriate.

Given the observation from past floods that significant damage to precious contents can occur in garages, sheds or "storage areas", it is also considered appropriate to set minimum floor levels for non-habitable buildings or rooms. This could be to a lesser standard such as the 5% AEP flood. For example:

> *Floor levels to be 300mm above the finished ground level or equal to or greater than the 5% AEP flood level (whichever is higher).*

Parts of the Killarney Vale and Long Jetty local catchments floodplain that are also subject to flooding from Tuggerah Lake should be subject to the higher FPL that applies to the land.

Building components

It is considered appropriate that any part of buildings constructed below the FPL should be installed with flood-compatible components. This is also consistent with the requirement in the Codes SEPP.

Structural soundness

It could be argued that in areas of shallow overland flow, a requirement to demonstrate the structural soundness of a building is unnecessary. However, since such a provision is contained in the Codes SEPP, it would be inconsistent to apply a lesser standard in the DCP for land below the flood planning level.

Inundation effects

It is considered appropriate that new buildings should not worsen inundation on adjacent properties. This also is consistent with a requirement in the Codes SEPP. However, there is an argument for defining what constitutes a significant adverse flood impact (e.g. >20 mm rise).

Car parking and driveway access

Car parking controls are important given the ease with which vehicles can become buoyant and float and then become floating debris with potential to block culverts and pose environmental hazards. Carport floor levels could arguably be set at the 5% AEP level or 300mm above the ground level, whichever is higher.

Driveway access controls are considered less critical (for single dwellings) for land subject to short-lived, shallow overland flows since, as discussed, there may be negligible warning of floods, no opportunity for safe evacuation, and relatively short durations of isolation—suggesting that for this catchment, on-site refuge above the PMF may be safer than evacuation.

Evacuation

Given the impracticality and perhaps even the danger of evacuation—if flood conditions on roads are worse than those encountered at a property—and the relatively short duration of isolation—having controls for the Killarney Vale and Long Jetty catchments that *require* evacuation may be inappropriate. In addition, the incremental difference in flood depths between the 1% AEP event and the PMF (see **Section 4.2.3**) suggest that requiring a proportion of floor space within new dwellings to be above the PMF level to serve as an on-site refuge in extreme floods is not essential for this catchment. It would, however, be a desirable feature, given the fickleness of human behaviours during floods, which could see people get into difficulties if their houses commence to flood and result in a burden for rescuers. The cost of providing a higher floor space may not be prohibitive, and would be a sensible long-term resilience measure.

Fencing

Fencing can have a significant impact on overland flows. Ideally, it should not impede the flow of floodwaters so as to result in additional flood impacts on surrounding land, and should be able to withstand flooding or to collapse in a controlled manner to prevent a ‘wave’ causing additional problems downstream. Council could consider introducing specific controls for fencing on land below the FPL, such as prohibiting brick/masonry fences (likely to create impediments). It is recognised however that implementing fencing controls can be difficult.

5 EXISTING 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 Killarney Vale/Long Jetty catchments.

5.1 Wyong Shire Local Flood Plan

The *Wyong Shire Local Flood Plan* (NSW SES, 2013) sets out procedures to follow before, during and after a flood including who is responsible for each of these activities within the former Wyong Shire area.

The current Local Flood Plan (LFP) was reviewed as part of the *Wyong River Floodplain Risk Management Study & Plan* (Catchment Simulation Solutions, 2018). Further comments relating specifically to the Killarney Vale/Long Jetty catchments study area are provided in **Table 15**.

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. There is scope for minor refinement, for example, to add one site for active reconnaissance during floods, but noting the challenges for active reconnaissance given the likelihood of fast rising and falling local overland flows.

Volume 2 was last updated in December 2007. This volume 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. In particular, it currently says very little about flooding risks from local overland flow catchments including the Killarney Vale/Long Jetty local catchments.

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. Much of the Killarney Vale/Long Jetty local catchments are included in Sector C, where for most residents the recognised response strategy is on-site refuge. Considerable effort is needed to provide the detail consistent with the new SES LFP template.

Table 15 Comments on Current Wyong Shire Local Flood Plan

Section	Description	Comment
Volume 1		
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 Lucinda Avenue, Killarney Vale, though probably mainly with a view to flooding from Tuggerah Lake. Tuggerah Parade, Long Jetty, is a similarly impacted road that could be added to the list. The speed with which overland flows in the KVLJ catchments tend to rise and fall may preclude active reconnaissance.
3.18.42	List of evacuation centres	The listed evacuation centres within the KVLJ local catchments include: • Diggers (315 The Entrance Road) – not directly affected in PMF; • Bateau Bay Bowling Club (5 Bias Avenue) – may be short-duration inundation in carpark; • The Entrance Leagues Club (3 Bay Village Road) – not directly affected in PMF; • Shelley Beach Golf Club (Shelley Beach Road) – not directly affected in PMF. The flood exposure (or immunity) of these evacuation centres is described in Section 3.3.1 of this report.
Volume 2 Hazard and Risk in Wyong		
1.1	Landforms and River Systems	The smaller watercourses in the LGA such as Saltwater Creek could be named.
1.2	Storage Dams	Not relevant to the KVLJ local catchments.
1.3	Weather Systems and Flooding	Needs to describe role of short-duration (1-2 hours' burst) rainfall for flooding in the KVLJ local catchments, which may be caused by short-lived thunderstorms.
1.4	Characteristics of Flooding	Needs to describe characteristics of overland flow inundation in the KVLJ local catchments, including degree of hazard, rapid rise, and short duration.
1.5	Flood History	Historical floods in the KVLJ catchments should be added, especially Feb 1981, as well as Nov 1984, Jun 2007 and Dec 2010 (see the KVLJ Flood Study). It should also be noted that various mitigation works were implemented after floods, which has mitigated but not eliminated the hazard.
1.6	Flood Mitigation Systems	The retarding basins within the KVLJ catchments should be added. Their performance is described in the KVLJ Flood Study.
1.7	Extreme Flooding	Information in the KVLJ Flood Study and this FRMS should be used to describe what happens in floods rarer than the 1% AEP event in the KVLJ catchments.
1.8	Coastal Erosion	Out of scope of this review.
2.1	Community Profile	Should be updated using 2016 Census data
2.2f	Specific Risk Areas	The many retirement villages in the KVLJ catchments could be taken to represent a distinct 'risk area' that might be highlighted.

Section	Description	Comment
2.7	Road Closures	The current LFP does not include such a list. This information is available in this study, though the typically short duration of closures associated with local overland flow inundation implies that the consequences for disruption/isolation would be short-lived.
2.8	Summary of Isolated Communities and Properties	Isolation as a result of local overland flow inundation is expected to the short-lived (although it would be longer for lake inundation).
Volume 3 SES Response Arrangements		
Ch. 1	Flood Warning Systems and Arrangements	The list of gauges monitored needs to be reviewed. There are rain gauges at Berkeley Vale, Bateau Bay and The Entrance, which could be added.
Ch. 2	SES Locality Response Arrangements	The current LFP breaks down Wyong Shire into six evacuation sectors. Sector C (Bateau Bay) covers the bulk of the KVLJ local catchments study area, with the remainder covered by Sector A South (The Lakes). The stated strategy for much of Sector C is for residents to seek on-site refuge. It is implied that flooding of Tuggerah Lake will require affected residents to evacuate.
Ch. 3	SES Dam Failure Arrangements	Not relevant to the KVLJ local catchments.
Ch. 4	SES Caravan Park Arrangements	The current LFP (Annex G) lists two flood prone caravan parks within the KVLJ local catchments study area (predominately impacted from Tuggerah Lake). The flood exposure of these caravan parks is described in Section 3.3.1 of this report.

5.2 Emergency Services' Capability

As of 2016, the Wyong SES unit had about 80 members, trained to various levels for rescue including some at level 3 (swift-water rescue capability). If a forecast highlights the Wyong area 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 the rapidity with which flash flooding can occur, adverse consequences are likely to occur across some sections of the Killarney Vale/Long Jetty local catchments before emergency services personnel can be deployed. As a result, it will be critical that the at-risk communities are able to cope with flooding, without reliance on the emergency services.

5.3 Response Strategy

5.3.1 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. It recognises that the safest place to be in a flood is well away from the affected area. Provided that evacuation can be safely implemented, this is the most effective strategy. 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.

5.3.2 Killarney Vale/Long Jetty Local Catchments Practice

It is noted that the current Wyong Local Flood Plan (Volume 3 Annex F clause 10, and map 3, dated 2007) endorses shelter-in-place (i.e., on-site refuge) as the appropriate strategy for most existing residents within the Killarney Vale and Long Jetty local catchments, where subject to overland flow. This is a pragmatic approach given:

- The worst flooding in these local catchments results from short storms – the 30-minute storm across the upstream sections and the 2-hour storm along major waterways. There may be no specific prior indication of flooding, and early evacuation in response to only general warnings such as a Flood Watch, Severe Weather Warning or Severe Thunderstorm Warning is likely to be socially unsustainable. Attempting to evacuate as flooding manifests itself may expose evacuees to adverse conditions such as heavy rainfall, hail, lightning, strong winds and the risk from flying debris, falling trees or power lines;

- Roads may be cut less than 30 minutes after the commencement of a storm, leaving very little opportunity for evacuation triggered by environmental cues;
- Roadways may be impassable for approximately 30 minutes to 2 hours, which means a relatively short period of isolation;
- Hydraulic hazard (based on depths and velocities across the terrain) even in the PMF is most often H1–H3, which according to the national guideline on Flood Hazard is not unsafe for adults or buildings (see **Plate 7**);
- Estimated depths of above-floor inundation even in the PMF are less than 1.2 metres for all buildings in the database), with the exception of The Entrance Reef Resort Motel, Long Jetty; depths greater than 1.2 metres are considered unsafe for adults (see **Plate 7**);

Nonetheless, evacuation is still recommended in some situations including the following:

- People whose prior medical condition means any isolation from medical help cannot be tolerated should evacuate prior to flooding. One such site subject first to isolation and then possibly to inundation under existing conditions is the flood island location of Kathleen White Crescent, Killarney Vale;
- Sites where the national hazard rating exceeds H4 could be unsafe for buildings and their occupants. One such site in Tuggerah Parade was identified earlier;
- At Reef Resort Motel flood depths in the PMF are estimated to reach about 2.2 metres over the ground. Here, evacuation from the ground floor units to the first-floor units might be feasible. This requires (1) confirmation of the structural integrity of the building to resist PMF-type flooding, and (2) the development and maintenance of sound emergency management protocols, including routine monitoring of inundation levels at the front of the motel during heavy rain;
- Given the longer duration of lake-driven flooding, which brings hazards associated with isolation and potential loss of services including sanitation, people who live in areas subject to lake inundation may need to evacuate if the lake is predicted or observed to flood. This is consistent with the Local Flood Plan.

An on-site refuge strategy requires that people know their risk exposure and plan how to respond. There is a risk that as floodwater first penetrates a house, people may panic and enter deeper, faster floodwater outside a building while attempting to evacuate. Information and education is required to help residents plan how to respond appropriately.

6 OPTIONS FOR MANAGING THE FLOOD RISK

6.1 General

As outlined in Section 3, a number of existing properties within the Killarney Vale and Long Jetty catchments are predicted to be exposed to a significant flood risk and/or significant financial impacts during floods within the local catchments. Accordingly, the following chapters outline options that could be potentially implemented 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.
- **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.
- **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.

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
- Feedback received from the community (refer Section 2.5.3).

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

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

Flood Modification Options	Property Modification Options	Response Modification Options
Stormwater upgrades from The Entrance Road at Gosford Ave to channel at rear of The Entrance Reef Resort	Voluntary purchase of select residential properties	Local flood plan updates including flood recovery assistance (e.g., garbage pickup, counselling).
Stormwater upgrades from Davidson Ave to open channel adjacent to Ferndale St	Upper Storey Flood Free Refuges	Community education strategy
Stormwater upgrades from Bonnieview St to open channel	Voluntary raising of select residential properties	Flash flood warning /forecasting system
Culvert upgrade under Hume Boulevarde and Wyong Road	LEP Modifications	
Culvert upgrade under Wyong Rd near Kathleen White Cres	DCP Modifications	
Blockage control structure upstream of culverts (eg: under Wyong Rd near Kathleen White Cres and under Hume Boulevarde/Wyong Road)		
Wyong Rd regrading and median modifications along Wyong Road near existing culvert between Brooke Ave and Davidson Ave		
Wyong Rd regrading and median modifications along Wyong Road near existing culvert between Tasman Ave and The Entrance Rd		
Introduction of kerb/gutter and potential minor regrading of Elsiemer St between Watkins St and The Entrance Rd		
Introduction of kerb/gutter and potential minor regrading of Pacific St between Nirvana St and Watkins St		
Regrading of Ferndale St between Davidson Ave and Tuggerah Lake foreshore		
Earthworks to create swale/low resistance overland flowpath around The Entrance Reef Resort (Corner of The Entrance Rd and Norfolk St)		
Regrading at the eastern end of Elewa Ave to drainage swale		
Purchase of vacant RMS shoulder on Wyong Road (between The Entrance Rd and Kathleen White Cres) and creation detention basin		

Flood Modification Options	Property Modification Options	Response Modification Options
Raise spillway and crest elevation of The Bay Village detention basin to provide greater storage volume		
Create detention basin within Shelly Beach Golf Course grounds at the corner of Bateau Bay Rd and Grandview St		
Create detention basin within reserve on Rhodin Dr		
Provision of underground storage tanks in The Entrance Rd between Anzac Rd and Norfolk St		
Provision of underground storage tanks in Gosford Ave between The Entrance Rd and Boomerang Rd		

6.2.3 Initial Assessment of Options

It was not considered feasible to undertake a detailed assessment of all options in **Table 16**. Therefore, a qualitative assessment of each potential option was completed to provide an initial assessment of the potential feasibility of each option and to determine which measures showed merit for further detailed assessment. The evaluation criteria / scoring system that was employed to complete this assessment is summarised in **Table 17** and the outcomes of the assessment are provided in **Table 18**.

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

Score:	Change in Flood Levels / Extents	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance
-2	Significant increases in levels / extents	Cost much higher than reduction in flood damages	Significant impacts	Significant disbenefit to emergency services	Significant technical challenges	Majority of community opposed
-1	Minor increases in levels / extents	Cost slightly higher than reduction in flood damages	Minor impacts	Slight disbenefit to emergency services	Some technical challenges	Some opposed
0	Negligible changes in levels / extents	Cost and reduction in flood damages roughly equal	No impacts	No impact on emergency services	Minor technical challenges	Neutral
+1	Minor reductions in levels / extents	Reduction in flood damages slightly higher than cost	Some benefits	Slight benefit to emergency services	Negligible technical challenges	Some support
+2	Significant reductions in levels / extents	Reduction in flood damages much higher than cost	Significant benefits	Significant benefit to emergency services	No technical challenges	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	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance	Overall Score
Flood Modifications Option	Blockage control structure upstream of culverts (e.g.: under Wyong Rd near Kathleen White Cres and under Hume Boulevarde/Wyong Road)	1	1	0	0	1	1	**4**
	Wyong Rd median modifications and regrading near culverts between Brooke Ave and Davidson Ave and between Tasman Ave and The Entrance Rd	1	1	0	2	-1	1	**4**
	Create detention basin within Shelly Beach Golf Course grounds at the corner of Bateau Bay Rd and Grandview St	2	0	0	1	-1	1	**3**
	Introduction of kerb/gutter and potential minor regrading of Elsiemer St between Watkins St and The Entrance Rd and Pacific St between Nirvana St and Watkins St	1	0	0	-1	1	2	**3**
	Stormwater upgrades from The Entrance Road at Gosford Ave to channel at rear of The Entrance Reef Resort	1	-1	0	1	-2	2	**1**
	Culvert upgrades between Hume Boulevarde and Wyong Road	1	-1	0	1	-2	2	**1**
	Culvert upgrade under Wyong Rd near Kathleen White Cres	1	-1	0	1	-2	2	**1**

Potential Measures	Evaluation Criteria / Score						
	Change in Flood Levels / Extents	**Economic Feasibility**	**Environmental Impacts**	**Emergency Response**	**Technical Feasibility**	**Community Acceptance**	**Overall Score**
Earthworks to create swale/low resistance overland flowpath around The Entrance Reef Resort (Corner of The Entrance Rd and Norfolk St)	1	-1	0	1	-1	1	**1**
Raise spillway and crest elevation of The Bay Village detention basin to provide greater storage volume	1	-1	0	1	-1	1	**1**
Stormwater Upgrades from Davidson Ave to open channel adjacent Ferndale St	1	-2	0	1	-2	2	**0**
Stormwater Upgrades from Bonnieview St to open channel	1	-1	0	0	-2	2	**0**
Regrading of Ferndale St between Davidson Ave and Tuggerah Lake foreshore	1	-2	0	1	-2	2	**0**
Regrading at the eastern end of Elewa Ave to drainage swale	1	-2	0	0	0	1	**0**
Purchase of vacant RMS shoulder on Wyong Road (between The Entrance Rd and Kathleen White Cres) and create detention basin	1	-1	-1	1	-1	1	**0**
Create detention basin within reserve on Rhodin Dr	1	-1	0	1	1	-2	**0**
Provision of underground storage tanks in Gosford Ave between The Entrance Rd and Boomerang Rd	1	0	0	0	-1	-1	**-1**

Potential Measures		Change in Flood Levels / Extents	Economic Feasibility	Environmental Impacts	Emergency Response	Technical Feasibility	Community Acceptance	Overall Score
		Evaluation Criteria / Score						
	Provision of underground storage tanks in The Entrance Rd between Anzac Rd and Norfolk St	1	-1	0	1	-2	-2	**-3**
Property Modification Options	DCP modifications	0	1	0	1	1	2	**5**
	LEP modifications	0	1	0	1	0	1	**3**
	Voluntary purchase of select residential properties	0	-2	1	2	0	-1	**0**
	Voluntary raising of select residential properties	0	-1	0	-1	-1	0	**-3**
	Voluntary flood proofing of select residential properties	0	-2	0	-1	0	0	**-3**
Response Modification	Community education strategy	0	1	0	2	1	1	**5**
	Local flood plan updates including flood recovery assistance (e.g., garbage pickup, counselling).	0	1	0	2	1	1	**5**
	Flash flood warning/forecasting system	0	-1	0	1	-1	1	**0**

As shown in **Table 18,** each measure was evaluated against six criteria. The expected performance of each measure against each criterion was scored between 2 (significant positive impact) and -2 (significant negative impact).

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. Those options with a net positive score are shaded in blue.

It should be reinforced that this assessment was qualitative in nature only and was only used to prepare a shortlist of options for further detailed investigation.

6.3 Flood Risk Management Options Assessed in Detail

Based upon the qualitative assessment presented in in **Table 18**, the options listed in **Table 19** were selected for detailed assessment.

6.3.1 Detailed 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 appraisal of the potential feasibility of each option.

As outlined in the previous section, a qualitative assessment of each potential option was completed to provide an initial appraisal of the likely feasibility of each option. However, as part of the detailed option assessment, it was considered important to provide a quantitative assessment of the relative advantages and disadvantages of each option. In this regard, each flood and property modification option was evaluated against the following criteria, where sufficient information was available:

- Change in flood levels/extents
- Economic feasibility
- Environmental impacts
- Emergency responses impacts
- Technical feasibility

Further details on each of these evaluation criteria is presented below.

The response modification options were generally not evaluated against these criteria as they will generally have negligible hydraulic and environmental impacts, are difficult to quantify in monetary benefits (i.e., response modification options will generally not reduce flood damages) and will generally improve emergency response.

Table 19 Options Selected for Detailed Investigations

Flood Modification Options		Property Modification Options	Response Modification Options
Drainage Upgrades	Blockage control structure upstream of culverts (eg: under Wyong Rd near Kathleen White Cres and under Hume Boulevarde/Wyong Road)	DCP modifications	Local flood plan updates including flood recovery assistance (e.g., garbage pickup, counselling).
	Culvert upgrade under Wyong Rd near Kathleen White Cres	LEP modifications	Community education strategy
	Culvert upgrades between Hume Boulevarde and Wyong Road		
	Stormwater Upgrades from The Entrance Road at Gosford Ave to open channel		
Above Ground Storages	Create detention basin within Shelly Beach Golf Course grounds at the corner of Bateau Bay Rd and Grandview St		
	Raise spillway and crest elevation of The Bay Village detention basin to provide greater storage volume		
Roadworks	Introduction of kerb/gutter and potential minor regrading of Elsiemer St between Watkins St and The Entrance Rd and Pacific St between Nirvana St and Watkins St		
	Modification/Removal of raised median strip along Wyong Rd between Brooke Ave and Davidson Ave and between Tasman Ave and The Entrance Rd		
Earthworks	Earthworks to create swale/low resistance overland flowpath around The Entrance Reef Resort (Corner of The Entrance Rd and Norfolk St)		

Change in Flood Levels/Extents

Flood modification options 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 flood 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 that each flood modification option is likely to have on existing flood behaviour, the TUFLOW hydraulic model was updated to include each flood modification option. The updated TUFLOW models were then used to re-simulate each of the design floods with the option in place. 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.

A focus was placed on the flood level differences during the 20% AEP and 1% AEP floods to provide an indication of the how the option would perform during relatively regular (i.e., 20% AEP) as well as rarer (i.e., 1% AEP) floods.

Economic Feasibility

A preliminary economic assessment of select flood modification and 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 that showed a positive hydraulic benefit. 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 detailed 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.

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.

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.

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.

6.4 Summary

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

- Flood Modification Options: Chapter7.
- 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 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:

- Drainage Upgrades
- Above Ground Storages
- Roadworks
- Earthworks

As discussed in Section 6.3.1, the hydraulic benefits of each flood modification option were assessed by including the option in the model and using the updated model to re-simulate each design flood. The hydraulic benefits were then quantified by preparing flood level difference mapping for each option. In addition, the number of properties predicted to be subject to changes in peak flood levels was determined for the 20% AEP and 1% AEP floods and is provided in **Table 20**. Negative numbers denote the number of properties subject to flood level reductions while positive numbers indicate he number of properties subject to flood level increases because the option.

The change in the number of properties subject to above floor inundation was also quantified for each option and is included in **Table 21**. Positive numbers indicate a reduction in the number of properties exposed to above floor inundation while negative numbers indicate an increase in the number of properties subject to above floor inundation. Those options that did not provide any change in above floor inundation are not included in **Table 21**.

In addition, the number of properties predicted to be exposed to a reduction in flood damage were also determined and is provided in **Table 22**. Positive numbers indicate a reduction in flood damages while negative numbers indicate an increase in flood damage.

Cost estimates for each option were also prepared and are included **Table 23**. **Table 23** also summarises the predicted reduction in flood damage costs if the option was implemented along with the associated benefit-cost ratio.

Further detailed discussion on each flood modification option investigated to assist in managing the existing flood risk is presented in the following sections.

Table 20 Number of Properties Subject to Flood Level Reductions for Each Flood Modification Option

Flood Level Change	Number of Properties Subject to Changes in Flood Level (-ve = Reductions and +ve = Increases)																	
	Drainage Upgrades								Detention Basins				Roadworks/Regrading					
	Debris Control Structures		Wyong Road Culvert Upgrades (near Kathleen White Cres)		Wyong Road Culvert Upgrades (near Hume Blvd)		Culvert Upgrades at The Entrance Reef Resort Motel		Shelly Beach Golf Course Basin		The Bay Village Basin Upgrades		Elsiemer St Roadworks		Wyong Road Regrading		The Entrance Reef Resort Motel Roadworks	
	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP	20% AEP	1% AEP
< ± 0.02m	-32, +26	-28, +22	-6, +2	-10, +16	-14, +4	-6, +17	-5, +5	-3, +17	-13, +1	-8, +2	0, 0	-15, +3	-3, +8	-13, +7	-7, +0	-35, +29	-6, +3	-6, +15
< ±0.1 m	-24, +14	-46, +15	-6, +0	-18, +0	-18, +17	-40, +0	-5, +22	-1, +0	-13, +2	-4, +2	0, 0	-47, +0	-23, +0	-36, +1	-3, +19	-26, +16	-2, +23	-2, +12
< ±0.2 m	-0, +1	-1, +1	-6, +0	-1, +0	-0, +0	-0, +0	-0, +1	-4, +0	-2, +0	-1, +0	0, 0	-3, +3	-1, +0	-1, +0	-0, +0	-1, +0	-0, +1	-1, +0
≥ ±0.2m	-5, +1	-4, +1	-0, +0	-0, +0	-0, +0	-0, +0	-1, +0	-4, +0	-0, +0	-0, +0	0, 0	-0, +0	-0, +0	-0, +0	-0, +0	-2, +0	-2, +0	-5, +0
Now Mostly Dry/Wet	-0, +1	-0, +5	-0, +0	-0, +1	-0, +1	-0, +0	-0, +0	-0, +0	-0, +0	-0, +0	0, 0	-0, +1	-0, +1	-0, +0	-0, +1	-0, +1	-0, +0	-0, +2

Table 21 Decrease in Number of Properties Subject to Above Floor Flooding for Each Flood Modification Option

Flood Event	Decrease in Number of Properties with Above Floor Inundation								
	Drainage Upgrades				Detention Basins		Roadworks/Regrading		
	Debris Control Structures	Wyong Road Culvert Upgrades (near Kathleen White Cres)	Wyong Road Culvert Upgrades (near Hume Blvd)	Culvert Upgrades at The Entrance Reef Resort Motel	Shelly Beach Golf Course Basin	The Bay Village Basin Upgrades	Elsiemer St Roadworks	Wyong Road Regrading	The Entrance Reef Resort Motel Roadworks
20% AEP	0	0	1	0	0	0	0	6	0
5% AEP	0	0	1	1	0	0	0	8	1
1% AEP	1	0	1	0	0	0	0	8	0
0.4% AEP	6	0	7	0	1	0	2	11	0
PMF	-1	3	0	1	3	9	0	1	1

Table 22 **Reduction in Number of Properties Subject to Flood Damage**

Flood Event	Reduction in Number of Properties Subject to Flood Damage								
	Drainage Upgrades				Detention Basins		Roadworks/Regrading		
	Debris Control Structures	Wyong Road Culvert Upgrades (near Kathleen White Cres)	Wyong Road Culvert Upgrades (near Hume Blvd)	Culvert Upgrades at The Entrance Reef Resort Motel	Shelly Beach Golf Course Basin	The Bay Village Basin Upgrades	Elsiemer St Roadworks	Wyong Road Regrading	The Entrance Reef Resort Motel Roadworks
20% AEP	1	0	2	0	1	0	1	6	0
5% AEP	0	0	2	1	0	0	3	8	1
1% AEP	1	5	1	-2	2	2	2	9	0
0.4% AEP	9	1	6	0	-2	6	2	12	0
PMF	-3	0	1	1	0	0	-1	0	1

Table 23 **Economic Assessment for Flood Modification Options**

Option		Cost	Total Damage with Option in Place	Reduction in Damage with Option in Place	Benefit-Cost Ratio
Drainage Upgrades	Debris Control Structures upstream of Wyong Road	$120,000	$4,259,467	$155,139	1.29
	Stormwater Upgrades near Kathleen White Crescent	$530,000	$4,411,248	$3,358	0.01
	Stormwater Upgrades near Hume Boulevard	$770,000	$3,998,373	$416,233	0.54
	Stormwater Upgrades near The Entrance Reef Resort Motel	$1,590,000	$4,034,742	$379,863	0.24
Detention Basins	Shelly Beach Golf Course Basin	$90,000	$4,361,726	$52,880	0.59
	Bay Village Basin Upgrade	$70,000	$4,397,443	$17,163	0.25
Roadworks/ Regrading	Installation of kerb and gutter along Elseimer St and Pacific St	$170,000	$4,399,118	$15,488	0.09
	Wyong Road Regrading	$1,020,000	$3,327,607	$990,000	1.09
	The Entrance Reef Resort Earthworks	$150,000	$4,080,388	$334,218	2.23

7.2 Drainage Upgrades

7.2.1 Blockage Control Structures Upstream of Wyong Road Culverts

Recommendation: Recommended for more detailed analysis.

The Killarney Vale and Long Jetty catchments are urbanised. As a result, there is significant potential for urban debris as well as vegetation matter to be mobilised and enter the drainage network. A number of culverts drain runoff from the local catchment beneath major roadways (e.g. Wyong Road). Any debris that is mobilised during rainfall events could lead to blockage of these culverts resulting in increased inundation depths and extents upstream of the structures. This option would aim to install blockage (debris) control structures upstream of culverts in key locations in order to minimise the potential for blockage of these culverts.

Two locations within the study area were selected for consideration based on the significant inundation depths and the potential for blockage to further increase the flooding problems. The locations that were selected are shown on **Figure 19** and include:

- Culverts under Wyong Road near Kathleen White Crescent;
- Culverts under Hume Boulevarde near Macarthur Street.

The blockage control structures would be installed as 'on-line' structures, meaning they would be permanently placed across the drainage channel allowing for continuous interception of debris. The exact design of the structure would be dependent on specific site conditions, however, it would likely be in the form of a "trash rack" installed at an angle with a debris accumulation "bay" that would allow debris to be captured without significantly interfering with the flow of water along the channel. An example of a blockage control structure that is currently located north of Wyong Road is shown in **Plate 15**.

To assess the hydraulic impacts of implementing the debris control structures, the TUFLOW model was updated to include a representation of each structure shown in **Figure 19**. This was achieved by modifying the blockage assigned to the culverts located downstream of the control structures from 50% to 10%. The debris control structures were assumed to comprise a 0.2 metres high rack which was assumed to be fully blocked by debris during each design flood (i.e., the blockage was "shifted" from the culverts upstream to the debris control structures).

The updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 16** and **Plate 17.**

Plate 16 and **Plate 17** show that this option is predicted to reduce existing flood levels during both the 20% and 1% AEP floods across multiple properties located upstream of each culvert. More specifically, the following changes in peak 20% and 1% AEP flood levels are anticipated:

Plate 15 Example of Blockage Control Structure with "offline" debris accumulation bay

Plate 16 Peak 20% AEP Flood Level Difference Mapping with Blockage Control Structures

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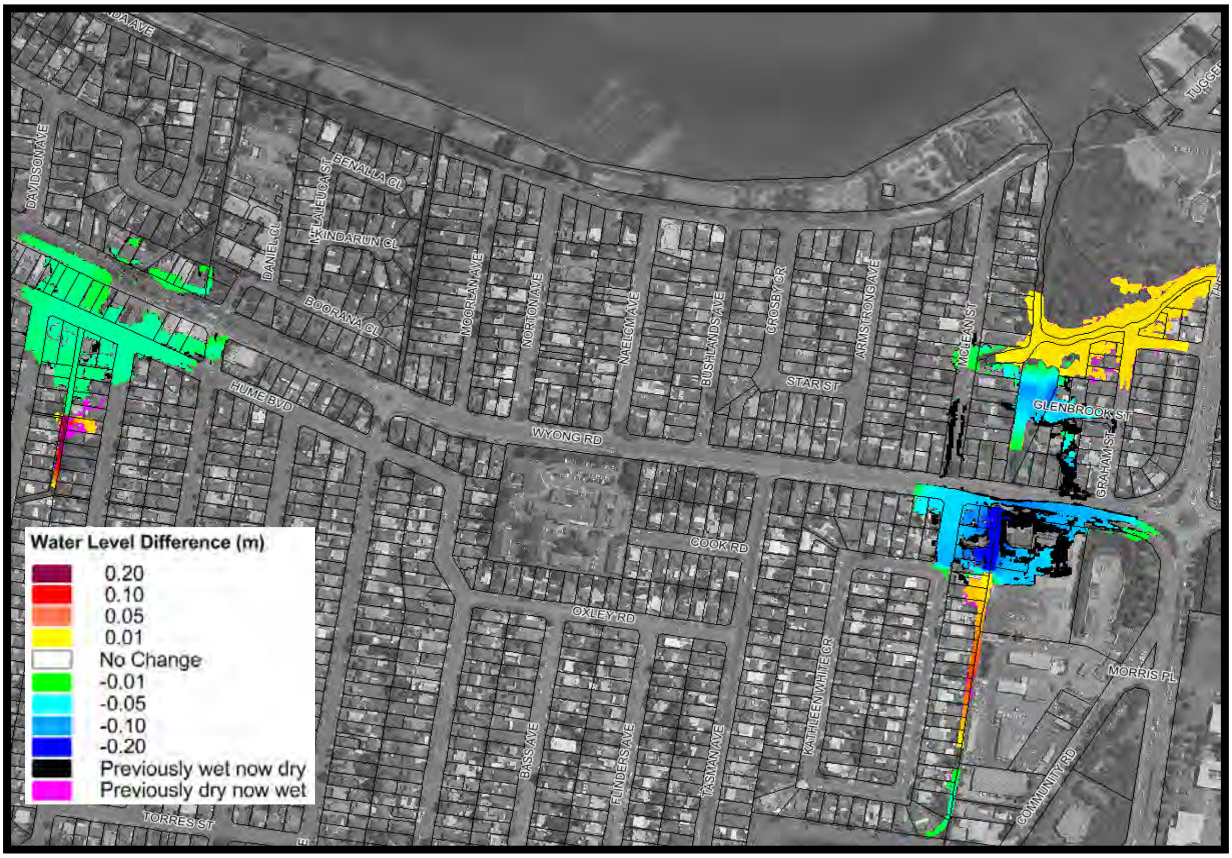

Plate 17 Peak 1% AEP Flood Level Difference Mapping with Blockage Control Structures

- Culverts under Wyong Road near Kathleen White Crescent:
    - Decreases of over 0.4 metres within the open drainage channel upstream of Wyong Road during the 20% AEP flood, and up to 0.35 metres during the 1% AEP flood. Flood level decreases are also predicted to extend onto adjoining properties in Kathleen White Crescent, with reductions of up to 0.1 metres predicted during the 20% AEP event and up to 0.06 metres during the 1% AEP event.
    - Increases upstream of the debris control structure of up to 0.07 metres in the 20% AEP flood and 0.04 metres in the 1% AEP flood. However, these are typically contained to the open channel. The rear of two properties backing onto the open channel experience increases of less than 0.03 metres during the 1% AEP event. Increases are also predicted across the northern end of Graham Street, adjacent to Saltwater Creek. These increases appear to occur as a result of the reduction in blockage that allows more water to pass beneath Wyong Road and into Saltwater Creek.
- Culverts under Hume Boulevarde:
    - Decreases of over 0.05 metres across properties on Macarthur Street and Cunningham Road, and across some commercial premises along Wyong Road during the 20% AEP event. Decreases of up to 0.03 metres are also predicted across Wyong Road itself. During the 1% AEP, the extent of decreases is more widespread. However, the decreases are typically not more than 0.03 metres.
    - Increases in levels are predicted during the 20% AEP event downstream of Wyong Road. The increases are predicted to extend all the way to Tuggerah Lake.

However, the increases are contained to the main drainage channel and are not predicted to exceed 0.02 metres.

Flood level reductions are predicted across more than 50 properties during the 20% AEP flood and more than 70 properties during the 1% AEP flood (although most of the reductions are less than 0.1 metres). The flood level reductions are sufficient to reduce the number of properties incurring external damage by one (1) during the 20% AEP. One (1) less property is also predicted to be flooded above floor level during the 1% AEP flood.

During the 1% AEP event, 39 properties are predicted to experience an increase in flood level. However, these increases, are typically restricted to areas immediately adjacent to the channel, are less than 0.02 metres and do not impact any buildings. It would be desirable to eliminate any increases in flood levels across existing private property. Therefore, refinement of the initial concept designs presented in this report is recommended to assist in reducing these adverse impacts.

The total cost to implement the blockage control structures in the two locations identified is estimated to be about $120,000 over the 50-year timeframe. This cost assumes that each trash rack would need to be replaced after 25 years and maintenance would be performed 4 times a year (i.e., ~ every 3 months). A detailed breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the blockage control structures was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the blockage control structures in place. The outcomes of the revised damages assessment determined that a reduction in total flood damage costs of $155,000 over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 1.29. Accordingly, the financial benefit of implementing the blockage control structures outweighs the cost.

The debris control structures provide some decreases in flood levels along Wyong Rd. This is particularly prominent in the 1% AEP and these reductions will increase the time that Wyong Road (a major evacuation route) is trafficable. In addition, reductions in flood levels are predicted to extend across the “sag” point in Kathleen White Crescent which cuts access to properties relatively early during large floods. Therefore, there is also increased opportunity for evacuation for these properties. Accordingly, this option does have the potential to afford emergency response benefits.

As the works are to be constructed across the existing open channels, the major technical challenge is the relatively restricted amount of space to implement the works. Consideration also needs to be given to providing sufficient space/easement for creating access for maintenance vehicles.

This option will likely afford beneficial environmental impacts by facilitating additional gross pollution interception and collection, thereby reducing the likelihood of these pollutants and urban waste entering Tuggerah Lake. The construction works are proposed within a class 3 acid sulphate soils zone. However, as the proposed works would not disturb this zone (i.e., the works would largely be completed “on top” of the existing channel) there is limited potential for disturbance of acid sulphate soils. No Aboriginal or other heritage sites are located within the proposed work.

Overall, this option does afford flood benefits for multiple properties located in the immediate vicinity of the Wyong Road culverts. This is particularly the case for properties in the vicinity of Kathleen White Crescent where access can be cut relatively early during large floods. The high benefit-cost ratio also makes this option worth pursuing from a financial perspective. Nonetheless, more detailed design and hydraulic investigations are needed to fully determine the viability of this option.

7.2.2 Culvert Upgrade Under Wyong Road near Kathleen White Crescent

Recommendation: Not recommended for implementation

As discussed in the previous section, a number of properties on Kathleen White Crescent are impacted by floodwaters. Flood behaviour in this area is significantly influenced by Wyong Road and the culverts the drain water beneath this roadway embankment. The results of the design flood simulations indicate that the major culvert crossings of Wyong Road do not have sufficient capacity to convey floodwaters. The excess water is predicted to “build up” behind the roadway embankment/median resulting in inundation of adjoining properties. Kathleen White Crescent, in particular, only has one entry/exit location that adjoins Wyong Road and this becomes inundated relatively early during floods, resulting in isolation of properties.

This option investigated the potential benefits associated with increasing the capacity of the culverts under Wyong Road near Kathleen White Crescent by including an additional 2.4 metre wide x 1.1 metre high culvert to supplement the existing triple 2.4 metre x 1.1 metre culverts. The location of the proposed upgrade is shown on **Figure 20**.

The existing culverts occupy the full width of the existing channel. Therefore, there is limited potential to include the new culvert in parallel to the current culverts. Instead, it is likely that the new culvert will need to be implemented as a lateral “offtake” from the main channel (at an approximate angle of 45 degrees, before passing beneath Wyong Road and then feeding back into the channel at an angle of about 45 degrees). The approximate alignment of the offtake and outlet are shown in **Figure 20**.

The TUFLOW model was updated to include the culvert upgrade shown in **Figure 20** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place are presented in **Plate 18** and **Plate 19.**

Plate 18 and **Plate 19** shows that this option is predicted to reduce existing flood levels during both the 20% and 1% AEP floods in areas upstream (i.e., south) of Wyong Road. More specifically, the following reductions in flood levels are anticipated:

- Reductions of up to 0.2 metres and 0.1 metres are predicted upstream of Wyong Road during the 20% AEP event and 1% AEP event, respectively. During the 1% AEP event, reductions are predicted to extend across properties on Kathleen White Crescent as well as the roadway itself. Smaller decreases are also predicted along Wyong Rd, as well as Glenbrook Street (however, the reductions are predicted to be less than 0.1 metres).

Plate 18 Peak 20% AEP Flood Level Difference Mapping with Culvert Upgrade under Wyong Road near Kathleen White Crescent

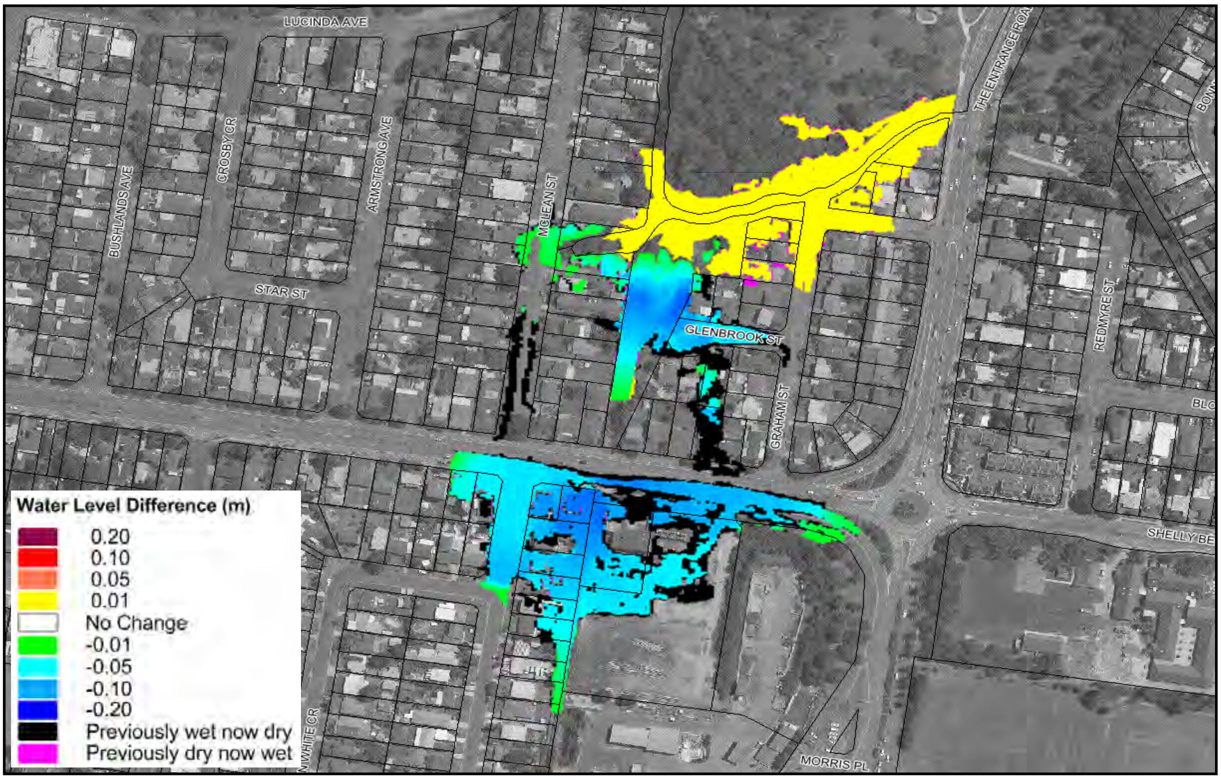

Plate 19 Peak 1% AEP Flood Level Difference Mapping with Culvert Upgrade under Wyong Road near Kathleen White Crescent

- No increases in peak flood level are predicted during the 20% AEP event. Negligible increases are predicted within Saltwater Creek during the 1% AEP flood (i.e. about 0.01 metres).

Flood level reductions are predicted across 18 properties during the 20% AEP flood and 29 properties during the 1% AEP flood, with most reductions being less than 0.1 metres. The flood level reductions are sufficient to result in 5 fewer properties incurring flooding during the 1% AEP flood. During the 1% AEP flood, 16 properties are predicted to experience flood level increases. However, this occurs primarily within Saltwater Creek and the increases do not exceed 0.02 metres.

The cost to implement the culvert upgrade under Wyong Road near Kathleen White Crescent is estimated to be about $530,000. A significant contributor to the cost is the management of traffic along Wyong Road, which is a major transportation route in the local area. A breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the culvert upgrade in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $3,300 was predicted over the 50-year design life of the culvert. This yielded a preliminary benefit-cost ratio of 0.01. Accordingly, the financial cost of installing this additional culvert at this location far outweighs the benefit.

A review of existing services in the vicinity of Wyong Road indicate a significant number of services, including:

- AusGrid electrical infrastructure located towards the east of the works zone;
- Water mains along both the northern and southern sides of Wyong Road;
- Jemena gas main on the norther side of Wyong Road;
- Optus cable extending diagonally across Wyong Road.

As a result of these services, care would need to be exercised during construction. However, it is not expected that relocation of these services will be required as the proposed culvert is similar in size to the existing culverts, helping to ensure appropriate clearances are already established.

The culvert upgrade provides some decreases in flood levels along Wyong Rd and Kathleen White Crescent. This will afford some emergency response benefits for properties adjoining Kathleen White Crescent as well as the broader community evacuating along Wyong Road.

Wyong Road is a major transportation route. Therefore, any works in this area does have the potential to impact on local traffic during construction.

The construction works are proposed within a class 3 acid sulphate soils zone. However, as the proposed works would not disturb this zone, the potential for acid sulphate soil exposure is considered to be limited. No Aboriginal or other heritage sites are located within the works zone.

Overall, this option only affords significant improvements during relatively large floods. However, the reduction in flood damage costs is not predicted to be significant resulting in a an extremely low benefit-cost ratio and the construction works would provide a significant disruption to local traffic. Therefore, this option is not recommended for implementation.

7.2.3 Culvert Upgrades between Hume Boulevard and Wyong Road

Recommendation: Not recommended for implementation

During each of the simulated design floods, the result of the modelling predicts inundation of a number of commercial properties adjoining Wyong Road between Davidson Avenue and Boorana Close as well as residential properties adjoining Hume Boulevarde, Cunningham Road and Macarthur Street. Runoff from this local subcatchment is largely controlled by a culvert system beneath Hume Boulevard and Wyong Road. The culvert along this section of watercourse comprises two separate structures:

- Two 1.6 metre wide x 1.2 metre high box culverts from the open channel upstream of Hume Boulevard to Wyong Road;
- Two 1.55 metre wide x 0.9 metre high box culverts from Wyong Road to open channel north of Wyong Road.

Accordingly, the downstream section of the existing culvert system has a smaller capacity relative to the upstream section of the culvert system.

This option would aim to provide additional flow capacity beneath Wyong Road, thereby reducing the extent and depth of floodwaters across properties to the south of Wyong Road. Initially, upgrading only the downstream section of the existing culvert was investigated and considered a dual 1.6 metre wide x 1.2 metre high box culvert extending from upstream of Hume Boulevard to downstream of Wyong Road. However, this was found to provide negligible hydraulic benefits so was not pursued further in isolation.

Instead, installation of an additional 1.6 metre x 1.2 metre culvert stretching from upstream of Hume Boulevarde to the downstream side of Wyong Road was investigated in combination with increasing the size of existing culvert section beneath Wyong Road. The location of the proposed upgrades is shown on **Figure 21**.

The TUFLOW model was updated to include the culvert upgrades shown in **Figure 21** and the updated model was used to re-simulate the design floods. Floodwater level difference mapping was prepared for the 20% and 1% AEP floods, as presented in **Plate 20** and **Plate 21.**

Plate 20 and **Plate 21** show that this option is predicted to generate flood level reductions as well as flood level increases during the 20% AEP and 1% AEP floods. More specifically, the following changes in peak 20% AEP and 1% AEP flood levels are predicted:

Plate 20 Peak 20% AEP Flood Level Difference Mapping with Culvert Upgrades between Hume Boulevard and Wyong Road

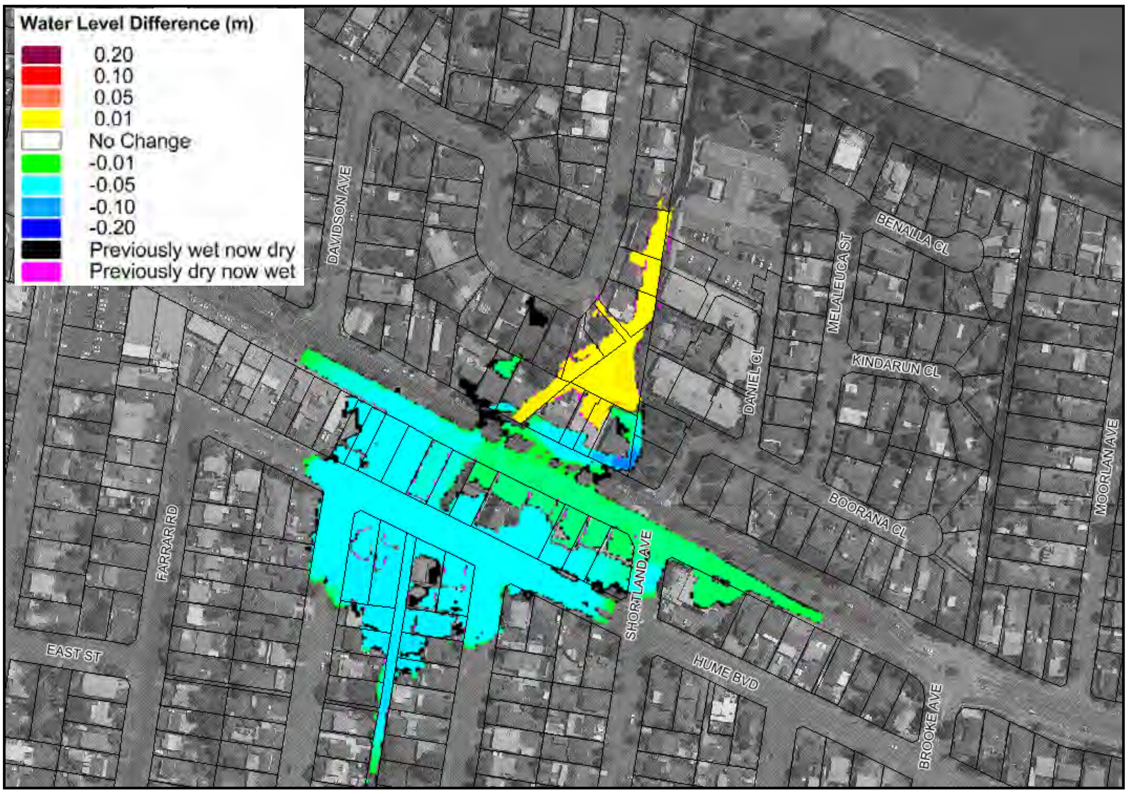

Plate 21 Peak 1% AEP Flood Level Difference Mapping with Culvert Upgrades between Hume Boulevard and Wyong Road

- Reductions of up to 0.05 metre along the open channel upstream of Hume Boulevarde during the 20% AEP and 1% AEP events. Flood level reductions are also predicted to extend across properties on Hume Boulevarde, as well as along the southern lanes of Wyong Road and adjoining commercial properties. The magnitude of the reductions typically varies between 0.05 to 0.1 metres during the 20% AEP flood, and 0.02 to 0.05 metres during the 1% AEP event.
- Increases are predicted during both the 20% AEP and 1% AEP events downstream (i.e., north) of Wyong Road. However, the increases are generally contained to the open channel and the magnitude of the increases is predicted to be less than 0.03 metres in the 20% AEP and 0.01 metres in the 1% AEP event.

Flood level reductions are predicted across 32 properties during the 20% AEP flood and 46 properties during the 1% AEP flood. The flood level reductions are sufficient to result in one less property being inundated above floor level during both the 20% AEP and 1% AEP events.

During the 1% AEP event, 17 properties are predicted to experience flood level increases. However, this is primarily the result of localised increases within the open channel (i.e., the open channel is contained within property boundaries and not a dedicated drainage reserve). However, these increases do not exceed 0.02 metres nor impact on any buildings.

The cost to implement the culvert upgrade is estimated to be about $770,000. A detailed breakdown of costs is provided in **Appendix D**. It should be noted that traffic management is a considerable component of the estimated cost.

The potential financial benefit associated with implementation of the culvert upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the culvert upgrade in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of $416,000 is anticipated over the 50-year design life. This yielded a preliminary benefit-cost ratio of 0.54. Accordingly, the financial cost of installing an additional culvert at this location outweighs the benefit by approximately two to one.

A number of services are contained within the “construction zone” for this option. This includes:

- Sewer main along Hume Boulevarde, crossing the proposed alignment of the new culvert;
- Optus cable extending along the southern side of Wyong Road;
- Jemena Gas main along the northern side of Wyong Road.

Therefore, suitable planning would be required prior to commencing construction works and care would need to be exercised during construction to ensure these services are not disturbed. It is not expected that relocation of services will be necessary to implement this option. However, if this was required, it would significantly add to the overall construction costs.

The culvert upgrade is predicted to reduce flood levels/depths along Wyong Road. These reductions will increase the time that Wyong Road is trafficable, which is particularly important given this road will function as a major flood evacuation route.

The construction works are proposed within a class 3 acid sulphate soils zone. However, as the proposed works would not disturb this zone, the potential for disturbance of acid sulphate soils is considered to be limited. No Aboriginal or other heritage sites are located within the works zone. This option does not provide any significant environmental impacts or benefits.

Overall, this option does afford some flood benefits for properties located near Hume Boulevard and Wyong Road. However, the low benefit-cost ratio, increases in flood levels downstream of Wyong Road and the potential disruption to traffic during construction indicate that this option is difficult to recommended for implementation.

7.2.4 Culvert Upgrades between The Entrance Road and the rear of The Reef Resort Motel

Recommendation: Not recommended for implementation

Significant floodwater depths are predicted at a trapped low point on The Entrance Road outside the Reef Resort Motel at the corner of Oaklands and Gosford Avenues. Floodwaters "pond" within The Entrance Road causing disruption to traffic and, during larger magnitude floods, inundation of The Reef Resort Motel. Currently, twin 0.9 metre diameter pipes drain water from the low point in The Entrance Road, underneath The Reef Resort Motel and into an open drainage channel located 40 metres west of the Motel. This channel continues to drain in a westerly direction and ultimately into Tuggerah Lake.

This option intends to increase the capacity of the stormwater network between The Entrance Road and the open channel to reduce the extent and depth of ponding within The Entrance Road and across the motel site. This aims to benefit the motel owners and occupiers, as well as roadway users of this important transportation link.

The proposed upgrades are shown in **Figure 22** and would include:

- Installation of an additional 3 x 0.9 metre diameter pipes along a similar alignment to the existing pipes, and;
- Installation of large grated 'strip' type stormwater inlets within the trapped low point on the western side of The Entrance Road and on the grounds of the motel.

Underground "coring" will likely be necessary to install the new pipes below the Motel structure. This would cause a disruption within the motel area during construction, however this is considered preferable to causing disruptions to traffic within The Entrance Road.

The TUFLOW model was updated to include the additional pipes and inlets shown in **Figure 22** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% AEP and 1% AEP events with this option in place are presented in **Plate 22** and **Plate 23.**

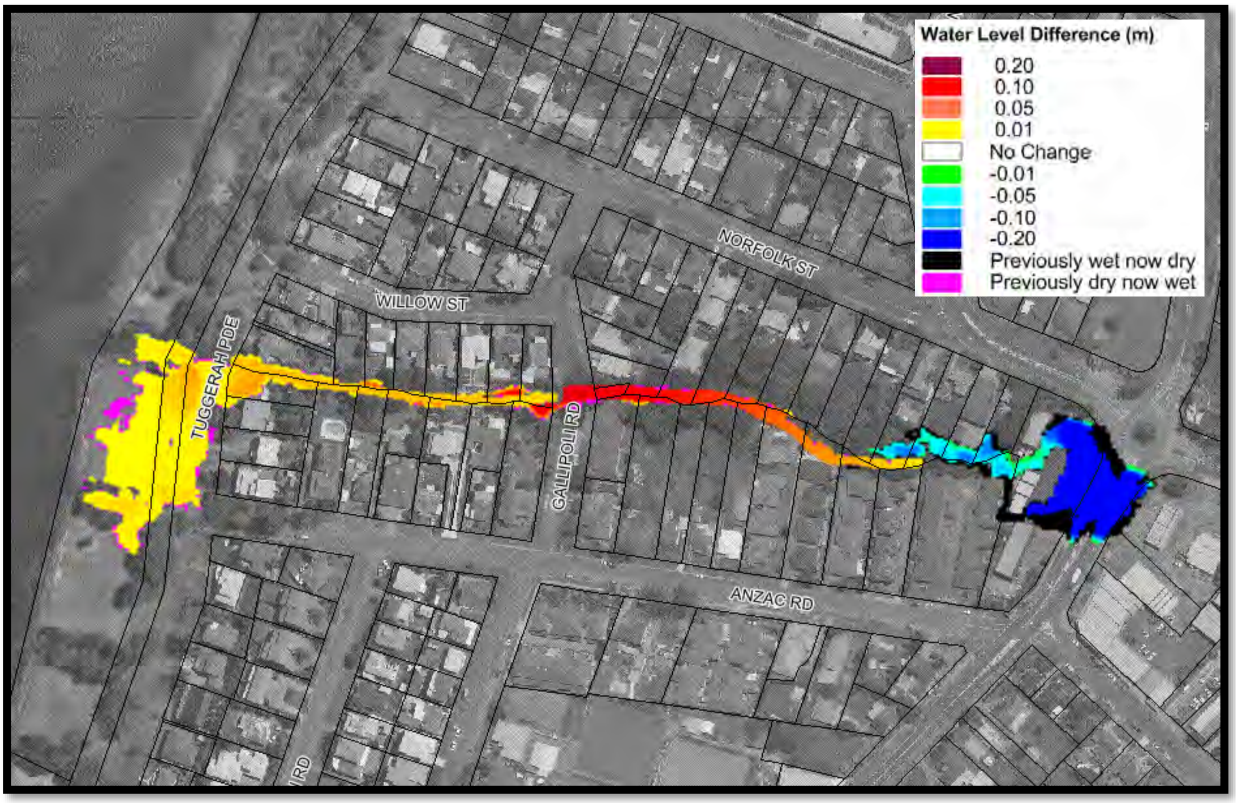

Plate 22 Peak 20% AEP Flood Level Difference Mapping with Culvert Upgrades between The Entrance Road and the rear of The Reef Resort Motel

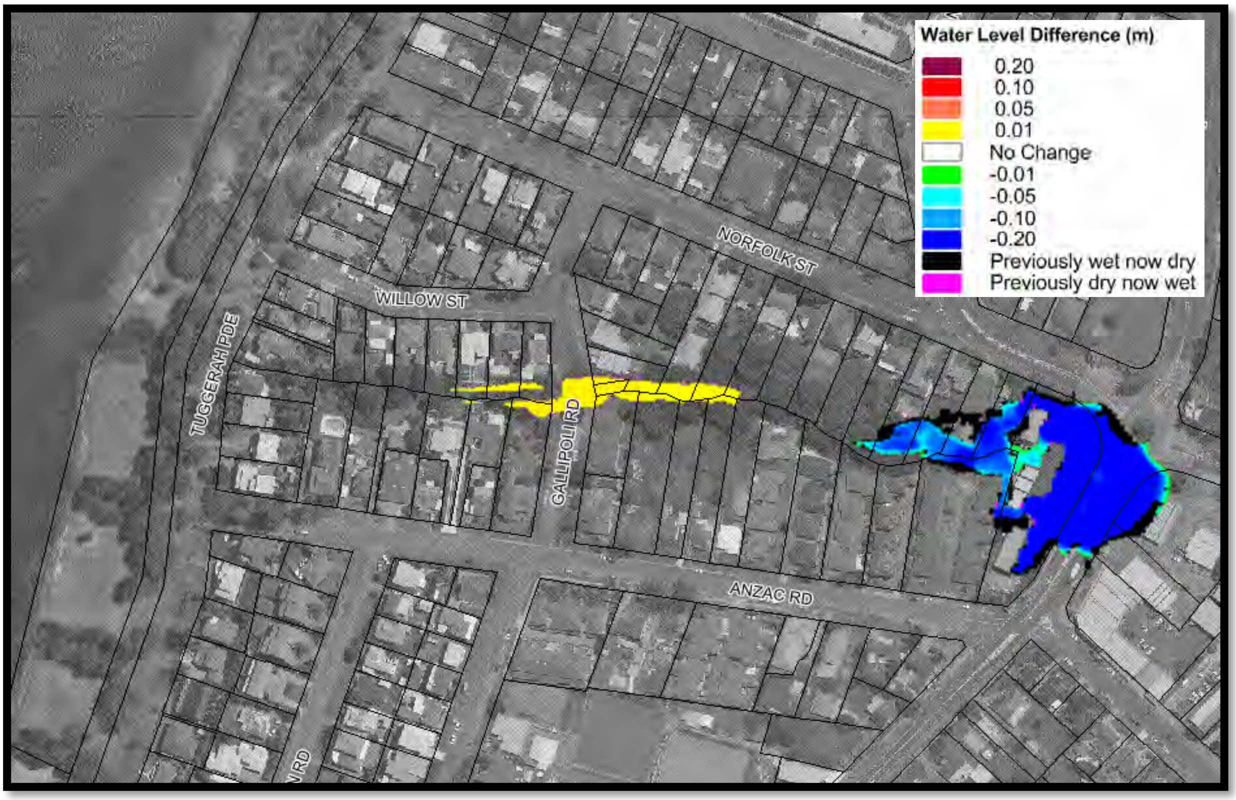

Plate 23 Peak 1% AEP Flood Level Difference Mapping with Culvert Upgrades between The Entrance Road and the rear of The Reef Resort Motel

Plate 26 and **Plate 27** show that this option is predicted to generate the following flood impacts during the 20% and 1% AEP floods:

- Reductions greater than 0.4 metres during the 20% AEP event and up to 0.3 metres during the 1% AEP event are predicted across The Entrance Road. Reductions between 0.3 and 0.6 metres are predicted within the motel. Peak flood level reduction greater than 0.1 metres are also predicted to extend across neighbouring properties to the west of the motel.
- Increases in flood level are predicted within the open channel downstream of the new pipes. Flood levels are predicted to increase from the pipe outlet down to Tuggerah Lake during the 20% AEP event (typical increases of are predicted to be about 0.05 metres, however, increases of up to 0.1 metres are predicted at some locations). These increases are generally contained to the open channel, however, the increases do extend over one residential property adjoining Tuggerah Parade. Therefore, additional localised mitigation would likely be required at this location to ensure the property is not disadvantaged by the drainage upgrades. During the 1% AEP event, increases are far less widespread with increases of no greater than 0.02 metres predicted.

Flood level reductions are predicted across 11 properties during the 20% AEP flood and 12 properties during the 1% AEP flood. The flood level reductions are sufficient to result in one fewer property incurring above floor inundation. However, during the 1% AEP event, 2 additional properties are predicted to be inundated above floor level as a result of the drainage upgrades.

The cost to implement the culvert upgrade between The Entrance Road and the rear of The Reef Resort Motel is estimated to be about $1.6 Million. A detailed breakdown of costs is provided in **Appendix D**. The “coring” that is required to implement this option is the primary contributor to the overall cost.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the additional culverts in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of almost $380,000 over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 0.24. Accordingly, the financial costs of installing the new pipes at this location outweighs the benefits.

The drainage upgrades provide some significant decreases in flood levels along The Entrance Road (i.e., >0.2 meters in the 20% AEP event and >0.4 metres in the 1% AEP event). Therefore, The Entrance Road will be subject to less frequent and server inundation, which will afford some evacuation benefits for the local area.

Several utilities are contained in close proximity to the proposed works. This includes:

- A water main;
- Optus cable; and,
- NBN cables.

Accordingly, additional care and preparation will be required to work in close proximity to these services. Relocation of the services is not expected to be necessary. However, if this was required to facilitate the work it would further reduce the cost effectiveness of this option.

The construction works are located within a class 5 (i.e., low) acid sulphate soils zone. Therefore, acid sulphate soil risk is considered to be low. No Aboriginal or other heritage sites are located within the works zone. This option is not likely to afford any significant environmental impacts (benefits or otherwise).

The adverse flood impacts on downstream properties and low benefit-cost ratio makes this option difficult to support. In addition, the regrading option discussed in Section 7.4.4 affords improved hydraulic benefits across Wyong Road and the Reef Resort Motel, is cheaper to implement and provides a higher benefit-cost ratio. Accordingly, the option discussed in Section 7.4.4 is recommended for implementation in preference to this option. Nevertheless, if it is ultimately determined that the option discussed in Section 7.4.4 is not feasible, this option could be revisited (e.g., the design could be potentially refined to reduce the adverse impacts and determine if more cost-effective effective options may be available that will improve the financial viability of this option).

7.3 Above Ground Storages

7.3.1 General

Above ground storages (also referred to as 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 dams. An example of a detention basin is provided in **Plate 24**.

Plate 24 Example of a Flood Detention Basin (MECA, 2017)

One of the primary challenges associated with implementing a detention basin in a “built up” catchment like Killarney Vale/Long Jetty is the lack of open space (detention basins typically require a significant land area/storage volume to provide a significant reduction in flows). Notwithstanding, the study area currently includes five basins. Therefore, opportunities to upgrade the existing basins and implement new basins were explored and are documented in the following sections.

7.3.2 Shelly Beach Golf Course Detention Basin

Recommendation: Not recommended for implementation

A significant overland flow path originates within the Shelly Beach Golf Course, moves through properties on Grandview St, towards Marquis Cl before entering Basin 2 downstream of Yakalla St. Properties near the intersection of Grandview St and Bateau Bay Road, in particular, experience inundation in relatively frequent events (20% AEP). The objective of this option was to construct a detention basin within the Shelly Beach Golf course to store water and reduce the quantify of flow travelling overland through these properties.

A concept for the proposed basin is included on **Figure 23.** As shown in **Figure 23**, the basin would include the following components:

- The basin wall would be located adjacent to an existing stand of native trees with a crest elevation at 10.6m AHD (the maximum wall height would be approximately 1 metre)
- A spillway at 10.4m AHD would be provided to discharge high flows into the existing swale.
- Three 0.45m diameter pipes will serves as a low flow outlet and will connect into the existing stormwater system at Grandview St.

The major limitation of this option is the fact that two independent flow paths converge at the location of the basin, which limits the location and height of the basin wall (i.e., a higher wall could be provided for one flow path, but this would likely obstruct the other flow path). In addition, it was desirable to try limit the potential for the works to adversely impact on the golf course (i.e., the functionality of the holes was to be maintained and the potential for extended periods of inundation across the course was to be limited).

It is understood that the golf course is owned by Council, however, is privately operated. Therefore, any works within the course would need to be made with agreement from the operators.

The TUFLOW model was updated to include the proposed detention basin and low flow outlet pipes shown in **Figure 23** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% AEP and 1% AEP events with this option in place are presented in **Plate 25** and **Plate 26.**

Plate 25 and **Plate 26** show that this option is predicted to afford reductions in flood levels downstream of the basin and increases in flood levels upstream of the basin. More specifically reductions of up to 0.1 metres in the 20% AEP and 0.16 metres in the 1% AEP are predicted across Grandview St properties. Reductions in flood level downstream of Grandview St are typically less than 0.05 metres during both the 20% AEP and 1% AEP floods.

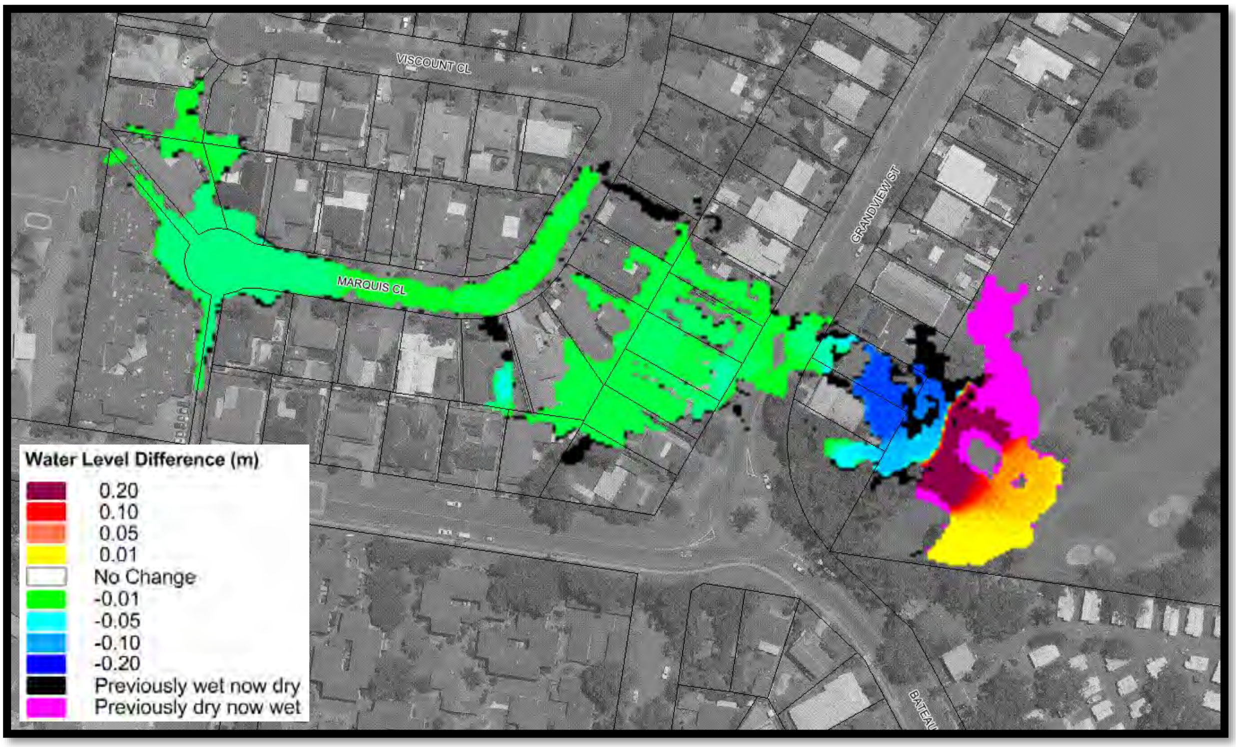

Plate 25 Peak 20% AEP Flood Level Difference Mapping with Shelley Beach Gold Course Basin

Plate 26 Peak 1% AEP Flood Level Difference Mapping with Shelley Beach Gold Course Basin

Flood level increases are typically contained within the golf course. However, increases in flood level are predicted to extend into the Shelley Beach Holiday Park during the 1% AEP event.

Flood level reductions are predicted across 28 properties during the 20% AEP flood and 13 during the 1% AEP flood. The reduced performance during the larger event suggests that the basin has insufficient capacity to efficiently attenuate larger floods. The flood level reductions are not sufficient to reduce the number of properties subject to above floor inundation, but will result in 2 fewer properties being exposed to flood damage. During the 1% AEP event, 4 properties are predicted to experience increases in flood level, however, the increases are generally less than 0.02 metres.

The cost to implement the Shelly Beach Golf Course basin is estimated to be about $90,000. A detailed breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the 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 damage assessment determined that a reduction in total flood damage costs of about $53,000 was anticipated over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 0.59. Accordingly, the financial costs of implementing this option outweighs the benefits.

The basin affords some limitation flood level reductions on Grandview Street, which is unlikely to provide any significant emergency evacuation benefits. No significant technical challenges are anticipated to implement this option.

The construction works are proposed within a class 4 acid sulphate soils zone (i.e. acid sulphate soils at depths beyond 2 metres below ground). Some excavation work would likely be necessary to install the low flow pipes, but this is unlikely to require excavation to depths of more than 2 metres. Accordingly, the acid sulphate soil potential is considered to be low.

The golf course is contained within the Shelly Beach Recreation and Flora Reserve Trust. However, as this option does not provide any significant changes to land use or vegetation type, this is unlikely to be a significant issue.

Overall, this option affords some minor flood benefits for properties located downstream of the proposed basin. When this is balanced against the poor financial benefits and the desire to maintain golf course amenity, it is difficult to recommend this option.

7.3.3 The Bay Village Detention Basin Upgrade

Recommendation: Not recommended for implementation

As discussed in preceding sections, a significant number of properties on Kathleen White Crescent are impacted by floodwaters in relatively frequent events. As Kathleen White Crescent is located downstream of The Bay Village Basin, the potential to upgrade this basin to afford additional attenuation of downstream flows was investigated.

This option would include raising the basin wall and spillway by around 0.3 metres. A concept design of the works proposed as part of this option are shown on **Figure 24**. As shown in **Figure 24**, a flood gate would also be installed on the outlet of The Bay Village stormwater system to ensure the elevated water levels within the basin do not "back up" the stormwater system and inundate section of the shopping centre.

The TUFLOW model was updated to include the proposed basin upgrade shown in **Figure 24** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% and 1% AEP events with this option in place were prepared. However, only the difference map for the 1% AEP event is presented in **Plate 27** as no changes in flood level were predicted by the model during the 20% AEP event. This outcome indicates that the existing basin is suitably sized to cater for the 20% AEP flood.

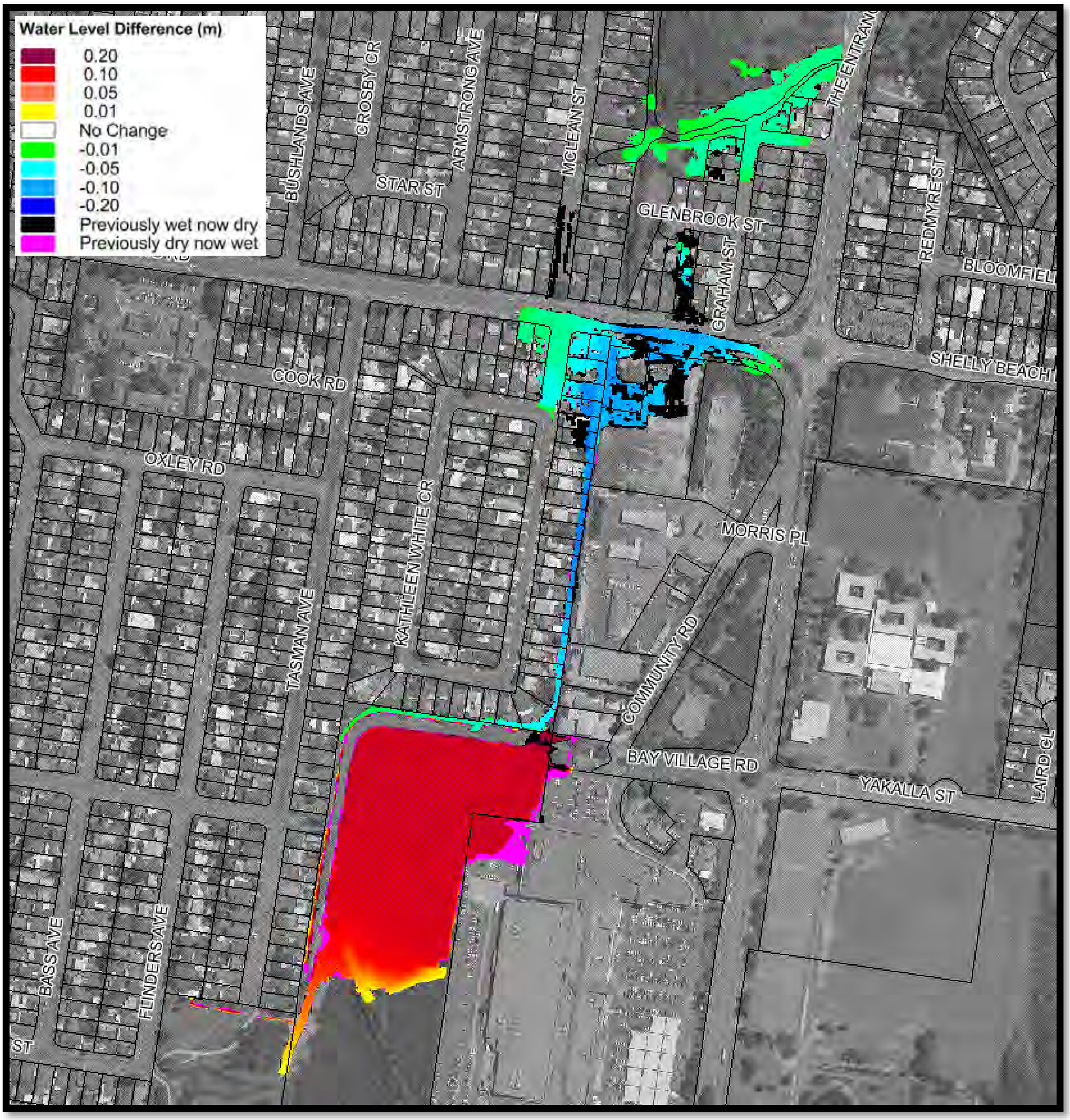

Plate 27 Peak 1% AEP Flood Level Difference Mapping with Bay Village Detention Basin Upgrade

Plate 27show that this option is predicted to alter peak 1% AEP flood levels in the vicinity of the basin. Specifically,

- Reductions of up to 0.1 metres are predicted along the open channel downstream of the basin, within properties on Kathleen White Crescent, and the southern travel lanes of Wyong Road. Decreases of up to 0.08 metres occur within properties north of Wyong Road, and decreases of up to 0.03 metres are anticipated within Saltwater Creek.
- Flood level increases of over 0.15 metres are predicted within the basin and across the north-western section of The Bay Village Shopping Centre carpark. This flood level increase will increase depths within the carpark area from over 0.6 metres to almost 0.8 metres during the 1% AEP event. Flood depths of this magnitude would result in significant damage to any vehicles parked in this area and would likely pose a significant risk to less mobile individuals.

As discussed, no flood level reductions are anticipated during the 20% AEP event. However, 65 properties are predicted to experience flood level reductions during the 1% AEP event. The flood level reductions are not sufficient to change the number of properties exposed to above floor inundation, but 2 fewer properties will experience flooding during the 1% AEP event.

The cost to implement the Bay Village Basin upgrade is estimated to be about $70,000. A detailed breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the basin upgrade in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of just over $17,000 could be expected over the 50-year design life. This yielded a preliminary benefit-cost ratio of 0.25.

The basin upgrade provides some decreases in flood levels along Wyong Rd between Kathleen White Crescent and The Entrance Rd in larger flood events. However, the additional evacuation time that this would afford is considered to be relatively small. As discussed, no changes in flood behaviour are expected during smaller events (e.g., 20% AEP event). Therefore, this option is considered to have relative minor emergency response benefits.

The options is unlikely to present any significant technical challenges and is not predicted to adversely impact on the local environmental or any heritage sites.

Overall, this option only affords improvements to flooding larger events. As a result, the reductions in flood damages is relatively minor leading to a low benefit-cost ratio. Therefore, this option is not recommended for implementation.

7.4 Roadworks/Regrading

7.4.1 General

During major floods within the Killarney Vale and Long Jetty catchment, the majority of flow is conveyed along existing creeks and drainage channels. However, there is also potential for overland flow paths to develop through properties and along roadways when the capacity of the local stormwater system is exceeded.

In general, it is desirable to contain overland flows within the road reserve rather than through properties as it reduces the potential for flood damage to be incurred. Therefore, the design of the local roadways can have an impact on the distribution of flows and potential for flood damage across the catchment. As a result, modifications to local roadways (e.g., regrading, removal of flow impediments, installation of kerb and gutter) was explored as a potential means to reduce the flooding problem across areas subject to overland flow. The outcomes of these investigations is discussed below.

7.4.2 Install Kerb and Gutter along Elsiemer Street and Pacific Street

Recommendation: Recommended for implementation

Kerb and gutter forms an important part of the conveyance system in an urban catchment. Kerb and gutter assists in capturing and directing flows into stormwater pits which can safely convey the flow underground. If the capacity of the stormwater system is exceeded, the kerbs can also assist in containing the majority of flow within the roadway thereby reducing the amount of flow spilling into adjoining properties.

Several streets within the study do not include kerb and gutter and are subject to notable overland flows. One such location stretches from Pacific St, along Watkins St and along Elsiemer St towards The Entrance Rd. The outcomes of the flood modelling indicate floodwaters travel diagonally across properties on the south-eastern corner of the intersection of Pacific St and Watkins St, and north-eastern corner of Watkins and Elsiemer St, before travelling longitudinally through an entire block of properties on the southern side of Elsiemer St. The lack of kerb and gutter in Elsiemer St (refer **Plate 28**) is a significant contributor to the overland flooding in this area.

This option would involve regrading and installation of kerb and gutter to contain a greater amount of flow within each roadway. The location of the works is shown in **Figure 25**. As shown on **Figure 25**, this option includes the following:

- Increase the existing kerb/nature strip height along a 70-metre section of Pacific Street to 0.3 metres. This could be achieved by retaining the current kerb (~0.15 m high) but completing minor regrading of the adjoining nature strip to provide an overall height of 0.3 metres relative to the edge of the existing road.
- Regrading the south-eastern portion of the intersection of Pacific and Watkins St to remove the high point near the roundabout (a reduction of between 0.1 and 0.4 metres).

- Increase the existing kerb height/nature strip along a 50 metre section of Watkins Street by 0.2 metres (to match the road centreline elevation). This could be achieved by retaining the existing kerb and regrading the nature strip between the top of the kerb and the adjoining property lines
- Install new kerb and gutter along a large section of Elsiemer St (most notably the southern side of the street). The new kerb and gutter and associated regrading of the nature strip should provide a total overall height of 0.3 metres above the existing edge of pavement (i.e., water depths up to 0.3 metres would be fully contained to the roadway).
- Install new kerb and gutter along the northern side of Elsiemer St at the intersection with The Entrance Rd to prevent diverted water moving across the site of a petrol station and retaining flood waters within the road reserve. This would be installed to a similar standard as the other areas (i.e., providing a total "barrier" height of 0.3 metres).

Plate 28 A typical location along Elsiemer St with no kerb and gutters.

The TUFLOW model was updated to include the road modifications shown in **Figure 25** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% AEP and 1% AEP events with this option in place are presented in **Plate 29** and **Plate 30.**

Plate 29 Peak 20% AEP Flood Level Difference Mapping with Kerb and Gutter installed along Elsiemer Street and Pacific Street

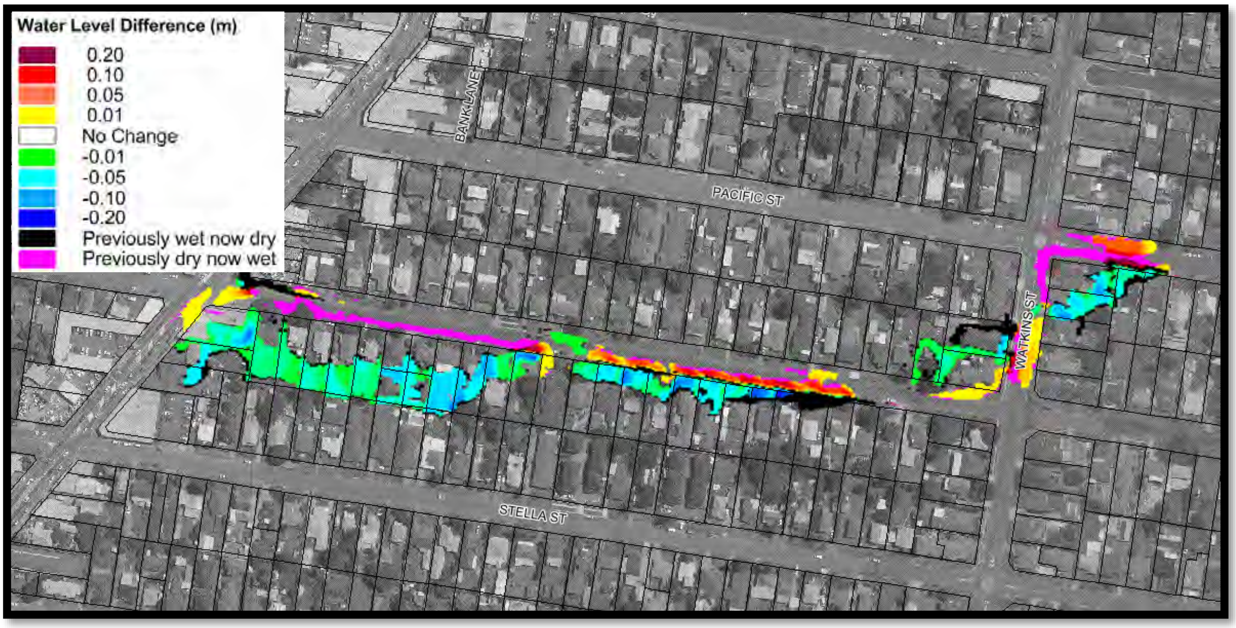

Plate 30 Peak 1% AEP Flood Level Difference Mapping with Kerb and Gutter installed along Elsiemer Street and Pacific Street

Plate 29 and **Plate 30** shows that this option is predicted to afford the following changes in flood levels and extents:

- Reductions at the intersection of Pacific St and Watkins St of over 0.05 metres in the 20% AEP and 1% AEP events. Significant areas are also predicted to no longer be flood affected in the 20% AEP.
- Reductions of up to 0.04 metres in the 20% AEP and 1% AEP events at the intersection of Watkins and Elsiemer St.

- Reductions of up to 0.1 metres within properties on Elsiemer St in the 20% AEP and 1% AEP events and large areas no longer flood affected in the 20% AEP event.
- Increases within the road reserve are predicted adjacent to all areas of reduction, and range between 0.02 and 0.1 metres in magnitude.

Flood level reductions are predicted across 27 properties during the 20% AEP flood and 50 during the 1% AEP flood. The flood level reductions are sufficient to reduce the number of properties incurring external damage by 1 during the 20% AEP and 2 during the 1% AEP.

The cost to implement the installation of kerb and gutter, as well as associated roadway regrading is estimated to be about $170,000. A detailed breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the kerb and gutter and regrading in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of over $15,000 over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 0.09.

The installation of kerb and gutter and regrading is not predicted to provide any significant emergency evacuation benefits. As the option is designed to retain more water in the roadways, it could be argued that the option provides reduced opportunity for evacuation. However, as evacuation is likely to be difficult given the limited advanced warning time and this option will arguably provide for safer refuge in place (as more water is excluded from buildings), this is considered to be an overall positive outcome.

No significant environmental impacts are anticipated, nor are any impacts on Aboriginal heritage sites. There is a heritage site located near the western end of Elsiemer St, however, all works should be contained within the road reserve and should not impact on this property.

The low benefit-cost ratio makes this option difficult to support from a financial standpoint. Nevertheless, given the relatively low capital cost and the hydraulic benefits across a significant number of residential properties, it is considered that this option should be pursued over the medium to long term long as part of Council's capital works program. If sufficient funding cannot be sourced for the complete option, installation of kerb and gutter on the southern side of Elsiemer St should be pursued as a minimum.

7.4.3 Wyong Road Median Modifications Near Culverts

Recommendation: Recommended for implementation

As discussed in Section 7.2.3 and 7.2.4, Wyong Road has a significant impact on flooding across Killarney Vale. More specifically, the limited capacity of the existing culverts coupled with the fact that Wyong Road (most notably the median strip) is elevated above the adjoining land, results in floodwaters "ponding" on the southern side of the road. This not only reduces the potential to utilise the southern (i.e., west bound) travel lanes during floods, it also cuts access to properties in Kathleen White Crescent and results in inundation of a large number of residential and commercial properties that front Wyong Road.

This option aims to reduce the frequency and depth of inundation along Wyong Road by regrading the roadway surface in the vicinity of the culvert crossings to allow water in excess of the capacity of the culvert to more readily pass over the roadway, thereby, reducing ponding depths. This would be facilitated by removing the elevated median at the culvert locations as well as some local regrading to ensure water is directed into the downstream channel and not downstream properties. **Figure 26** indicates the location of the proposed works.

The TUFLOW model was updated to include the regrading works shown in **Figure 26** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% AEP and 1% AEP events with this option in place are presented in **Plate 31** and **Plate 32.**

Plate 31 and **Plate 32** show that this option is predicted to generate flood level decreases as well as increases during the 20% AEP and 1% AEP floods. Specifically,

- Reductions along Wyong Road (north of Hume Blvd) of up to 0.4 metres are predicted during the 20% AEP and 1% AEP events. Reductions of less than 0.05 metres are predicted along Hume Blvd in the 1% AEP event.
- Increases along the open drainage channel downstream of Wyong Road are predicted with increases of up to 0.05 metres in the 20% AEP and 0.04 metres in the 1% AEP event. In addition, some increases are predicted to extend outside of the open channel across properties on Ferndale St during the 1% AEP event (however, the magnitude of these increases are less than 0.02 metres).
- Flood level reductions along Wyong Road near Kathleen White Crescent are negligible during the 20% AEP event, with some minor decreases of less than 0.02 metres on Wyong Road and in Glenbrook St. During the 1% AEP event, decreases across properties south of Wyong Road (e.g., Kathleen White Cres) of up to 0.05 metres are predicted, with larger decreases of up to 0.25 metres along Wyong Road itself. A number of properties located north of Wyong Road are also predicted to become “flood free” during the 1% AEP event.
- Flood level increases are predicted during the 1% AEP event within Saltwater Creek. However, the magnitude of these are no greater than 0.01 metres.

Flood level reductions are predicted across 10 properties during the 20% AEP flood and 64 properties during the 1% AEP flood. The flood level reductions are sufficient to results in 6 fewer properties with above floor inundation during the 20% AEP flood and 8 fewer buildings with above floor flooding during the 1% AEP flood.

During the 1% AEP event, 46 properties are predicted to experience flood level increases. The flood level increases are typically less than 0.02 metres and are generally contained to the open channels downstream of Wyong Road (where property boundaries extend into the open channel).

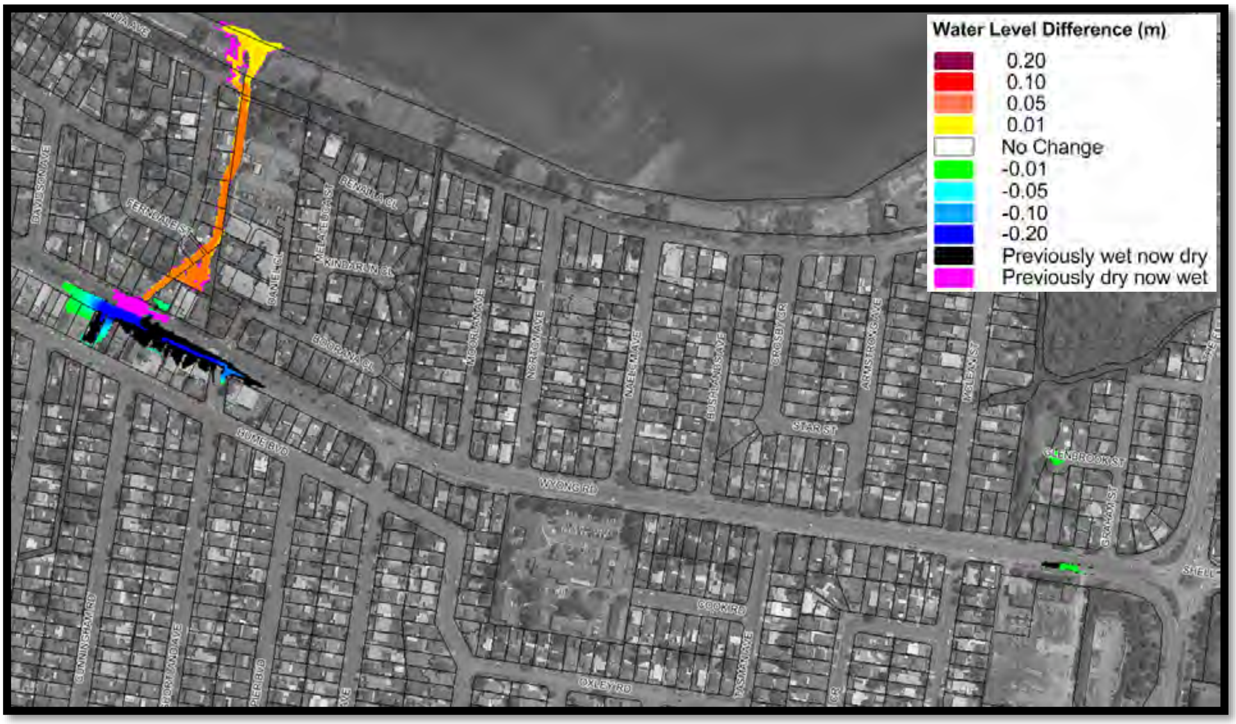

Plate 31 Peak 20% AEP Flood Level Difference Mapping with Wyong Road Regrading

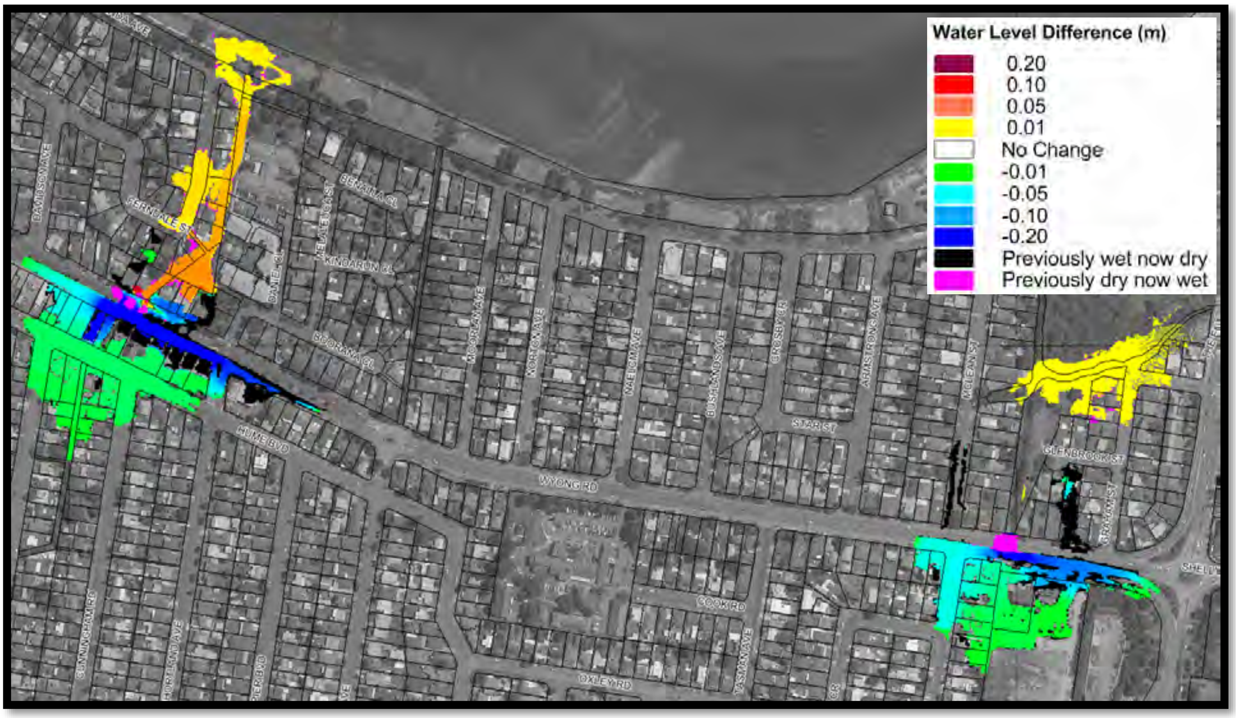

Plate 32 Peak 1% AEP Flood Level Difference Mapping with Wyong Road Regrading

The cost to implement the roadway regrading is estimated to be $990,000. A detailed breakdown of costs is provided in **Appendix D**. A significant contributor to the cost is the management of traffic along Wyong Road (which is a major transportation route for the local area) while the regrading is completed.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the roadway regrading in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of over $1.08 Million over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 1.09. Accordingly, the financial benefits of the roadway regrading outweigh the costs.

The roadway regrading provides some decreases in flood levels on Wyong Road of up 0.25 meters in the 1% AEP event near Kathleen White Crescent and over 0.4 meters in both the 20% AEP and 1% AEP events downstream of Hume Blvd. This will result in less frequent traffic disruption along Wyong Road, Kathleen White Crescent and Hume Boulevard.

There are a significant number of services. They include:

- AusGrid electrical infrastructure located towards the east of the works zone.
- Water mains along both the northern and southern sides of Wyong Road
- A Jemena gas main is located on the norther side of Wyong Road
- An Optus cable extends diagonally across Wyong Road

It is likely that some relocation of services will be required as part of the works. An estimate of the costs associated with these relocations is included in the overall cost estimate for the option.

As the works will require the closure of sections of Wyong Road as the works progress, there will be disruption to local traffic.

The construction works are proposed within a class 3 acid sulphate soils zone. However, as the proposed works would likely only extend into the roadway subgrade disturbance of acid sulphate soils is unlikely. There are no Aboriginal or other heritage sites located within the area.

Overall, this option does afford flood benefits along Wyong Road (i.e., reduced flood impacts for local properties and less frequent inundation of local roadways). In addition, the benefit-cost ratio indicates pursuing this option would yield a positive financial outcome. Accordingly, this option is recommended for implementation. As noted above, small flood impacts are predicted across some properties. Therefore, it is suggested that the concept design developed as part of the current study should be refined to minimise these impacts in the first instance.

7.4.4 The Entrance Reef Resort Regrading

Recommendation: Undertake discussions with The Entrance Reef Resort owners to confirm if they would be willing to participate

As discussed in Section 7.2.4, significant floodwater depths are predicted at a trapped low point on The Entrance Road near the corner of The Entrance Rd and Oaklands/Gosford Ave. This is likely to cause disruption to traffic along this bust transportation route and inundate the adjoining Reef Resort Motel.

The objective of this option is to regrade parts of the Reef Resort Motel grounds (primarily car parking areas) to reduce the ponding depths across the motel and The Entrance Road by enabling water to move more readily around the motel buildings. The concept design for this option is shown on **Figure 27** and includes:

- regrading of the carpark on the eastern and northern sides of the main motel building. The regrading would typically lower the existing carparking elevations by around 0.2 metres.
- construction of an overland flow path / swale behind the main building (the swale directs flow from the car park into the open channel at the rear of the motel.
- the existing solid brick fence across the front of the motel would be converted to an 'open' type to allow more efficient movement of water from The Entrance Road to the regraded area.

The TUFLOW model was updated to include the regrading works shown in **Figure 27** and the updated model was used to re-simulate each design flood. Peak floodwater level difference mapping for the 20% AEP and 1% AEP events with this option in place are presented in **Plate 33** and **Plate 34.**

Plate 33 and **Plate 34** shows that this option is predicted to produce the following hydraulic impacts:

- Flood level reductions of over 0.4 metres are anticipated along The Entrance Road during the 20% AEP and decreases of up to 0.6 metres are predicted in the 1% AEP event. Decreases across the motel site are predicted to vary from 0.3 metres in the 20% AEP event and 0.5 metres in the 1% AEP event.
- Increases in flood level are predicted to be primarily contained along the open drainage channel that runs from the rear of the motel down to Tuggerah lake. Increases in flood levels of up to 0.1 metres are predicted during the 20% AEP and 1% AEP floods. Increases of up to 0.03 metres in the 20% AEP and 0.02 metres in the 1% AEP are predicted in the vicinity of Tuggerah Lake. These increases are predicted to extend into one residential building near Tuggerah Parade.

Flood level reductions are predicted across 10 properties during the 20% AEP flood and 14 properties during the 1% AEP flood. It is noted that flood level increases are predicted to impact on more than 20 properties during the 20% AEP and 1% AEP events. However, the increases typically do not exceed 0.1 metres and are contained to the main drainage channel (i.e., do not impact on most buildings). However, one building fronting Tuggerah Parade is predicted to be exposed to a flood level increase, which will likely increase the potential for damage relative to existing conditions.

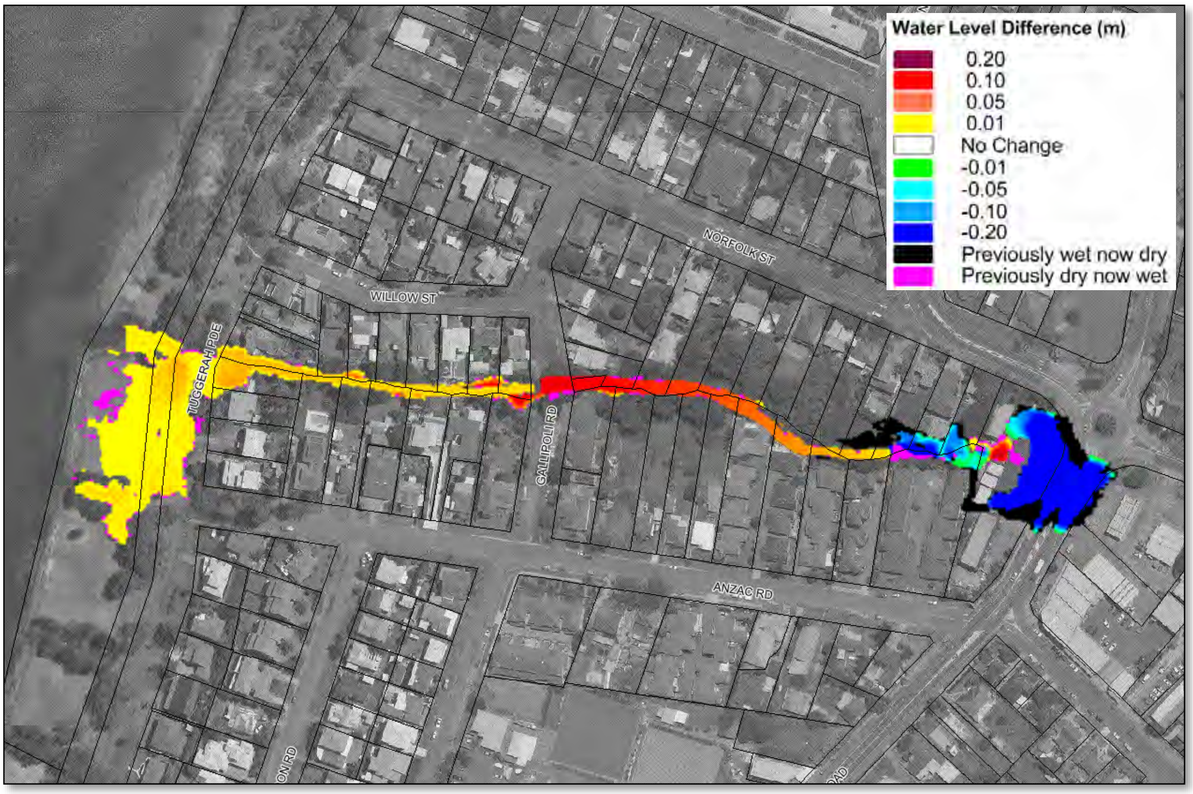

Plate 33 Peak 20% AEP Flood Level Difference Mapping with Regrading across the Reef Resort

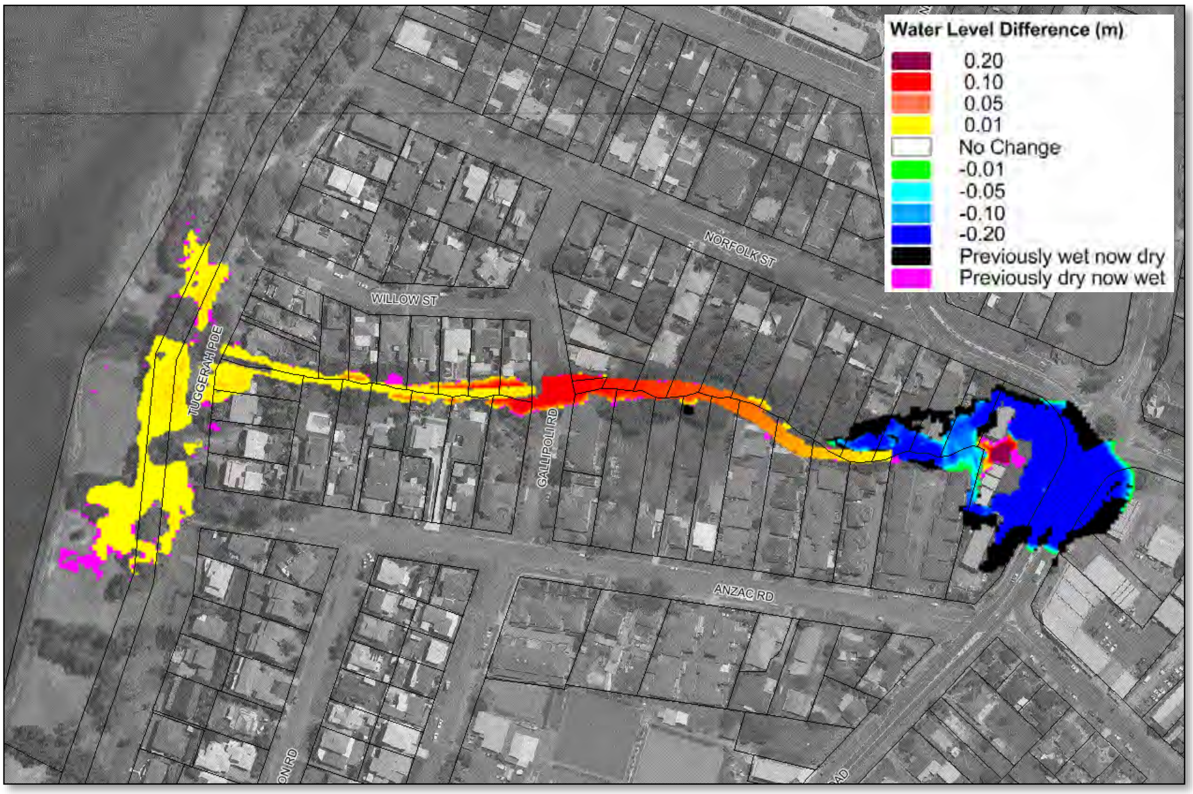

Plate 34 Peak 1% AEP Flood Level Difference Mapping with Regrading across the Reef Resort

The cost to implement the regrading within The Reef Resort Motel is estimated to be about $150,000. A detailed breakdown of costs is provided in **Appendix D**.

The potential financial benefit associated with implementation of the upgrade was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the regrading implemented. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of over $330,000 over the 50-year design life is expected. This yielded a preliminary benefit-cost ratio of 2.23. Accordingly, the financial benefits of conducting the works significantly outweighs the costs.

The works provide decreases in flood levels across The Entrance Road indicating that works would result in less frequent and less severe flooding of the roadway. Accordingly, the works would likely afford some emergency response benefits by allowing The Entrance Road to remain trafficable for longer periods of time.

Although a water main, Optus cable and NBN cable extend along the western side of The Entrance Road, the regrading is contained within the motel site. As a result, relocation of existing services should not be necessary. Nevertheless, further detailed investigation should be undertaken prior to any works being undertaken to confirm.

The regrading works are proposed within a class 5 acid sulphate soils zone indicating a low potential for acid sulphate soils. No Aboriginal heritage or other heritage sites are located within the works zone.

Overall, this option does afford some noteworthy flood benefits for The Entrance Reef Resort and The Entrance Road. However, there is a need to investigate options for reducing the potential for adverse flood impacts across downstream properties (i.e., adjacent to Tuggerah Parade). This could be potentially achieved through implementation of a lower level (i.e., ~0.1m high) levee.

The high benefit-cost ratio indicates this option is worth pursuing. As the works will be undertaken across The Entrance Reef Resort, and the major beneficiary is also the resort, it is recommended that discussions are held with the property owners to confirm the extent of the flooding problem and whether they see any benefit in pursuing the works. Opportunities to share the implementation cost between Council and resort owners could also be explored.

7.5 Recommendations

The following flood modification options have been evaluated as part of the study and are considered viable for further consideration to assist in managing the existing flood risk across the Killarney Vale/Long Jetty local catchments:

- Killarney Vale:
    - Blockage control structures upstream of Wyong Road
    - Wyong Road Median modification near culverts
- Long Jetty:
    - Roadwork and installation of kerb and gutter along Elsiemer St and Pacific St

- Regrading across The Reef Entrance Resort

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 are typically used to manage <u>existing</u> flood risk while planning measures are employed to manage <u>future</u> flood risk.

A review of the flood modelling results determined that there would be no properties within the study area that would be eligible for traditional property modification options (e.g., voluntary house purchase, flood proofing or house raising). Accordingly, the property modification options focussed on planning options. Planning options considered as part of the current study included:

- Changes to Wyong LEP
- Changes to Wyong DCP

Further discussion on the potential planning modifications that could be implemented are provided in the following sections.

8.2 Changes to Wyong LEP

<u>Recommendation</u>: Recommended for implementation

A review of the relevant clauses of Wyong LEP 2013 was prepared in Section 4.3.1. Among the recommended changes are:

- Apply to amend the definition of flood planning level provided in the LEP dictionary so as to apply a variable freeboard across the Killarney Vale Long Jetty catchments, since Council considers that application of a 0.5m freeboard is appropriate for properties subject to flooding from Tuggerah Lake and for some properties downstream of detention basins, while a 0.3m freeboard is appropriate for much of these overland flow catchments; and
- Apply to amend Clause 7.3 to provide Council with discretion to be assured of either safe evacuation or safe on-site refuge above the PMF.

8.3 Changes to Wyong DCP

<u>Recommendation</u>: Recommended for implementation

As a new Central Coast DCP is prepared, it will be important to take into consideration the different kinds of flood behaviour and different risks across Central Coast LGA. Controls that may be appropriate to manage overland flow inundation risks in the Killarney Vale and Long Jetty local catchments were outlined in Section 4.3.2. Among the suggestions are:

- Application of a lower freeboard of 0.3m for incorporation into habitable floor levels of dwellings in the majority of the study area;
- Installation of flood-compatible components for any parts of buildings constructed below the FPL;
- Carport floor levels and sheds could be set at the 5% AEP level or 300mm above the ground level, whichever is higher; and,
- Given the impracticality and perhaps even the danger of evacuation, having controls for these catchments that *require* evacuation may be inappropriate.

Some specific issues are considered in more detail below:

8.3.1 Granny flats

One issue about which Council has expressed concern is the intensification on flood prone land of residential land uses through secondary dwellings such as granny flats. These can increase the number of people living in flood prone areas and increase the imperviousness of catchments thereby increasing runoff.

A resident may seek to install a secondary dwelling as complying development or by obtaining development approval.

Under clause 23 of the *Affordable Rental Housing SEPP 2009*, development for the purposes of a secondary dwellings is complying development subject to various requirements including that the development meet the relevant provisions of the Building Code of Australia (see Section 4.1.1) and clause 3.5 of the *Exempt and Complying Development Codes SEPP 2008* (see Section 4.2.2). As noted previously, clause 3.5 of the Codes SEPP permits development 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, access, and car parking.

Thus, one means of potentially controlling the growth of secondary dwellings on flood prone land is to ensure that the five categories of land on which complying development is not permitted – flood storage area, floodway area, flow path, high hazard area or high risk area – are carefully considered and mapped. This would direct residents wishing to install a secondary dwelling on such land to the development approval process though Council's LEP and DCP. In general, this approach would afford only limited opportunity for controlling development for the purposes of secondary dwellings in the Killarney Vale/Long Jetty overland flow catchments given the limited lots subject to these categories in the 1% AEP flood.

Wyong DCP 2013 includes secondary dwellings such as granny flats as 'medium to high density residential' for the purposes of the DCP. For all land below the flood planning level (FPL), a performance-based assessment is to be provided demonstrating that the proposed development is compatible with the flooding characteristics of the site, with reference to Section 3.2 and Appendix C of the floodplain management chapter of the DCP. It is however not clear whether development for the purposes of a secondary dwelling would require only the requirements in Section 3.2 to be addressed or also the more extensive criteria included in Appendix C. If Council wishes to exert greater control, it would require the more extensive criteria in Appendix C to be addressed, including the requirement that "the proposed development should not result in any increased risk to human life". Especially for proposed development in high hazard or high risk areas, it is difficult to envisage how permitting a new secondary dwelling would not increase risk to human life.

In relation to the concern that attached or separate secondary dwellings (as opposed to secondary dwellings *within* the principal dwelling) increase the imperviousness of catchments thereby increasing runoff, one option would be to test the sensitivity of the hydrological regime to the growth of such secondary dwellings, and if justified, to apply FPLs based on an ultimate development scenario that includes for secondary dwellings. A test would need to apply some conditions for secondary development to qualify as complying development, including in relation to what land use zones permit such development, minimum lot sizes (450 m^2) and maximum floor area (60 m^2) (see clause 23 of the Affordable Rental Housing SEPP).

8.3.2 On-site Refuges

As discussed in Section 5.3.2, evacuation in advance of flooding may be impractical and unsafe for many properties in the Killarney Vale and Long Jetty catchments, because critical durations (i.e., the length of storm producing the worst flooding) are typically less than 2 hours. Roads may be cut less than 30 minutes after the commencement of a storm, leaving very little opportunity for evacuation triggered by environmental cues. Attempting to evacuate as flooding manifests itself may expose evacuees to adverse conditions such as heavy rainfall, hail, lightning, strong winds and the risk from flying debris, falling trees or power lines, in addition to stormwater on roads.

For these overland flow catchments, with generally modest depths of flooding at most dwellings and short durations of isolation, on-site refuge may often be a safer strategy than evacuating.

Historically, dwellings in these catchments have not been required to be designed in a manner that facilitates safer on-site refuges. This would generally require a certain area of floor space – such as 20% of the gross floor area – to be above the level of the PMF. Also, if such an on-site refuge area is proposed, the structure would need to be able to withstand the forces of floodwater, debris and buoyancy in the PMF. Sometimes, it is required that the refuge be externally accessible e.g. via a balcony.

The new Central Coast DCP could be written to require on-site refuges above the PMF where fitting. When dwellings in the already developed Killarney Vale/Long Jetty overland flow catchments are redeveloped, this would provide an additional measure of resilience against floods, possibly with little additional cost given the modest flood height range (e.g., via a mezzanine level). It is also noted that the NSW SES would only countenance on-site refuge as an acceptable emergency response if a refuge above the PMF level, in suitably built structures, is provided. This would also mitigate the risk of people behaving dangerously (e.g. attempting to evacuate through deeper water) if and when floodwater began to inundate their dwelling floors.

On the other hand, the modest flood height range between the 1% AEP flood level and the PMF level in these overland flow catchments – mostly below 0.5m and at most about 1.2m (Section 4.2.3) – means that if habitable floors were constructed to the level of the 1% AEP flood plus freeboard, the flood hazard in the PMF might still be considered tolerable (see Section 5.3.2). This suggests that it may be difficult to justify the impost of requiring home builders to incorporate a PMF on-site refuge for dwellings in this catchment. Accessibility considerations might also dissuade some residents from incorporating a refuge that might add two or more steps.

On balance, it is recommended that in the interests of gradually increasing the resilience of communities, suitable on-site refuges be required as residential development in the Killarney Vale/Long Jetty local catchments is renewed.

8.3.3 Fencing Policy

An important consideration in the management of overland flows is the location and type of boundary fencing that crosses or deflects overland flows. Fences can pose a significant hazard to properties upstream, through raising flood levels, and to properties downstream, from the resulting surge of water should the fence fail. It is difficult to model these effects because of the variability of fencing within the catchments – brick, paling, Colorbond or a combination thereof.

An assessment of the sensitivity of overland flows in the Killarney Vale/Long Jetty catchments to fencing was undertaken. The base case flood modelling for the Flood Study included defined fence alignments along cadastral boundaries but excluded fences fronting roadways.[2] The sensitivity test removed fences that were included in the base case flood model where the velocity-depth product exceeded 0.2 m^2/s (a 0.4 m^2/s threshold was originally investigated but it was found very few fences would be selected). The 20% AEP and 1% AEP design events were run. Flood level difference mapping was generated to compare peak flood levels to the base case. It was found that flood levels tend to decrease upstream of removed fences but increase downstream of removed fences (the maximum increase in level was determined to be about 0.1 metres during the 20% AEP and 0.2 metres during the 1% AEP). Areas that would most benefit from replacement of solid fencing with flood-compatible fencing would be where significant overland flow velocities and depths pass through consecutive properties. Once such area occurs along Elsiemer Street, Long Jetty, (the 20% AEP and 1% AEP flood level differences associated with removal of fences in this area is shown in **Plate 36**).

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[2] Generally, a global blockage factor of 75% was applied to fences (i.e., some water was allowed to pass through). In critical locations, a Google Street View assessment was conducted to provide a more detailed assessment of fence types and the associated blockage (minimum blockage factor was 20%). A solid brick wall along the front of the Reef Resort was modelled as a 100% blockage. Fence collapse was not modelled.

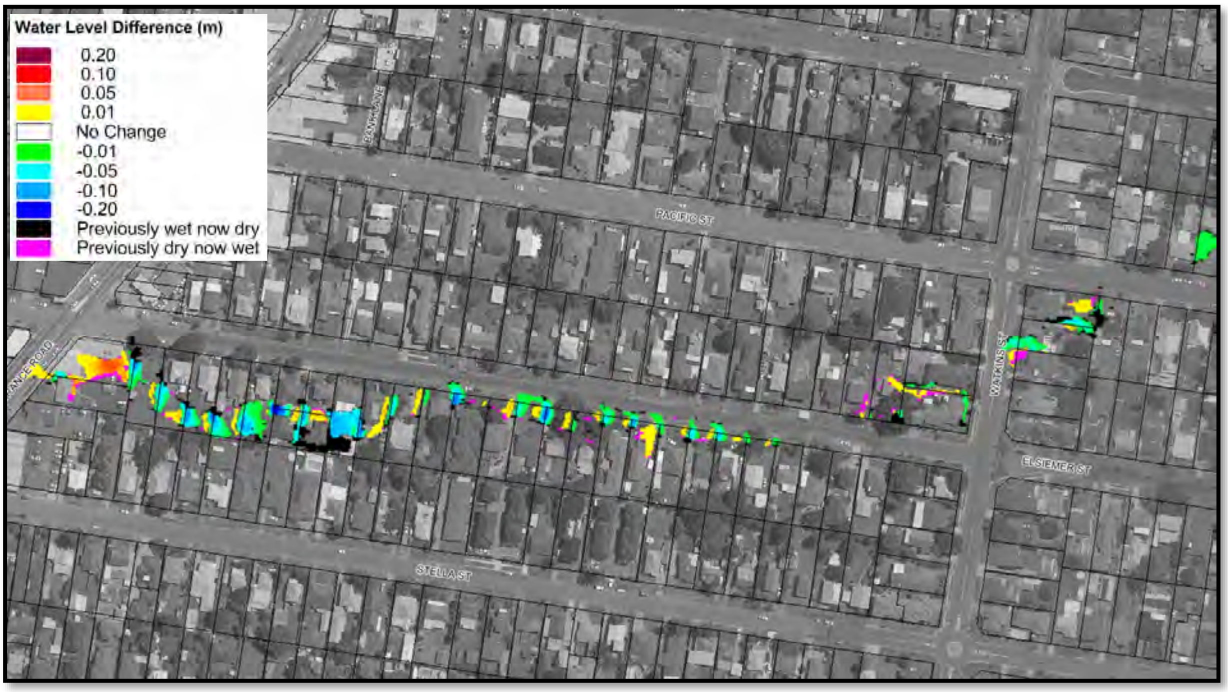

Plate 35 **20% AEP flood level difference map associated with removal of fences near Elsiemer Street, Long Jetty.**

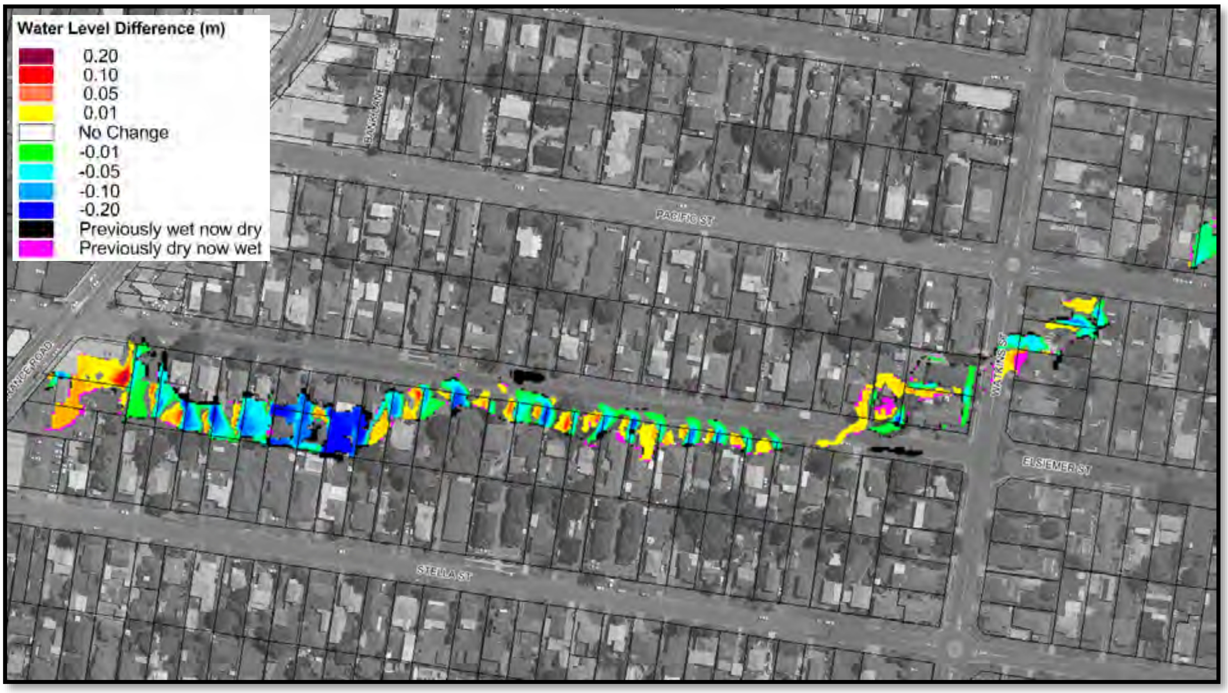

Plate 36 **1% AEP flood level difference map associated with removal of fences near Elsiemer Street, Long Jetty.**

However, adverse impacts are still typical downstream of the areas benefitting. Persuading downstream property owners to accept the increases that could result from a dedicated project to replace all existing fences along a flow path with flood-compatible fences could be difficult, and potentially raise threat of litigation, even if the incremental downstream increases from such a change would be lower than the sudden increase to velocities and depths that could occur if fences collapse under current conditions.

Fences on flood prone land may be erected either as complying development under the Codes SEPP or with development approval.

The Codes SEPP disallows as exempt development the construction or installation of fencing (other than fencing as a barrier for a swimming pool) on a flood control lot in certain residential, business and industrial zones (see clauses 2.33, 2.37).

The Codes SEPP includes the following specification for fencing as complying development in clause 3.29(2 and 3), under the Housing Code:

- *A fence erected … on a lot must … (f) be designed so as not to restrict the flow of any floodwater*.

Clause 3.29(6) indicates that the above clause

- *Is satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirement is satisfied.*

Clause 3B.57 contains similar provisions for fencing under the Low Rise Medium Density Code, and Clause 3C.32 contains similar provisions for fencing under the Greenfield Housing Code.

Section 4.1 of the floodplain management chapter of Wyong DCP 2013 lists the following objectives:

- *To ensure that fencing does not result in any significant obstruction to the free flow of floodwaters*
- *To ensure that fencing will remain safe during floods and not become moving debris that potentially threatens the security of structures or the safety of people.*

It requires that:

- *Fencing is to be constructed in such a manner that it will not modify the flow of floodwaters or cause damage to surrounding land*
- *Fencing construction is to withstand flood waters including debris loads.*

Comparing the clauses in Wyong DCP 2013 to equivalent clauses in chapter 11 of Fairfield City DCP, the following observations are noted:

- It may be difficult to have any fencing that does not in any way modify the flow of floodwaters, especially if that fencing needs to be able to withstand floodwaters including debris loads
- The Wyong DCP excludes the option found in Fairfield City DCP for fences to *"collapse in a controlled manner"*
- The Wyong DCP excludes any prescriptive criteria including the options for appropriate fencing found in Fairfield City DCP being:
    - *a) An open collapsible hinged fence structure or pool type fence;*

b) Other than a brick or other masonry type fence (which will generally not be permitted); or
c) A fence type and siting criteria as prescribed by Council.

Central Coast Council could consider amending the requirements for fencing on flood prone land after the more prescriptive manner of Fairfield City Council. However, there may be little advantage in doing so given the more general requirements for fencing as complying development found in the Codes SEPP.

Also, it is understood that maintaining flood-compatible fences – such as those open at the bottom to allow the free movement of overland flows – is notoriously difficult to achieve, given changes of ownership and residents' everyday requirements for securing pets and privacy. Ongoing education highlighting the problems that can occur without flood-compatible fencing may be a more effective strategy for achieving the objectives sought in the Wyong DCP 2013.

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 Killarney Vale/Long Jetty local catchments:

- Amend the LEP (or shape a new Central Coast LEP) as described in Section 8.2
- Amend the DCP (or shape a new Central Coast DCP) as described in Section 8.3 including promoting suitable on-site refuges where fitting.

9 RESPONSE MODIFICATION OPTIONS

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 Killarney Vale and Long Jetty catchments.

Response modifications options considered as part of the study include:

- Emergency response planning (i.e., planning before a flood)
- Options to aid in post-flood recovery

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

9.1 Emergency Response Planning

9.1.1 Local Flood Plan Updates

Recommendation: Incorporate flood behaviour and risk exposure information for the Killarney Vale/Long Jetty local catchments

The Wyong Local Flood Plan (LFP) was reviewed in Section 5.1. This identified areas of the LFP requiring revision, especially to Volume 2, which needs to align with the structure and contents of the new NSW SES LFP template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. In particular, it currently says very little about flooding risks from local overland flow catchments including the Killarney Vale/Long Jetty local catchments.

9.1.2 Community Education

Recommendations:

- Conduct an audit of previous flood education initiatives in the LGA over the past 5-10 years
- Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community

As noted in Section 5.2, given the size of the at-risk communities in Central Coast LGA and the rapidity with which flash flooding can occur, adverse consequences are likely to occur across some sections of the Killarney Vale/Long Jetty local catchments before emergency services personnel can be deployed. This emphasises the importance of the at-risk communities being equipped to respond appropriately to flooding, without reliance on the emergency services. But a community survey conducted for this floodplain risk management study indicated that

36% of people who responded to the survey did not even know whether their property could be potentially flooded or not (refer Section 2.5.3). This highlights a need for improved provision of flood information in addition to equipping people with knowledge of how to prepare for, respond to and recover from flooding.

A few broader points are made before considering needs and opportunities for the current study area.

First, whatever approaches are implemented to increase community flood resilience in the Killarney Vale/Long Jetty local catchments should be congruent with initiatives throughout Central Coast LGA to ensure a consistent and strategic rather than an ad hoc approach to community flood education. A first step could be to audit flood education initiatives recommended and possibly implemented in the LGA over the past 5-10 years. This would include the *Flood & Coastal Storms Education Strategy* (2011) developed by the NSW SES, and any recommendations from adopted floodplain risk management plans. A second step would be to commission robust social research to form a new baseline of current levels of flood awareness and readiness, including any discernible spatial differences across this large and geographically diverse LGA. Then, new initiatives could be pursued, and their effectiveness tested, based on a solid evidence base.

Second, historically the NSW Floodplain Management Program has been reluctant to fund community education initiatives. One reason is that this is seen as the primary responsibility of the NSW SES, with Councils supporting the SES. Second is the recognised need for sustained investment to build and maintain community flood awareness and readiness, especially in the absence of major floods that serve as a natural reminder of the risk, and also in the face of dynamic communities such that people with no prior knowledge or experience of flooding may move into a flood prone area. Historically the Floodplain Management Program has funded capital expenditure but not maintenance expenditure. This means that Council funding to assist the NSW SES may have to be sourced elsewhere.

9.1.3 Flood Information

Recommendation:
- Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data

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 have 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 Central Coast Council on-line mapping tool. The existing flood extent information provided on Council's online mapping page could be expanded to convey additional 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". This however might require additional Council resources and training to answer inquiries about what this information means and how it could be used to assist in the preparation of property-level flood response plans.

Collateral to answer "FAQs" may also need to be developed and updated to accompany any upscaling of flood information availability. For example, people are often concerned about the perceived impact of flood information on property values and insurance premia. Potential answers have been developed by Floodplain Management Australia and the Insurance Council of Australia and could be used as a starting point for preparation of a specific FAQ sheet.

If Council's existing mapping website cannot accommodate this information, it could be included in a separate flood information portal website. It would be desirable to have a single authoritative website to minimise confusion.

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 personalised flood plans; and,
- 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 warnings, live information on nearby rain gauges and river gauges, and the latest advice from relevant organisations such as NSW SES and RMS. If well maintained, a website 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 BoM Severe Weather 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' rainfall and river gauge information in the context of past events. This can also include live identification of flooded roads and identification of alternative flood evacuation routes for any point in the catchment
- integration with rainfall forecasting systems and real time flood modelling to predict the extents and timing of the current flood and generate required warnings.

9.1.4 Flood Education

Recommendations:
- Disseminate educational messages about the dangers of entering or playing in floodwater and staying at home may be safer than attempting to evacuate late
- Consider site-specific community outreach to recognised flooding "hot spots"

A number of key messages need to be heard and received by people in the Killarney Vale/Long Jetty local catchments 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 dangers posed by inundation of roads in the study area. Messages could also provide technical information to dissuade drivers from crossing flooded roads, such as the depths at which cars float. Messages could also target the motivations for crossing water, such as by encouraging childcare centres and schools to advise parents during storms or floods that their children are safe. In catchments with stormwater drains, it is vitally important to include "play" in the message, recognising that young lives have been lost during storms when youths get in trouble in rapidly flooding culverts and drains.
- "It's often safer to stay than to attempt to evacuate late." The potential depths of above-floor inundation for dwellings in the study area are typically lower than potential depths on roadways, which in combination with high flow velocities and adverse weather conditions could lead to highly hazardous driving conditions. Also, the duration of local catchment flooding is relatively short, lending itself to messaging such as "Wait a few hours".

For this study area, there are some "hot spots" of flood risk exposure (Section 3.5) where site-specific outreach (e.g. SES door-knocking or "meet the street" type events) may be warranted to convey the flood risk and to help residents plan for how they could best prepare and respond to flooding.

9.2 Options to Aid in Post-Flood Recovery

9.2.1 Local Flood Plan Updates

Recommendation: Include additional flood recovery responsibilities for various agencies

The Wyong Shire Local Flood Plan (LFP) sets out the responsibilities of various agencies in post-flood recovery. The LFP implies that recovery largely rests with the SES with assistance from other agencies, as required. This section of the LFP also requires updating to ensure it is consistent with current arrangements.

It is also 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.

9.2.2 Disaster Relief

Recommendation: For consideration following a major storm/flood

Disaster relief provides financial assistance following the declaration of a natural disaster. A Natural 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 an assessment 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
- 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.

9.3 Recommendations

The following response 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 Killarney Vale/Long Jetty local catchments:

- Local Flood Plan Updates:
  - Update the Local Flood Plan, especially to incorporate flood behaviour and risk exposure information for the Killarney Vale/Long Jetty local catchments (NSW SES)
  - Amend the Local Flood Plan to reflect additional flood recovery responsibilities for various agencies (NSW SES)
- Community Education:

- Conduct an audit of flood education initiatives recommended (and potentially implemented) in the LGA over the past 5-10 years (NSW SES, Council)
- Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community flood education (Council)
- Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data (Council)
- Continue to disseminate messages about the dangers of entering or playing in floodwater (NSW SES)
- Consider targeted messages to convey that staying may be safer than attempting to evacuate late (NSW SES)
- Consider site-specific community outreach to recognised flooding “hot spots” (NSW SES, Council)

- Flood insurance:
  - Individual property owners should consider taking out a flood insurance (individual property owners)
  - Make available flood data to property owners and advocate for fair premia to increase affordability of flood insurance (Council);

10 Draft Floodplain Risk Management Plan

10.1 Introduction

The draft Floodplain Risk Management Plan sets out a preferred set of options that can be implemented in the short, medium and long term to manage the flood risk across Killarney Vale and Long Jetty. 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 Killarney Vale and Long Jetty Catchments Floodplain Risk Management Plan are summarised in **Table 24** and are also shown in **Figure 28**. 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, 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 6, 7 and 8 of this report.

Several options are also included for further investigation to confirm their financial and technical feasibility.

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. The high capital cost associated with the implementation of the flood modification options means that these options will likely need to be distributed over an extended timeframe (10 years is suggested). However, this will be dependent on the budgetary commitments of Council and availability of funding from other sources.

10.3.2 Costs and Funding

Table 24 summarises the expected cost to implement each of the recommended options. The most significant costs are associated with the Wyong Road modification. As a result, it is recommended that this option is staged over a ~8 year timeframe so the costs can be distributed.

In addition to the capital costs, some options will incur ongoing maintenance costs. As noted in **Table 24**, many of the options will require an investment in time from various agencies including Central Coast Council and the State Emergency Service in addition to monetary contributions.

Funding for implementation of the plan could be obtained from the following sources:

- Central Coast Council's capital works 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 (particularly with the low benefit-cost ratios for a number of options). 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 (e.g., regrading across The Entrance Reef Resort may not be eligible for State Government funding). It should also be noted that ongoing costs (e.g., maintenance of debris control structures) 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 24**, most options/investigations are scheduled for implementation within 5-years. Therefore, it is recommended that the Plan be revisited after 5 years to determine if the implementation of the plan is proceeding in accordance with the suggested timeframes and whether an update of the Plan may be necessary.

Table 24 Draft Floodplain Risk Management Plan

FM	Flood modification option	PM	Property modification option	RM	Response modification option

Option		Report Section	Implementation Responsibility	Capital Cost	BCR	Priority	Timing	Comments
FLOOD MODIFICATION OPTIONS								
Killarney Vale								
KV FM1	Blockage Control Structures Upstream of Wyong Road	7.2.1	Council	$55,000	$2,000 per annum	High	2 years	Trash rack would likely need to be replaced after ~25-years at a total current cost of $26,000 for 2 racks
KV FM2	Wyong Road median modification near culverts	7.4.3	Council	$990,000	-	Medium	8 years	Implementation could be split into 2 stages to help distribute costs
Long Jetty								
LJ FM3	Roadworks and installation of kerb and gutter along Elseimer St and Pacific St	7.4.2	Council	$170,000	-	Medium	4 years	
LJ FM4	Regrading across The Reef Entrance Resort	7.4.4	Council + resort owners	$150,000	-	High	5 years	Discussions with resort owners should be initiated within 1-year to confirm their willingness to participate

Option			Report Section	Implementation Responsibility	Capital Cost	BCR	Priority	Timing	Comments
PROPERTY MODIFICATION OPTIONS									
Killarney Vale & Long Jetty									
KVLJ PM1	LEP Amendments		8.2	Council	Council time	$0	Medium	2 years	
KVLJ PM2	DCP Amendments		8.3	Council	Council time	$0	Medium	2 year	
RESPONSE MODIFICATION OPTIONS									
Killarney Vale & Long Jetty									
KVLJ RM1	Local Flood Plan Updates	Incorporate flood behaviour and risk exposure information for the Killarney Vale/Long Jetty local catchments	9.1.1	NSW SES	SES time	$0	Medium	2 years	
KVLJ RM2	Local Flood Plan Updates	Include additional flood recovery responsibilities for various agencies	9.2.1	NSW SES	SES time	$0	Medium	2 years	

Option			Report Section	Implementation Responsibility	Capital Cost	BCR	Priority	Timing	Comments
KVLJ RM3	Community Education	Conduct an audit of previous flood education initiatives in the LGA over the past 5-10 years	9.1.4	NSW SES and Council	SES and Council time	$0	High	2 years	
KVLJ RM4		Commission a baseline survey of community flood awareness and readiness, to inform an ongoing strategic approach to community flood education	9.1.4	Council	$10k	$0	High	1 year	
KVLJ RM5		Expand the type of flood information made available on spatial data platforms, with appropriate resources to explain the meaning of the data	9.1.4	Council	Council time	Council time	Medium	1 year + ongoing updates	
KVLJ RM6		Disseminate educational messages about: • the dangers of entering or playing in floodwater • staying at home may be safer than	9.1.4	NSW SES	SES time	SES time	High	1 year	

Option			Report Section	Implementation Responsibility	Capital Cost	BCR	Priority	Timing	Comments
		attempting to evacuate late							
KVLJ RM7		Consider site-specific community outreach to recognised flooding "hot spots"	9.1.4	NSW SES & Council	SES and Council time	SES and Council time	High	1 year	

11 References

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APPENDIX A

COMMUNITY CONSULTATION

9. IF YOU HAVE ANY OTHER SUGGESTIONS FOR REDUCING THE FLOODING PROBLEMS, PLEASE DESCRIBE THEM BELOW.

10. DO YOU HAVE ANY ADDITIONAL INFORMATION THAT YOU THINK MAY ASSIST IN THE STUDY?

Killarney Vale & Long Jetty 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. Once complete, please return the questionnaire via email or mail (no postage stamp required) by **22 December 2017**. Alternatively, if you have internet access, an online version of the questionnaire can be completed at: www.yourvoiceourcoast/Killarney-Vale-Long-Jetty-Floodplain-Risk-Management

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: ______

I wish to stay informed for the duration of the study:

☐ Yes ☐ No

1. WHAT TYPE OF PROPERTY DO YOU LIVE IN / OWN?

☐ Residential

☐ Commerical

☐ Industrial

☐ Other (Please specify:______)

How long have you lived at this property? ______years

2. HAVE YOU EXPERIENCED PREVIOUS FLOODS IN THIS AREA?

☐ Yes

☐ No (go to Question 4)

3. HOW DID THE BIGGEST OF THESE FLOODS AFFECT YOU?

Tick all that apply:

- ☐ flooding over main building floor
- ☐ flooding of garage/sheds
- ☐ lost access due to flooding of roads
- ☐ sewerage system was not working at our property
- ☐ other (Please specify: ______________________________)
- ☐ not applicable / not affected

4. 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

5. HOW DO YOU ANTICIPATE YOU WOULD RESPOND IN A FUTURE MAJOR FLOOD IN THIS AREA?

Tick one:

- ☐ evacuate early to an official evacuation centre
- ☐ evacuate elsewhere – please describe: ______________________________
- ☐ remain at my house
- ☐ other – please describe ______________________________
- ☐ don't know/not sure

6. IF YOU ARE LIKELY TO EVACUATE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

Please select all factors that would apply:

- ☐ 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)

7. IF YOU ARE LIKELY TO REMAIN AT YOUR HOUSE, WHAT FACTORS ARE MOST IMPORTANT TO YOU?

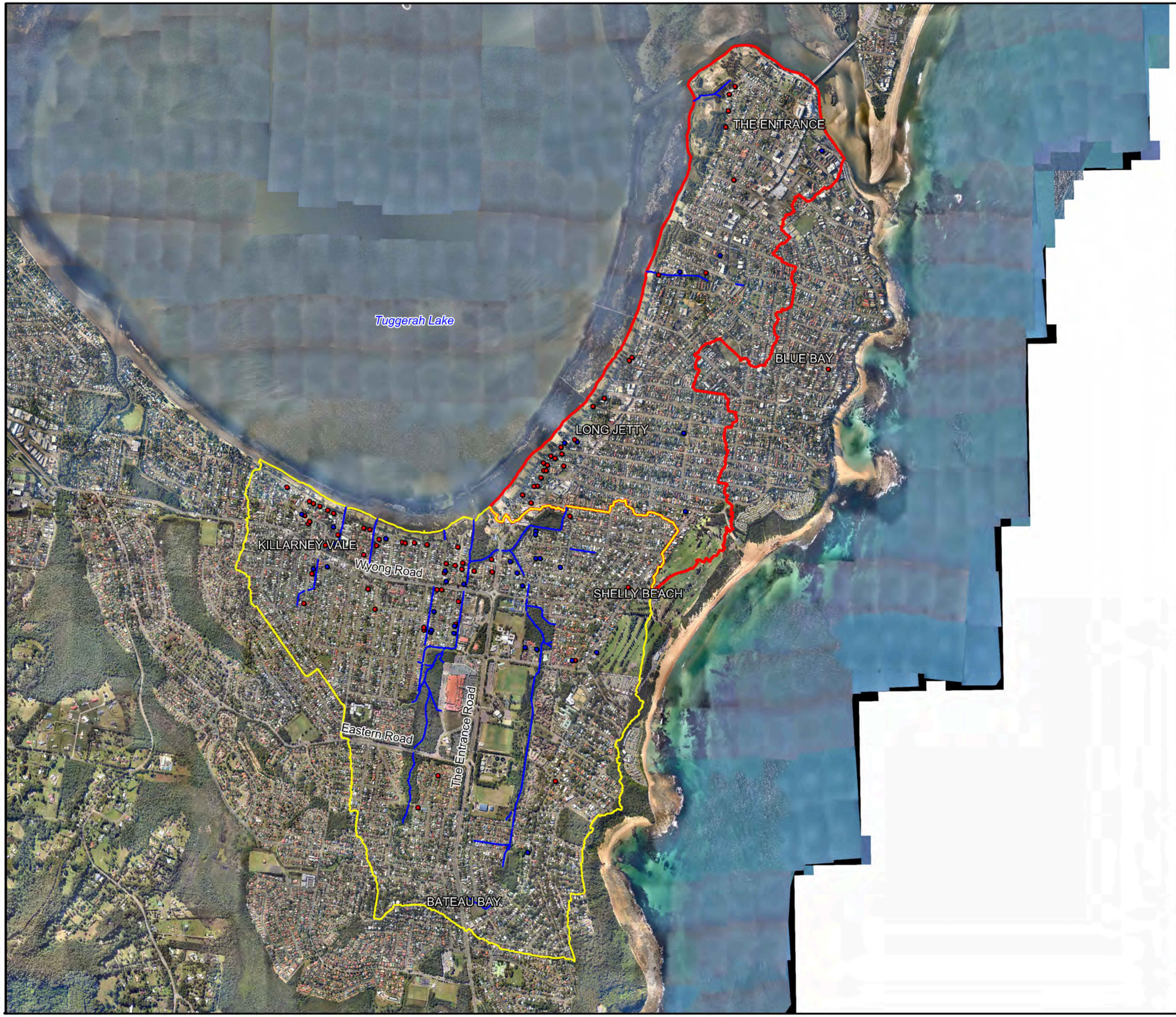
Please select all factors that would apply:

- ☐ 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)

8. TO ASSIST US IN DEVELOPING A SHORT LIST OF POTENTIAL FLOOD RISK REDUCTION MEASURES, PLEASE TELL US HOW IMPORTANT IT IS FOR A PARTICULAR MEASURE TO ADDRESS THE FOLLOWING FACTORS:

How important is it that the flood risk reduction measure:	Not Important	Slightly Important	Moderately Important	Very Important	Extremely Important
Improves community access and recreational use					
Does not disadvantage individual members of the community					
Provides safety to the community during flooding					
Raises community awareness and understanding of the local flood risk					
Does not threaten local plants and animals and their habitat					
Does not cause water quality issues					
Initial costs (i.e., design/construction) require minimal council expenditure					
Requires minimal ongoing council expenditure after implementation					
Reduced flood damages to the community					
Does not cause negative flood impacts to other areas (both upstream and downstream)					

Further information on different risk reductions measures and the advantages and disadvantages of each is available at: www.yourvoiceourcoast/Killarney-Vale-Long-Jetty-Floodplain-Risk-Management



Central Coast Council

LEGEND

- Killarney Vale Catchment
- Long Jetty Catchment
- Watercourses

Questionnaire Response Locations
Has flooding been experienced?

- Yes
- No

Notes:

Aerial photograph date: 2013

N W E S

Scale 1:24,000 (at A3)

0 0.5 1.0 Km

Figure A1: Spatial Distribution of Questionnaire Responses

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigA1 Community Questionnaire .wor

Community Questionnaire Responses - Killarney Vale / Long Jetty Floodplain Risk Management Study Part 1 of 2

#	1 What Type of Property Do you live in/own?					2 Have you experienced previous floods in this area?		3 How Did the Biggest of These Floods Affect You?						4 Do You Know If Your House / Business Has a Risk of Being Flooded			5 How Do You Anticipate You Would Respond in a Future Major Flood In This Area?					6 If You are Likely to Evacuate, What Factors are Most Important to You?				
	Residential	Commercial	Industrial	Other - Please Specify	How Long Have You Lived at this Property (years)?	Yes	No	Flooding over the main building floor	Flooding of garage / sheds	Lost access due to flooding of roads	Sewerage system was not working at our property	Other - Please Specify	Not applicable / not affected	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	Evacuate early to an official evacuation cetnre	Evacuate elsewhere - please describe	Remain at my house	Other - please describe	Don't know / not sure	Discomfort / inconvience / 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)
1	X				20	X				X				X							X	X	X			
2	X				30	X			X	X	X					X		Friend OR Motel				X	X	X		
3	X				40	X									X				X					X		
4	X				12		X		X	X				X					X							
5	X				48	X				X				X							X	X	X			
6	X				15		X		X			This happened in the easy coast low of 1976,no furhter issues water backed up into kitchen sink		X		X			X							
7	X					X			X		X					X	X					X				
8	X				25	X						Back Yard				X			X					X		
9	X				4	X									X				X							X
10	X						X							X					X			X		X		
11	X				12	X						Self no 95,Neigbour no 93														
12	X				29	X							X			X		FRIEND HOUSE IN SYDNEY							Security of Premises while absent	
13	X				3	X										X	X					X	X	X		
14	X						X		X							X					X					X
15	X					X						Flooding at one end of the street,we Coud still access our property though.		X			X					X		X		
16	X				4	X								X				Take my Pets + go to my Daugher home in sydney				X		X		
17	X						X						X			X				wait for instructions				X		
18	X				7		X						X			X			X							X
19	X				22		X									X			X			X	X	X		
20	X						X									X			X							X
21	X				30		X		X	X	X	No power fallen trees + Power wne		X					X			X		X		
22	X				17	X								X					X							X
23	X				16	X				X						X			X							X
24	X					X										X		Geoff's Parents						X		
25	X				4.5		X									X					X	X				
26	X				13		X		X					X				Friend OR Relative						X		
27	X					X										X					X					X
28	X				12		X						X			X			X			X		X		
29	X				12	X				X				X				Go to my place fo other residence ie. 445 brush rd Glenning Valley.		For Cabins-Refund Bookings For the period		X				
30		X			30	X					X	This occurred as no resuce as the 2016 storm				X	X						X		Need to use medical Equipments	
31	X				60	X				X					X				X							X
32	X				12	X									X				X							X
33	X				21		X		X					X					X			X				
34	X					X				X				X					X						Road Cldusre @ En of Street	
35	X				22	X				X						X					X	X				
36	X					X							X			X			As long as I Cloud.if things got too Dangerous then to move.							X
37	X				30		X																			
38	X				15	X				X					X				X							X
39	X				2		X						X	X			X							X	Concerned of theft + brealding in by opportunist	
40	X				25		X								X				X							X
41	X				26	X			X	X				X		X			X							X
42	X						X								X				X					X		
43	X					X					X					X				Would Evalate at the time		X	X	X		
44	X				25	X						Earden Flooded-Rose to top setp and patio		X					upstaris if possible or go to friends				X			
45	X				16	X				X		Backyard under water also under elevated verandh			X				X							
46	X				2.5		X							X			X							X		
47	X				26	X				X				X							X					
48	X				16		X						X		X						X			X		
49	X				23	X						Surface water flooding from Glof Course council rectified flooding with bigger pipes				X	X					X				
50	X						X									X			X							
51	X				22		X									X					X	X		X		
52	X					X				X		Drainage Ditches full		X					X	Call your People and friggon cmplain for sure					Drowning? Are you kidding! Who write this?	
53	X					X					X					X			X					X		
54	X				2		X							X			X					X		X		
55		X			1989	X				X						X				All Units are Tenanted						
56	X				12		X								X				X							X
57	X				6	X				X					X				X							X
58	X				28		X									X	X					X				
59	X					X						Washed over garden and surrounding nature reserve.		X				relocate to my sons house							Damage to my house and property	
60	X						X							X			X							X		
61	X					X				X						X			X			X				

#	1 What Type of Property Do you live in/own?					2 Have you experienced previous floods in this area?		3 How Did the Biggest of These Floods Affect You?						4 Do You Know If Your House / Business Has a Risk of Being Flooded			5 How Do You Anticipate You Would Respond in a Future Major Flood In This Area?					6 If You are Likely to Evacuate, What Factors are Most Important to You?				
	Residential	Commercial	Industrial	Other - Please Specify	How Long Have You Lived at this Property (years)?	Yes	No	Flooding over the main building floor	Flooding of garage / sheds	Lost access due to flooding of roads	Sewerage system was not working at our property	Other - Please Specify	Not applicable / not affected	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	Evacuate early to an official evacuation cetnre	Evacuate elsewhere - please describe	Remain at my house	Other - please describe	Don't know / not sure	Discomfort / inconvience / 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)
62	X				21	X				X					X				X							X
63	X					X			X	X						X			X			X	X	X		X
64	X				24		X							X							X			X		
65	X					X			X	X						X			X					X		
66	X				27	X					X					X			X			X				
67	X				6	X		X						X					X					X		
68	X				20	X				X				X					X							X
69	X						X									X			X					X		
70	X				3		X									X			X							X
71			X		4.1	X				X				X				X							Business property.Loss of income	
72	X				10 MONTH	X						Minor Flooding up to Road Gutter		X			X					X	X	X		
73	X					X						Drains Floods Back Yard,Lucinda Avenue,Amstrong avenue Flooded.		X					X							
74	X				4	X				X			X							Park Car Up Glhdstan + wade thru water						X
75	X					X				X				X				FRIEND HOUSE				X		X		
76	X				17	X				X	X			X			X							X		
78	X				25	X				X							X						X	X		
79	X				2		X						X			X			as water lelels have never reached my home in history of floods in the area							X
80	X					X			X	X	Electricity Failed lost Forzen			X				FRIEND PLACE						X		
81	X				3		X							X					X							X
82	X				2		X									X		FAMILY				X			PETS	
83	X				31	X				X					X				X							X
84	X				13		X							X				FAMILY				X		X		
85	X				8.5	X				X		Open Drain(subject to tides etc from)(Tuggerah lake)became massive danger as with flooding it was impossible to gauge			X				X							X
86	X				7		X									X	X							X		
87	X				67	X			X	X	X			X					X							
88	X				28		X					Road Became flooded			X				X							X
89	X				50	X			X	X	X					X			X	get everything in low laying shads and sleep outs up high				X	MY DOG	
90	X				23	X			X	X				X			X		X			X	X	X		
91	X					X			X	X						X					X	X				
92				MOTEL	6	X				X				X			X					X				
93	X				2	X					X	Lost access to walking path by lucinda ave				X			X					X	Safety of my home against looting	
94	X				3.5	X			X	X				X					X							X
95				investment property					X		X			X			X							X		
96	X				12	X			X	X					X				X							X
97	X				34	X				X				X					X							X
98	X				13		X									X					X		X			
99	X				13	X		X	X	X		Lost Power due to u/ground supply		X				X	X			X	X	X		
100	X				16	X							X		X				X							X
101	X				47	X				X					X				X							
102	X				20	X			X	X				X					X							X
103	X				16		X									X			X							
104	X				10	X			X					X						Stay unless driected to evaluate then go to ther property in sudney				X		
105				CARAVAN PARK Family Onwed Business	80	X				X				X						Raise Customers Belongings above flood hight						X
106	X				12	X				X					X				X							X
107	X				10		X								X				X							X
108	X						X						X			X		go to my niece at bateau bay				X	X			
109	X				30	X			X	X				X				Relatives in toowoon bay				X	X	X	Difficulty with insurance claims	
110	X			This is Holiday House.Located at 13 lakeside pde	20	X			X	X				X				Return homes to ry da amornd						X		
111	X				17	X				X				X					X							X
112	X				12	X							X		X				X							X
113	X						X								X		X							X		
114	X				30	X				X	X	Water over Road and in yard did not enter house		X							Probably not an issue because it is a weekend,this is not my main residence	X				
115	X				17		X								X		X					X		X		
116	X				4		X						X		X		X					X				
117	X				11	X				X				X					X							
118	X				18	X						Flooding from the property Nearst door		X							X		X			
119	X					X				X												X		X		

#	1 What Type of Property Do you live in/own?					2 Have you experienced previous floods in this area?		3 How Did the Biggest of These Floods Affect You?						4 Do You Know If Your House / Business Has a Risk of Being Flooded			5 How Do You Anticipate You Would Respond in a Future Major Flood In This Area?					6 If You are Likely to Evacuate, What Factors are Most Important to You?				
	Residential	Commercial	Industrial	Other - Please Specify	How Long Have You Lived at this Property (years)?	Yes	No	Flooding over the main building floor	Flooding of garage / sheds	Lost access due to flooding of roads	Sewerage system was not working at our property	Other - Please Specify	Not applicable / not affected	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	Evacuate early to an official evacuation cetnre	Evacuate elsewhere - please describe	Remain at my house	Other - please describe	Don't know / not sure	Discomfort / inconvience / 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)
120	x				30	x						Flooding implication willow creek and erosjon of back yard,trees lost and undermined near of property nor folk st the entrance of oakland ave			x				x				x	x		x
121	x						x									x			x							x
122	x					x				x						x	x		x			x				
123	x				12	x			x					x	x				x							
124	x				9	x							x		x				x							x
125	x						x									x		Relatives				x		x		
126						x			x	x	x	x		x					x			x				
127						x			x					x					x					x		
128						x			x	x	x			x					x							x
129						x				x						x					x	x				
130						x			x	x	x	x		x					x							x
131						x			x	x				x					x							x
132						x		x	x					x					x							

Community Questionnaire Responses - Killarney Vale / Long Jetty Floodplain Risk Management Study Part 2 of 2

#	7 If You Are Likely To Remain At Your House, What Factors Are Most Important To You?						8 To Assist Us In Developing a Short List of Potential Flood Risk Reduction Measures, Please Tell Us How Important It Is For A Particular Measures to Address the Following Factors										9 If You Have Any Other Suggestions For Reducing The Flooding Problems, Please Describe Them	10 Do You Have Any Additional Information That You Think May Assist In The Study
	Discomfort / inconvience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for the security of my property if I evcuate	Other - please describe	Not Applicable (I intend to evacuate from my house)	Improves community access and recreational use	Does not disadvantage individual members of the community	Provides safety to the community during flooding	Raises community awareness and understanding of the local flood risk	Does not threaten local plants and animals and their habitat	Does not cause water quality issues	Initial costs (i.e., design/construction) require minimal council expenditure	Requires minimal ongoing council expenditure after implementation	Reduced flood damages to the community	Does not cause negative flood impacts to other areas (both upstream and downstream)		
1				X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	-	-
2							Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important		
3						X	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
4			X				Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important		
5				X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
6		X		X			Moderately Important		Very Important	Very Important	Extremely Important	Extremely Important		NOT Important	Moderately Important	Very Important		
7							Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
8				X			Moderately Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Extremely Important		
9			X				Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important		
10	X						Slightly Important	Very Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Slightly Important	Slightly Important	Extremely Important	Very Important		
11																		
12						X	Slightly Important	Moderately Important	Extremely Important	Very Important	Slightly Important	Very Important	Very Important	Very Important	Very Important	Extremely Important		
13	X			X			Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important		
14	X			X			Slightly Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		NO
15	X			X			NOT Important	Very Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Very Important		
16		X					NOT Important	Very Important	Extremely Important	Slightly Important	Extremely Important	Extremely Important	NOT Important	NOT Important	Slightly Important	Very Important		
17				X			NOT Important	Moderately Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Very Important	Very Important		
18			X							Very Important								
19	X	X		X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Extremely Important		
20	X						Slightly Important	Moderately Important	Extremely Important	Extremely Important	Slightly Important	Very Important	Slightly Important	Moderately Important	Very Important	Extremely Important		
21		X		X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Extremely Important		
22	X			X			Slightly Important	Very Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important		
23		X		X			Very Important	Extremely Important	Very Important	Slightly Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Extremely Important		
24				X			NOT Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important		
25	X			X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important		NOT Important	NOT Important	Extremely Important	Extremely Important		
26	X						Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
27	X			X			Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important		Very Important	Moderately Important	Extremely Important	Extremely Important		
28	X	X		X			Very Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important	Very Important		
29	X						Extremely Important	NOT Important	Slightly Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important		
30						X	NOT Important	NOT Important	Extremely Important	Extremely Important	Very Important	Very Important	Slightly Important	Slightly Important	Very Important	Very Important		
31			X				Moderately Important	NOT Important	Very Important	Moderately Important		Slightly Important	NOT Important	NOT Important	Very Important	Very Important		
32			X				Moderately Important	Very Important	Extremely Important	Very Important	Slightly Important	Very Important	Very Important	Moderately Important	Extremely Important	Very Important		
33	X							Moderately Important	Extremely Important					Extremely Important	Extremely Important	Moderately Important		
34				X			Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Very Important	NOT Important	Extremely Important	Extremely Important	Extremely Important		
35				X			Slightly Important	Moderately Important	Moderately Important	Moderately Important	NOT Important	Very Important	Slightly Important	Slightly Important	Moderately Important	Moderately Important		NO
36				X			Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
37																		
38	X		X				Very Important	Very Important	Very Important	Extremely Important	Very Important	Extremely Important	Moderately Important	Very Important	Very Important	Extremely Important		
39				X			Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Very Important		
40			X															
41			X		Natural flow of flood water is not impoted blocked on wastern side of tuggerah lake by leavees		Moderately Important	Extremely Important	Extremely Important	Slightly Important	Very Important	Extremely Important	NOT Important	NOT Important	Extremely Important	Extremely Important		
42				X			Slightly Important		Extremely Important	Extremely Important	NOT Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
43	X	X		X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important		
44	X	X					Moderately Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Slightly Important	Moderately Important	Very Important	Very Important		
45			X				Very Important	Very Important	Very Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Very Important	Extremely Important		
46							Moderately Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Very Important		
47	X									Moderately Important								
48				X			NOT Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important		Extremely Important		
49	X	X		X			Moderately Important	Very Important	Extremely Important	Very Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
50				X			Slightly Important	NOT Important	Extremely Important	Moderately Important	Extremely Important	Very Important	Moderately Important	Slightly Important	Extremely Important	Extremely Important		
51	X			X			Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
52					so my death will be on your hands!		Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important			
53		X					Moderately Important	Moderately Important	Very Important	Moderately Important	Very Important	Extremely Important	Moderately Important	Very Important	Very Important	Very Important		
54						X	Extremely Important	Extremely Important	Very Important	Very Important	Moderately Important	Very Important	NOT Important	Slightly Important	Very Important	Extremely Important		
55						X	Very Important	Moderately Important	Very Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Very Important		
56			X		X													
57			X				Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
58						X	Slightly Important	Moderately Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important		
59	X	X		X			Slightly Important	Moderately Important	Very Important	NOT Important	Slightly Important	Very Important	Slightly Important	Moderately Important	Very Important	Slightly Important		
60	X						Very Important	Very Important	Extremely Important	Very Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Very Important	Extremely Important		
61			X				Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Moderately Important	Moderately Important		
62			X				Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Extremely Important	NONE	NO
63	X			X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
64				X			Very Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important		
65		X		X			Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
66	X						Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
67		X					Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	NOT Important	NOT Important	Extremely Important	Very Important		
68	X			X	Cost of Repairs+ Messy Clean up		Slightly Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Slightly Important	Moderately Important	Moderately Important		

#	7 If You Are Likely To Remain At Your House, What Factors Are Most Important To You?						8 To Assist Us In Developing a Short List of Potential Flood Risk Reduction Measures, Please Tell Us How Important It Is For A Particular Measures to Address the Following Factors										9 If You Have Any Other Suggestions For Reducing The Flooding Problems, Please Describe Them	10 Do You Have Any Additional Information That You Think May Assist In The Study
	Discomfort / inconvience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for the security of my property if I evcuate	Other - please describe	Not Applicable (I intend to evacuate from my house)	Improves community access and recreational use	Does not disadvantage individual members of the community	Provides safety to the community during flooding	Raises community awareness and understanding of the local flood risk	Does not threaten local plants and animals and their habitat	Does not cause water quality issues	Initial costs (i.e., design/construction) require minimal council expenditure	Requires minimal ongoing council expenditure after implementation	Reduced flood damages to the community	Does not cause negative flood impacts to other areas (both upstream and downstream)		
69		X		X			Moderately Important	Slightly Important	Very Important	Very Important	Slightly Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Very Important		
70					I don't think property would flood.of I am wrong,I'd be there to take action		Moderately Important	NOT Important	Very Important	Very Important	NOT Important	Very Important	Slightly Important	Moderately Important	Very Important	Slightly Important		NO
71				X			Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Moderately Important	Very Important	Very Important		
72		X		X			Moderately Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important		
73	X						NOT Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important		
74			X				Moderately Important	Extremely Important	Extremely Important	Very Important	NOT Important	Moderately Important	Extremely Important	Very Important	Extremely Important	Very Important		
75	X			X			Very Important	Very Important	Extremely Important	Very Important	Very Important	Very Important	Slightly Important	Very Important	Very Important	Very Important		
76		X							Extremely Important	Extremely Important	Extremely Important				Extremely Important	Extremely Important		
78							Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important						
79			X				Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Extremely Important		
80						X	Extremely Important	Very Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important		
81			X	X			Moderately Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Slightly Important	Slightly Important	Very Important	Moderately Important		
82		X		X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
83	X	X	X				Slightly Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Slightly Important	Slightly Important	Very Important	Moderately Important		
84						X	NOT Important	Slightly Important	Very Important	Slightly Important	Very Important	Extremely Important	Slightly Important	Slightly Important	Very Important	Very Important		
85			X				Very Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important		
86				X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
87		X	X	X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
88			X		Street only as we are on high side		Moderately Important	Moderately Important	Very Important	Very Important	Slightly Important	Very Important	Extremely Important	Very Important	Very Important	Moderately Important	NO	
89		X		X			Very Important	Very Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important		
90	X			X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
91			X		house has four stages to front + back doors		Moderately Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	NO	NO
92						X	NOT Important	Moderately Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	NOT Important	NOT Important	Moderately Important	NOT Important		
93	X			X			Slightly Important	Very Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important		
94		X		X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
95	X						Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
96	X		X				Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	NOT Important	NOT Important	Very Important	Very Important		
97	X						Moderately Important	Very Important	Very Important	Extremely Important	Moderately Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important		
98				X			Very Important	Very Important		Very Important	Very Important	Very Important	Very Important	Extremely Important		Very Important		
99	X	X		X	Would Depend on severity of flooding		Moderately Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Extremely Important	Very Important		
100			X				Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	NOT Important	NOT Important	Extremely Important	NOT Important		
101			X						Extremely Important			Extremely Important						
102	X		X	X			Moderately Important	Very Important	Extremely Important	Moderately Important	NOT Important	Moderately Important		Moderately Important	Extremely Important	Moderately Important		
103	X	X		X			Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important		
104					Safety would stay only if safe to dose		Very Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Moderately Important	Very Important	Very Important		
105					Saving Customers Property From water Damage		NOT Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Very Important	Very Important		
106			X				NOT Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Very Important	Very Important		
107			X				Very Important	Slightly Important	Slightly Important	NOT Important	NOT Important	Moderately Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important		
108							Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
109							Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Extremely Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important		
110						X	Slightly Important	Slightly Important	NOT Important	NOT Important	Moderately Important	Slightly Important	Slightly Important	Slightly Important	NOT Important	Slightly Important	N\A	NO
111					Unlikley that house would be flooded 2 storey house stay up staris		Moderately Important	Moderately Important	Extremely Important	Extremely Important	Slightly Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important		
112			X				Very Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	NO	NO
113		X					Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important		
114						X	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important	Very Important	Moderately Important	NOT Important	Very Important	Very Important		
115						X	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
116				X			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
117	X		X				Extremely Important	Very Important	Very Important	NOT Important	Slightly Important	Very Important	NOT Important	NOT Important	Extremely Important	Extremely Important		
118				X			Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	NOT Important	Very Important	Very Important	Very Important		
119	X			X			Extremely Important		Extremely Important					Extremely Important	Extremely Important	Extremely Important		
120	x	x		x			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important						
121	x	x		x			Moderately Important	Very Important	Very Important	Extremely Important	Moderately Important	Extremely Important	Slightly Important	Very Important	Very Important	Very Important		
122			x				Slightly Important	Slightly Important	Moderately Important	NOT Important	Slightly Important	Very Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important		
123			x				Slightly Important	Very Important	Slightly Important	Slightly Important	Slightly Important	Very Important	Extremely Important	Extremely Important	Very Important	Very Important		
124			x				Slightly Important	Slightly Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Moderately Important	Very Important	Very Important		no
125	x			x			Very Important	Very Important	Very Important	Slightly Important	Very Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important		

#	7 If You Are Likely To Remain At Your House, What Factors Are Most Important To You?						8 To Assist Us In Developing a Short List of Potential Flood Risk Reduction Measures, Please Tell Us How Important It Is For A Particular Measures to Address the Following Factors										9 If You Have Any Other Suggestions For Reducing The Flooding Problems, Please Describe Them	10 Do You Have Any Additional Information That You Think May Assist In The Study
	Discomfort / inconvience / cost of evacuating	Need to care for animals	My house cannot be flooded and we can cope with isolation	Concern for the security of my property if I evcuate	Other - please describe	Not Applicable (I intend to evacuate from my house)	Improves community access and recreational use	Does not disadvantage individual members of the community	Provides safety to the community during flooding	Raises community awareness and understanding of the local flood risk	Does not threaten local plants and animals and their habitat	Does not cause water quality issues	Initial costs (i.e., design/construction) require minimal council expenditure	Requires minimal ongoing council expenditure after implementation	Reduced flood damages to the community	Does not cause negative flood impacts to other areas (both upstream and downstream)		
126		x					Extremely Important	Moderately Important	Very Important	Moderately Important	Extremely Important	Extremely Important	NOT Important	NOT Important	Extremely Important	Very Important		
127				x			Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Slightly Important	Very Important	Moderately Important		
128		x	x	x			Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important		
129			x				Extremely Important	Very Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	No	
130		x					Moderately Important	Moderately Important	Very Important	Extremely Important	Very Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important		
131					x		Slightly Important	Extremely Important	Extremely Important	NOT Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important		
132	x		x				Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Slightly Important		

Appendix B

Australian Rainfall & Runoff 2016 Assessment

AUSTRALIAN RAINFALL AND RUNOFF 1987 VERSUS 2016 ASSESSMENT

The *'Killarney Vale / Long Jetty Catchments Overland Flood Study'* (Catchment Simulation Solutions, 2014) derived design flood estimates based upon hydrologic procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia, 1987) (referred to herein as ARR1987). Since publication of this flood study, a revised version of Australian Rainfall and Runoff has been released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, additional investigations were completed to confirm the impact that the revised hydrologic procedures may have on design flood behaviour across the Killarney Vale and Long Jetty catchments and determine the most appropriate hydrologic procedures to carry forward into the floodplain risk management study.

Although the original flood study utilised a direct rainfall TUFLOW model to simulate hydrologic and hydraulic processes, the large number of simulations required by ARR2016 required the bulk of the hydrologic analysis in this assessment to be completed in a XP-RAFTS hydrologic model. Once the XP-RAFTS model was used to narrow down the number of storms that required assessment, the remainder of the analysis was completed in TUFLOW as per the original study.

The outcomes of the investigations are summarised below. It should be noted that only the 1% AEP (1 in 100-year ARI) event was investigated as part of this assessment.

Design Rainfall Depths

Point design rainfall depths for the 1% AEP event were downloaded from the Bureau of Meteorology's 1987 and 2016 IFD webpage. This design rainfall information is presented in **Table 1** for storm durations varying between 5 minutes and 24 hours. The design rainfall intensities were extracted from the IFD grid cell located closest to the centroid of the study area (33.777^{o} south, 150.688^{o} east).

The comparison provided in **Table 1** indicates that the ARR2016 rainfall depths are up to 34% higher than the ARR1987 depths for storm durations less than or equal to 6 hours. For storm durations longer than 6 hours, the ARR2016 rainfall depths are lower than the ARR1987 rainfall depths. The average difference between the ARR2016 and ARR1987 rainfall depths is +20%.

In general, the critical duration across the Long Jetty and Killarney Vale catchments is less than 6 hours. Therefore, the "base" ARR2016 rainfall depths are likely to be higher than the equivalent ARR1987 rainfall depths for the critical storm durations across Long Jetty and Killarney Vale.

Table 1 1% AEP Point Design Rainfall Depths

Storm Duration	Rainfall Depth (mm)		Difference
	1987	2016	
5 mins	20.0	26.8	+34%
10 mins	31.1	41.7	+34%
15 mins	39.3	52.3	+33%
20 mins	45.9	60.6	+32%
30 mins	56.5	73.3	+30%
45 mins	68.6	87	+27%
1 hour	78.4	97.4	+24%
2 hours	107	125	+17%
3 hours	128	144	+12%
6 hours	174	183	+5%
12 hours	236	234	-1%
24 hours	315	304	-3%

Areal Reduction Factors

ARR2016 highlights that the "point" rainfall depths presented in **Table 1** are only applicable for catchment areas up to 1 km^2. Therefore, ARR 2016 recommends applying areal reduction factors that aims to recognise that there is unlikely to be a uniformly high rainfall intensity across all sections of large catchments, particularly for relatively short duration rainfall bursts. Although ARR 1987 did include areal reduction factors, this largely drew from overseas research.

The ARR2016 areal reduction factors are calculated based upon the contributing catchment area at a particular location (i.e., greater reductions are applied to larger catchment areas), the severity of the design event being considered (greater reductions are applied to rarer design storms) and the storm duration (greater reductions are applied to shorter storm durations). For longer storm durations, a range of additional parameters are required for the specific area, which are available for download from the ARR2016 Data Hub (a copy of the information downloaded from the data hub is included at the end of this document). The resulting areal reductions factors are provided in **Table 2**.

Areal reduction factors were also extracted from Figure 1.6 of ARR1987 and are included in **Table 2**. It is noted that no reduction factors are provided in ARR1987 for durations less than 30 minutes. Therefore, it was assumed that the 30-minute reduction factors also applied for shorter storm durations. It is also noted that it is very difficult to extract precise reductions factors for catchment areas less than 50 km^2 as the areal reduction curves in Figure 1.6 very rapidly converge to 1.0 for small catchment areas.

The factors provided in **Table 2** show that the ARR1987 factors are globally higher than the ARR2016 reduction factors. The most significant differences occur for shorter storm durations. As the storm durations approach 24 hours, the differences in reductions factors are generally negligible.

Table 2 Areal Reduction Factors for the 1% AEP event

Storm Duration	Areal Reduction Factor	
	1987	2016
5 mins	0.98	0.75
10 mins	0.98	0.82
15 mins	0.98	0.85
20 mins	0.98	0.86
30 mins	0.98	0.88
45 mins	0.98	0.90
1 hour	0.98	0.90
2 hours	0.99	0.91
3 hours	0.99	0.92
6 hours	0.99	0.95
12 hours	1.00	0.97
24 hours	1.00	0.99

The areal reductions factors summarised in **Table 2** were applied to the point rainfall depths summarised in **Table 1** to define areal reduced design rainfall depths for the combined Killarney Vale and Long Jetty catchments. The areal reduced rainfall intensities are summarised in **Table 3**.

Table 3 Areal Reduced 1% AEP Design Rainfall Depths

Storm Duration	Rainfall Depth (mm)		Difference
	1987	2016	
5 mins	19.6	20.1	3%
10 mins	30.5	34.2	12%
15 mins	38.5	44.5	15%
20 mins	45.0	52.1	16%
30 mins	55.4	64.5	16%
45 mins	67.2	78.3	16%
1 hour	76.8	87.7	14%
2 hours	106	114	7%
3 hours	127	132	5%
6 hours	172	174	1%
12 hours	236	227	-4%
24 hours	315	301	-4%

The comparison provided in **Table 3** shows that application of the areal reduction factors provides notable reductions in the ARR2016 rainfall depths, particularly for the shorter storm durations. However, even with the reduction factors applied, the ARR2016 rainfall depths are still higher than the ARR1987 rainfall depths for all durations less than or equal to 6 hours. However, the average increase in rainfall depth has reduced from 20% with no reduction factors applied to 8% with the reduction factors applied.

It should be noted that the ARR2016 areal reductions factors summarised above were calculated based upon the overall study area of 8.8 km^2 and are strictly only applicable at the downstream end of the study area. Across areas further upstream, the contributing catchment area will be less leading to higher areal reduction factors. Unfortunately, it is prohibitively time consuming to calculate different areal reduction factors for a range of different contributing catchment areas. Therefore, the overall study area was used as the basis for calculating the areal reduction factors.

Temporal Patterns

One of the most significant differences between ARR2016 and ARR1987 is in the use of storm temporal patterns (i.e., the patterns describing the distribution of rainfall throughout the storm). ARR1987 employed a single temporal pattern for each AEP/storm duration while ARR2016 uses 10 temporal patterns for each AEP/storm duration.

The ARR2016 temporal patterns were downloaded from the ARR data hub. In accordance with ARR2016 for catchments with an area less than 75 km^2, the "point" temporal patterns rather than "areal" temporal patterns were selected to describe the temporal variation in rainfall.

A total of ten temporal patterns were applied to the areal reduced rainfall depths for the 1% AEP for each storm duration. This provided a storm database comprising 246 different storms for the 1% AEP event.

Rainfall Losses

ARR2016 also utilises a different approach for defining initial rainfall losses. The ARR1987 approach applies a constant initial loss and continuing loss rate for all storms. A pervious initial loss of 10mm and a pervious continuing loss rate of 2.5 mm/hr was adopted as part of the *'Killarney Vale / Long Jetty Catchments Overland Flood Study'* (Catchment Simulation Solutions, 2014).

The ARR2016 approach employs an initial rainfall loss that varies according to the storm severity and duration. The ARR2016 initial rainfall losses are calculated by subtracting median pre-burst rainfall losses from the overall storm loss for the area. This aims to recognise that the most intense downpour is frequently preceded by rainfall that would serve to "wet" the catchment, thereby reducing the potential for rainfall during the main "burst" to infiltrate into the underlying soils.

An attempt was made to download the overall storm loss and median pre-burst rainfall losses for the Long Jetty and Killarney Vale catchments from the ARR2016 Data Hub. However, this yielded erroneous outputs. More specifically, the ARR2016 data hub showed an overall initial rainfall loss for the area of -99 mm and no median pre-burst rainfall. Therefore, a search of nearby locations was completed to find more realistic rainfall loss values. This ultimately yielded a location close to Wyong with valid pre-burst rainfall losses and a storm initial loss of 49 mm.

The "pre-burst" initial rainfall losses are summarised in **Table 4**. It was noted that no pre-burst rainfall losses are provided on ARR2016 data hub for storm durations less than 1 hour. Therefore, it was assumed that the pre-burst rainfall losses for the 1 hour storm also applied for storm durations less than 1 hour.

Table 4 ARR2016 Initial Rainfall Losses for the 1% AEP flood

Storm Duration	Storm Initial Loss (mm)	Median Pre-burst Depth (mm)	Burst Initial Loss (mm)
5 mins	49	0	49
10 mins		0	49
15 mins		0	49
20 mins		0	49
30 mins		0	49
45 mins		0	49
1 hour		0	49
2 hours		0.6	48.4
3 hours		7.5	41.5
6 hours		18	31
12 hours		35	14
24 hours		27.9	21.1

As shown in **Table 4**, initial ARR2016 rainfall losses of between 14 and 49 mm were calculated. In all cases, the ARR2016 initial rainfall losses are higher than the ARR1987 initial rainfall losses typically adopted as part of previous study (i.e., 10mm). For storm durations less than 3 hours (i.e., the critical durations across the study area), the ARR2016 initial rainfall losses are significantly higher than the ARR1987 initial losses.

Continuing loss rates are applied in ARR2016 in a similar manner to how they were used in ARR1987. However, the values have changed. ARR2016 specifies a continuing loss rate of 2.9 mm/hour for the study area (unlike the initial rainfall losses, valid continuing loss values are available in the ARR2016 Data Hub). This continuing loss is higher than ARR1987 which recommends a continuing loss rate of 2.5 mm/hour.

It is noted that the loss values summarised above are for rural/pervious areas. For catchments with a significant impervious proportion, Section 3.5.3.1 of Book 5 of ARR2016 suggest that initial losses for impervious areas would typically vary between 0 and 1 mm with the continuing loss rate being effectively zero (i.e., CL = 0 mm/hr). This is similar to what has adopted for the *'Killarney Vale / Long Jetty Catchments Overland Flood Study'*. Therefore, an initial loss of 1 mm and a continuing loss rate of 0 mm/hr was adopted to define rainfall losses across impervious sections of the study area.

Hydrologic Assessment

To gain an understanding of what impacts ARR2016 is predicted to have on peak discharge estimates relative to ARR1987, ARR2016 was applied to the XP-RAFTS hydrologic model that was developed as part of the flood study. It should be noted that the XP-RAFTS model only covers the Saltwater Creek catchment. Nevertheless, this was considered to provide a good representation of the overall catchment and was suitable for assessing the hydrologic impacts of ARR2016 across the study area.

ARR2016

The “base” XP-RAFTS model was updated to include each of the 246 1% AEP design storms. Each design storm was routed through the XP-RAFTS model using the *Storm Injector* utility (Catchment Simulation Solutions, 2017).

The peak discharges from the full suite of temporal patterns were reviewed to determine the “critical” temporal pattern for each storm duration. In accordance with guidance provided in ARR2016, the temporal pattern that generated the closest, but next highest peak discharge to the average discharge, was selected as the “critical” temporal pattern for each subcatchment. The average discharge was calculated based on assessment of the peak discharge generated by all temporal patterns for a particular storm duration.

A review of the results yielded a wide variety of critical durations and temporal patterns across the XP-RAFTS model area. More specifically, 21 different critical temporal patterns were identified when considering all subcatchments within the XP-RAFTS model (temporal pattern 4363 being the most common). The critical storm durations ranged from 10 minutes up to 6 hours.

Therefore, ARR2016 yields a challenge when trying to define critical storms across multiple areas of a catchment. A major goal of this assessment was to quantify the impact of ARR2016 on discharge estimates as well as the impact on flood hydraulic (e.g., peak flood levels). It was considered that simulation of more than 20 different storms in the hydraulic model would be prohibitively time consuming. Therefore, the critical temporal patterns and durations were only extracted at 14 “key” locations. A key location was defined as a location where peak discharges and flood levels were provided in the flood study report.

Table 5 summarises the peak discharges and critical durations at each of the “key” locations based upon ARR2016. It shows the critical durations vary between 10 minutes and 360 minutes. In general, the 10 and 30-minute durations were critical at most locations with the 120 to 360-minute durations being critical in those subcatchments with detention basins.

Once the assessment was restricted to the 14 locations, it reduced the total number of critical durations and temporal patterns from 21 to a more manageable 4. The final critical durations and temporal patterns that were selected for the hydraulic analysis included:

- 1% AEP 180 minute storm: temporal pattern number 4653;
- 1% AEP 120 minute storm: temporal pattern number 4614;
- 1% AEP 30 minute storm: temporal pattern number 4505; and,

- 1% AEP 10 minute storm: temporal pattern number 4363.

Table 5 Comparison between ARR 1987 and ARR2016 1%AEP peak discharges

Location	XP-RAFTS Subcatchment ID	Critical Duration (mins)		Peak 1% AEP Discharge		
		ARR1987	ARR2016	ARR1987	ARR2016	Difference
Basin A	1.03	120	120	3.6	3.5	-0.1
Rushby St	1.04	90	10	15.8	13.3	-2.5
Basin B	1.08	360	180	11.7	11.0	-0.7
Yakalla St	1.09	120	120	20.4	18.5	-1.9
Basin C	1.11	360	180	20.0	16.1	-3.9
Bloomfield St	1.12	90	180	26.9	23.8	-3.1
The Entrance Rd	1.14	90	10	9.1	8.3	-0.8
McLachlan Ave	10.01	90	10	10.1	8.4	-1.7
Neale St	10.02	90	30	12.0	8.9	-3.1
Sabrina/Nepean St	11.02	120	10	18.5	16.0	-2.5
Eastern Rd Basin	11.03	120	120	21.9	18.0	-3.9
Bay Village Basin	11.05	120	30	30.8	26.9	-3.9
Wyong Rd	11.06	120	120	3.6	3.5	-0.1

ARR1987

The XP-RAFTS model was also used to simulate rainfall-runoff processes for the 1% AEP event based upon ARR1987. This involved running a range of different storm durations (5 minutes up to 24 hours) to determine the critical duration at each of the critical locations. In accordance with ARR1987, the critical duration was selected as the storm duration that produced the highest peak 1% AEP discharge at each location. Peak discharges and critical storm duration at each of the critical locations are summarised in **Table 5**.

The critical durations presented in **Table 5** shows that the critical durations for ARR1987 vary between 90 minutes and 540 minutes, with the 90 and 120 minute storm durations being the most common. In general, the critical ARR1987 durations are longer than the ARR2016 critical durations.

Table 5 also shows that the ARR1987 peak 1% AEP discharges are higher than the ARR2016 peak discharges (the ARR1987 peak 1% AEP discharges are 13% higher than the ARR2016 discharges, on average). Therefore, despite ARR2016 providing higher design rainfall depths, it appears that the higher ARR2016 initial and continuing rainfall losses are sufficient to reduce the peak ARR2916 discharges below the ARR1987 peak discharges.

As noted above, ARR2016 is predicted to produce shorter critical storm durations relative to ARR1987. Therefore, not only is ARR2016 providing lower peak discharges, the shorter storm durations are providing smaller runoff volumes relative to ARR1987. This is likely to have a notable impact on flood levels, depths and extents particularly in the vicinity of the flood detention basins. To further quantify the impacts that ARR2016 is predicted have on peak 1% AEP flood levels and extents, a hydraulic assessment was completed using the TUFLOW model that was developed as part of the flood study. The outcomes of this assessment are presented in the following sections.

Hydraulic Assessment

To assess the impact that the revised ARR2016 hydrology would have on peak flood levels and extents, the critical 1%AEP ARR2016 rainfall hyetographs for the 90, 120 and 360 minute storm durations were applied to the TUFLOW model. The TUFLOW model was also used to simulate the 1% AEP flood based upon the ARR1987 hydrology, as per the original flood study.

Hydraulic Impacts

To assist in quantifying the impacts that ARR2016 is predicted to have on peak water levels and extents, flood level difference mapping was prepared. The difference map was prepared by subtracting peak ARR1987 flood levels from the ARR2016 flood levels. This enabled the magnitude and location of changes in flood levels and inundation extent to be quantified. The resulting difference mapping is presented in the attached **Plate 1**.

Plate 1 shows that ARR2016 will generate lower 1% AEP flood levels across some areas and higher water levels across other areas. The most notable differences are predicted to occur in the vicinity of the flood detention basins. Therefore, it appears that ARR2016 is producing higher peak flood levels in the immediate vicinity of storage dependent elements such as detention basins.

Plate 1 shows that the ARR2016 is predicted to generate lower peak 1% AEP water levels along the Tuggerah Lake foreshore. These differences are not associated with the differences in hydrology but rather the fact that ARR1987 analysis incorporated longer storm durations (i.e., 360 minute storm). This allowed the lake water level to rise further relative to ARR2016 where the longest storm duration simulated was 180 minutes.

In all instances, the differences between ARR2016 water levels and ARR1987 water levels is predicted to be less than 0.1 metres and, in most cases, less than 0.05 metres. Therefore, the magnitude of the flood level differences is relatively minor.

Summary

The outcomes of this assessment have determined that ARR2016 will generally produce lower design discharges, flood levels and flood extents when compared with ARR1987 for the 1% AEP flood across the majority of the study area. This is despite the ARR2016 rainfall intensities being higher than the ARR1987 rainfall intensities. The lower discharges, levels and extents are primarily associated with the higher initial and continuing rainfall losses for ARR2016.

In general, the differences in flood levels are minor (i.e., less than 0.1 metres). Therefore, the revised ARR2016 approaches don't appear to afford a sufficient difference to warrant a revised hydrologic approach as part of the Killarney Vale and Long Jetty Floodplain Risk Management Study and Plan. Therefore, it is recommended that ARR1987 be retained for the hydrologic analysis as part of the current study.

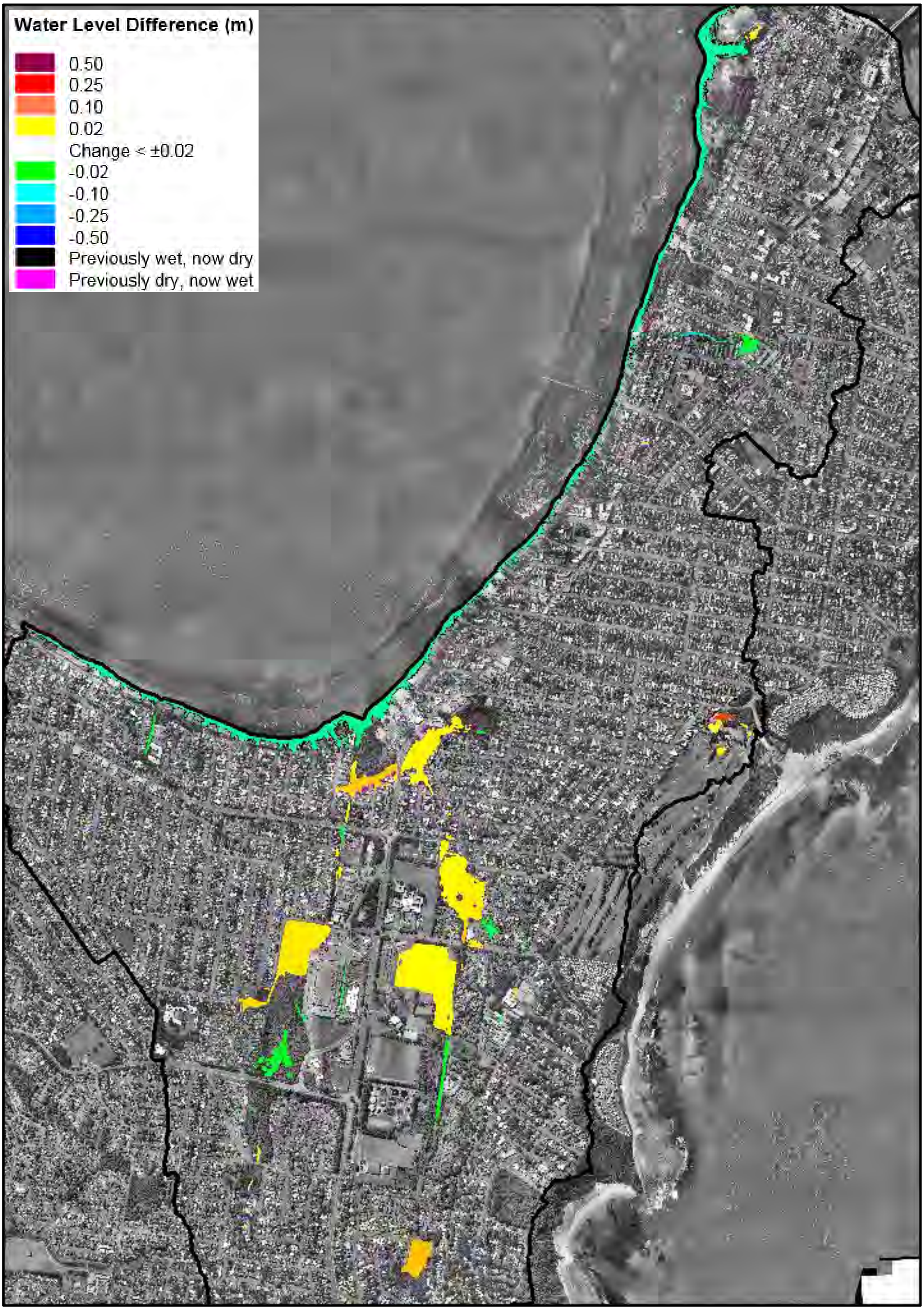


Plate 1 ARR2016 water level difference map for 1% AEP flood

APPENDIX C

FLOOD DAMAGE CALCULATIONS

Catchment Simulation Solutions

Canberra Office
13 Weatherburn Place
BRUCE ACT 2617
(02) 6251 0002
(02) 6251 8601
cryan@csse.com.au

Sydney Office
Suite 2.01
210 George Street
SYDNEY NSW 2000
(02) 8355 5500
(02) 8355 5505
dtetley@csse.com.au

D1 FLOOD DAMAGE COST CALCULATIONS

1.1 Property Database

A property database was developed as part of the study to enable flood damages calculations to be completed. The database was developed in GIS and included all habitable (i.e., residential, commercial and industrial) buildings located within the PMF extent. The following information was included as additional fields within the GIS database for each building:

- Generic property type (i.e., residential, commercial or industrial);
- Building floor level – refer to the following sections for further information on how the building floor levels were defined;
- Building floor area;
- Residential building type (i.e., two storey, single level high set or single level low set); and,
- Commercial or industrial property contents value (normal or high value).

The information contained in the property database was used with the design flood level information and depth-damage curves to establish a tangible flood damage estimate for each building located within the Killarney Vale and Long Jetty catchments for each design flood. Further information on how the flood damage estimates were established is provided below.

1.2 Building Floor Levels

It is necessary to have information describing the floor height / level of every building within the PMF extent to enable the number of properties subject to above floor flooding (and the associated damage cost) to be estimated. For this study, the floor levels were estimated using a "drive by" survey using the following process:

1. Google Street View was used to estimate how high the floor level of each building was elevated above the adjoining ground (e.g., using standard step or brick heights as a guide);
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).

1.3 Flood Level Estimates

The number of properties subject to above floor flooding during each design flood can be estimated by comparing the building floor levels against peak design flood levels at each building. However, the adopted modelling approach for the study involved applying rainfall directly to the TUFLOW model (including building footprints). As a result of this modelling approach, all buildings will be "wet" even though they may not be subject to over floor flooding resulting from flow entering the building from the upstream catchment.

The "filter" described in **Section 3.2.2** was applied to the raw modelling results to distinguish between areas of negligible and more significant overland flooding. Accordingly, this filtering process should remove shallow inundation as a result of rainfall being applied directly to the buildings and ensure only flood levels from significant overland flow areas adjoining each building are included.

1.4 Flood Damage Calculations

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.

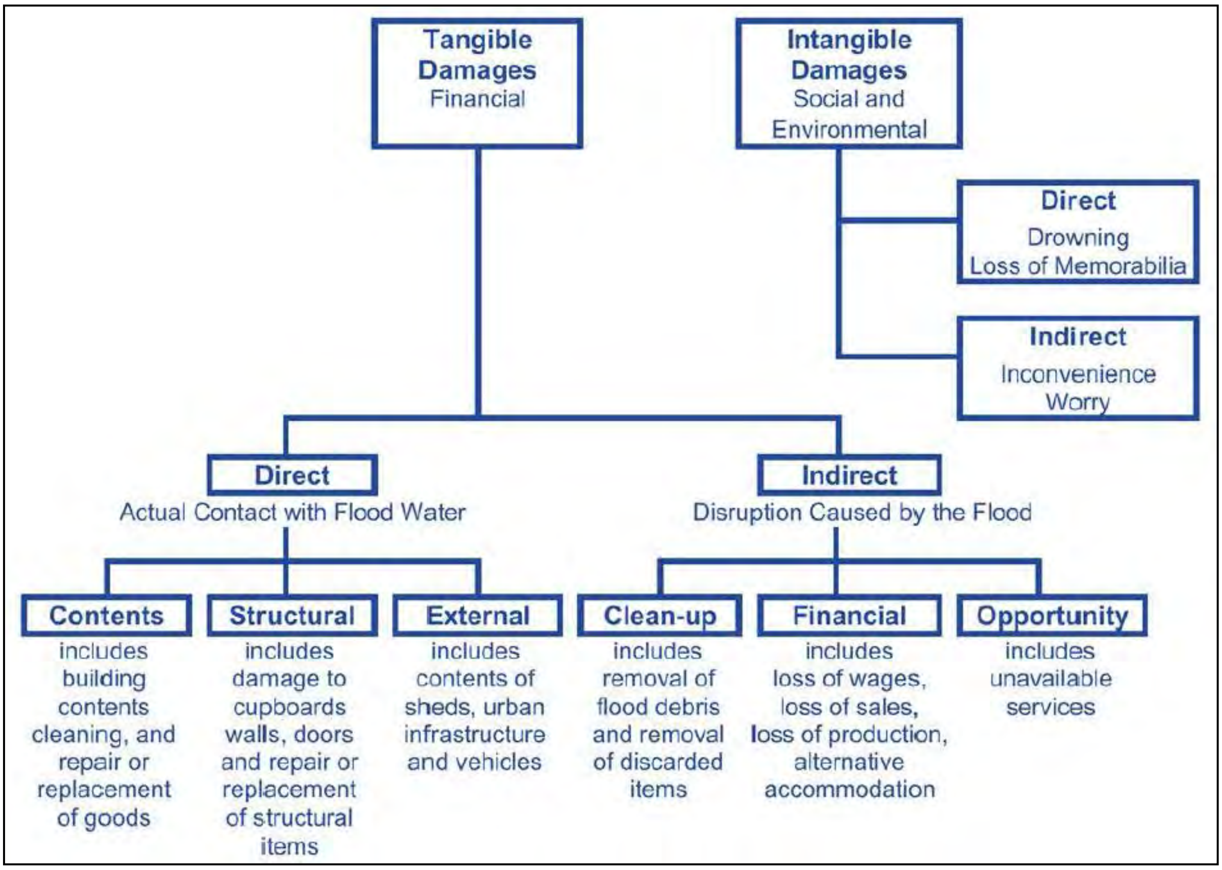


Plate 1 Flood Damage Categories (NSW Government, 2005)

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by floodwaters). 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 floodwater coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific flood 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 monetary values to intangible damages, only tangible damages were considered as part of this study. Further information on how damages costs were estimated for different property types is presented in the following sections.

1.4.1 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 default parameters to be defined to enable a meaningful damage estimate to be derived that is appropriate for the local catchment. The default parameters that were adopted for the Killarney Vale and Long Jetty catchments are summarised 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 the fact 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 OEH Guideline caps external damage to a value of $6,700. However, this was considered too large for the types of floodwaters depths across most of the Killarney Vale and Long Jetty catchments. Based upon experience when calculating damages for other urban catchments, the external damage was limited to $1,000 when no above floor inundation was determined.

The damage curves for 'single storey low set' and 'two storey' properties commence at -0.5 metres, which was considered to be appropriate for the catchment. However, the 'single storey high set' damage curves commenced at -5 metres, which was considered to be too high for the catchment. 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 lot (i.e., the minimum elevation within each lot at which inundation will first occur and, therefore, where damage costs may first commence). This determined that the median difference between the building floor level and minimum ground level within the corresponding lot was 1.22 metres. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced when the flood level was 1.2 metres below the floor level.

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 3.00 October 2007

PROJECT	DETAILS	DATE	JOB No.
Killarney Vale Long Jetty FPRMS	Residential Damages (190m2)	6/03/2018	xx

BUILDINGS

Regional Cost Variation Factor	1.02	From Rawlinsons					
Post late 2001 adjustments	1.77	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	0.5	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	190	m^2		240 m^2 is Base			
Building Size Adjustment	0.8						
Total Building Adjustment Factor	**1.21**						

CONTENTS

Average Contents Relevant to Site	$ 47,500		Base for 240 m^2 house	$ 60,000		
Post late 2001 adjustments	1.77	From above				
Contents Damage Repair Limitation Factor	0.75	due to no insurance	short duration		long duration	
Sub-Total Adjustment Factor	1.33	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	**1.33**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.33**					

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	1.77	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	3	weeks
Additional accommodation costs /Loss of Rent	$ 430	$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	-1.20	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		

KVLJResidentialDamageCurves.xlsx Residential Curve Input 190m2 Duncan McLuckie 23/04/2018 Page 1 of 1

Building floor areas were calculated for each building using GIS building polygons. The building floor area serves as one of the residential damage curve inputs. A typical representative building floor area of 190 m^2 was adopted for the study area and was used as input to develop the residential damage curves.

The OEH flood damage calculation spreadsheet includes allowances for the following flood damage components:

- Damage to building contents (direct cost);
- External damage (e.g., cars, sheds, fences, landscaping) (direct cost);
- Clean up costs (indirect cost); and,
- Alternate accommodation costs while clean up occurs (indirect cost).

As outlined above, the OEH residential depth-damage curves include allowances for both direct and indirect flood damage costs and the resulting depth-damage curves are presented on the following page.

1.4.2 Commercial and 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 'Wyong River Floodplain Risk Management Study' (Catchment Simulation Solutions, 2018), flood damage curves for commercial and industrial properties were derived. The base curves were developed based upon data collected following the Nyngan and Inverell floods during the 1990s, as well as data gained from interviews of 41 businesses in Gloucester. These base curves were then supplemented with data gained from the 'Lower Wyong River Floodplain Risk Management Study' (Paterson Consulting, 2010) which included interviews of 18 property owners located in the Tuggerah Straight Industrial Area in 1996.

Due to close proximity of the Killarney Vale and Long Jetty catchments to the Wyong River catchment, the Wyong River catchment damage curves were also adopted for use as part of the current study. However, the curves were adjusted from 2016 dollars to 2017 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the catchments.

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.

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
Type	**1**	**2**	**3**
AFD from Modelling	**Damage**	**Damage**	**Damage**
-5.00	$0	$0	$0
-1.20	$1,000	$0	$0
-1.10	$1,000	$0	$0
-1.00	$1,000	$0	$0
-0.90	$1,000	$0	$0
-0.80	$1,000	$0	$0
-0.70	$1,000	$0	$0
-0.60	$1,000	$0	$0
-0.50	$1,000	$1,000	$1,000
-0.40	$1,000	$1,000	$1,000
-0.30	$1,000	$1,000	$1,000
-0.20	$1,000	$1,000	$1,000
-0.10	$1,000	$1,000	$1,000
0.00	$1,000	$1,000	$1,000
0.10	$63,231	$60,927	$46,207
0.20	$66,239	$63,621	$48,092
0.30	$69,246	$66,314	$49,978
0.40	$72,253	$69,008	$51,863
0.50	$75,261	$71,702	$53,749
0.60	$78,268	$74,395	$55,634
0.70	$81,276	$77,089	$57,520
0.80	$84,283	$79,782	$59,405
0.90	$87,290	$82,476	$61,291
1.00	$90,298	$85,170	$63,176
1.10	$93,305	$87,863	$65,062
1.20	$96,313	$90,557	$66,948
1.30	$99,320	$93,250	$68,833
1.40	$102,327	$95,944	$70,719
1.50	$105,335	$98,638	$72,604
1.60	$108,342	$101,331	$74,490
1.70	$111,350	$104,025	$76,375
1.80	$114,357	$106,719	$78,261
1.90	$117,364	$109,412	$80,146
2.00	$120,372	$112,106	$82,032
2.10	$121,277	$112,698	$82,446
2.20	$122,183	$113,289	$82,860
2.30	$123,088	$113,881	$83,274
2.40	$123,994	$114,473	$83,689
2.50	$124,900	$115,065	$84,103
2.60	$125,805	$115,656	$84,517
2.70	$126,711	$116,248	$126,687
2.80	$127,616	$116,840	$127,338
2.90	$128,522	$117,432	$127,989
3.00	$129,427	$118,023	$128,640
3.10	$130,333	$118,615	$129,291
3.20	$131,238	$119,207	$129,942
3.30	$132,144	$119,799	$130,592
3.50	$133,955	$120,982	$131,894
4.00	$138,482	$123,941	$135,149
4.50	$143,010	$126,899	$138,404
5.00	$147,538	$129,858	$141,658

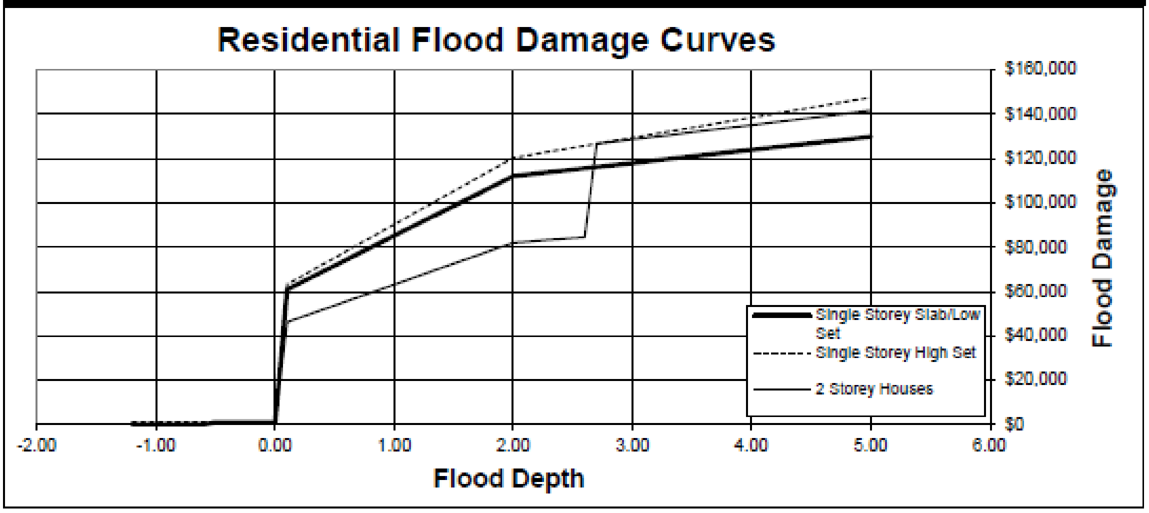


Table 1 Content Value Categories for Commercial Property Types

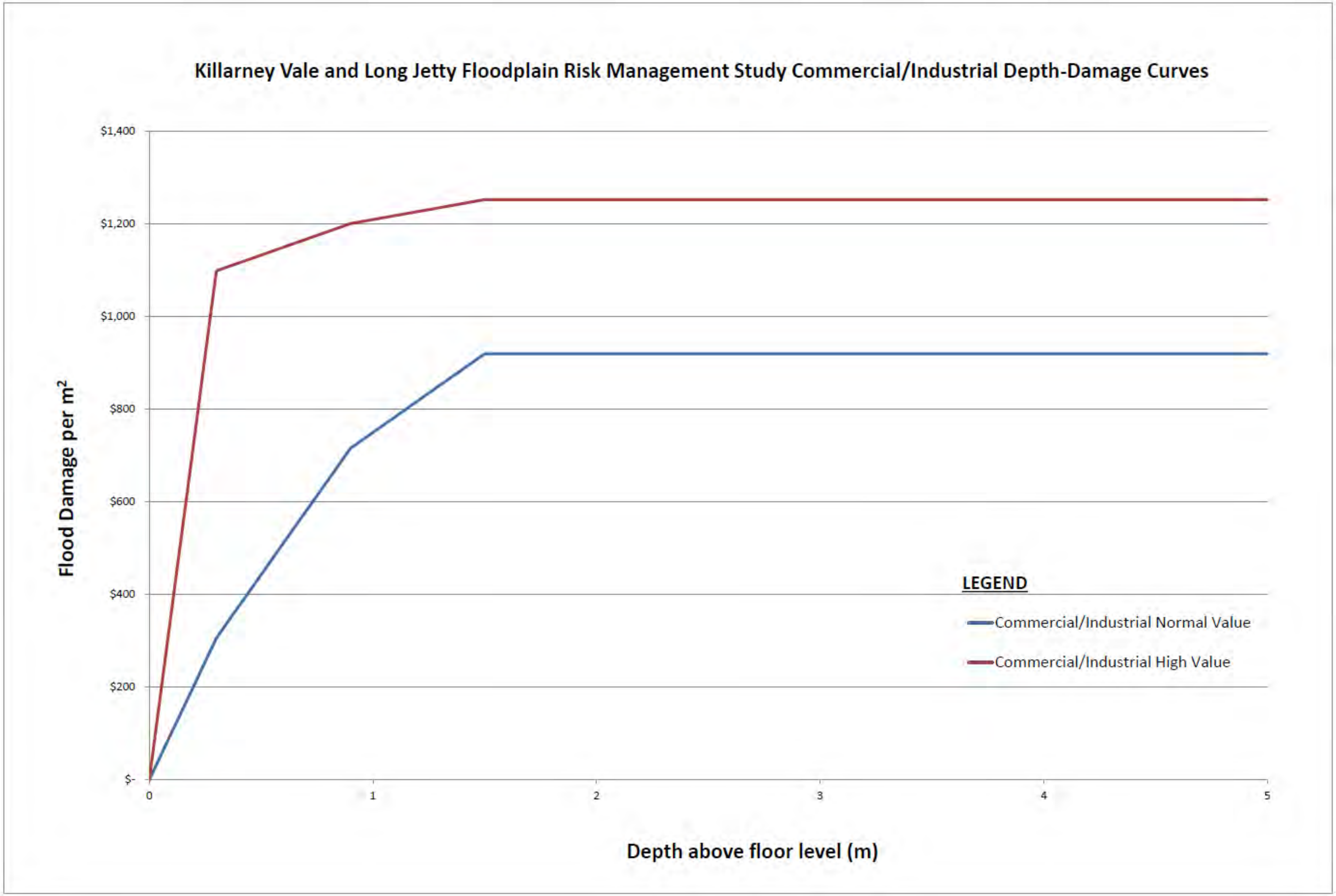
Normal Value Contents	High Value Contents
Food stores	Electrical shops
Grocers	Chemists
Corner stores / mixed business	Shoe Shops
Take away food	Clothing stores
Hairdressers	Bottle shops
Banks	Bookshops
Dry cleaners	Newsagents
Professions (e.g., solicitors)	Sporting goods
Small hardware	Furniture
Small 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	

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 20% of the direct flood damages, and this was added to the base damage curves.


Killarney Vale and Long Jetty Floodplain Risk Management Study Commercial/Industrial Depth-Damage Curves
$1,400
$1,200
$1,000
$800
$600
$400
$200
$-
0
1
2
3
4
5
Flood Damage per m²
Depth above floor level (m)
LEGEND
Commercial/Industrial Normal Value
Commercial/Industrial High Value

1.4.3 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 residential, commercial and industrial damages.

1.4.4 Potential versus Actual Damages

The flood damage calculations outlined above are damages based on a 'do nothing' scenario. However, building occupants may be able undertake measures to minimise flood damage if they are provided with sufficient advance warning of an impending flood (and assuming they are home at the time of flood). Flooding across the Killarney Vale and Long Jetty catchments is typically associated with relatively short rainfall bursts with little warning time. As a result, it was considered that there would be limited opportunity for residents and business owners to minimise damages and no adjustment was taken to adjust the potential flood damages to actual flood damages.

1.5 Summary of Inundation Costs

1.5.1 Damage Costs

Flood damages were calculated using the flood level surfaces for each design flood in conjunction with the appropriate depth-damage curves and floor level for each building. The residential, commercial and industrial property damage estimates were subsequently summed with the infrastructure damage estimates to calculate the total flood damages for each design event.

The flood damage estimates for each design flood are summarised in **Table 4**. The number of buildings that are predicted to incur damage (including those inundated above floor level) are summarised in

Table 5 and **Table 4**.

The results presented in **Table 4** shows that a 1% AEP flood has the potential to cause over $2.3 million dollars of damages. In general, damage to residential property is the primary contributor to the total damage bill for each event.

1.5.2 Average Annual Damages

The total flood damages for each flood event were plotted on a chart against the probability of each flood occurring (i.e., AEP). The chart was then used as the basis for calculating the average annual damages (AAD) for the study area for existing conditions. 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 is calculated as being $291,000.

1.6 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, it should be reinforced that the damage costs are <u>estimates only</u> and do not take into account future fluctuations in property and asset values. Therefore, the damage estimates should only be considered an approximation.

Table 3 Summary of Flood Damages for Existing Conditions

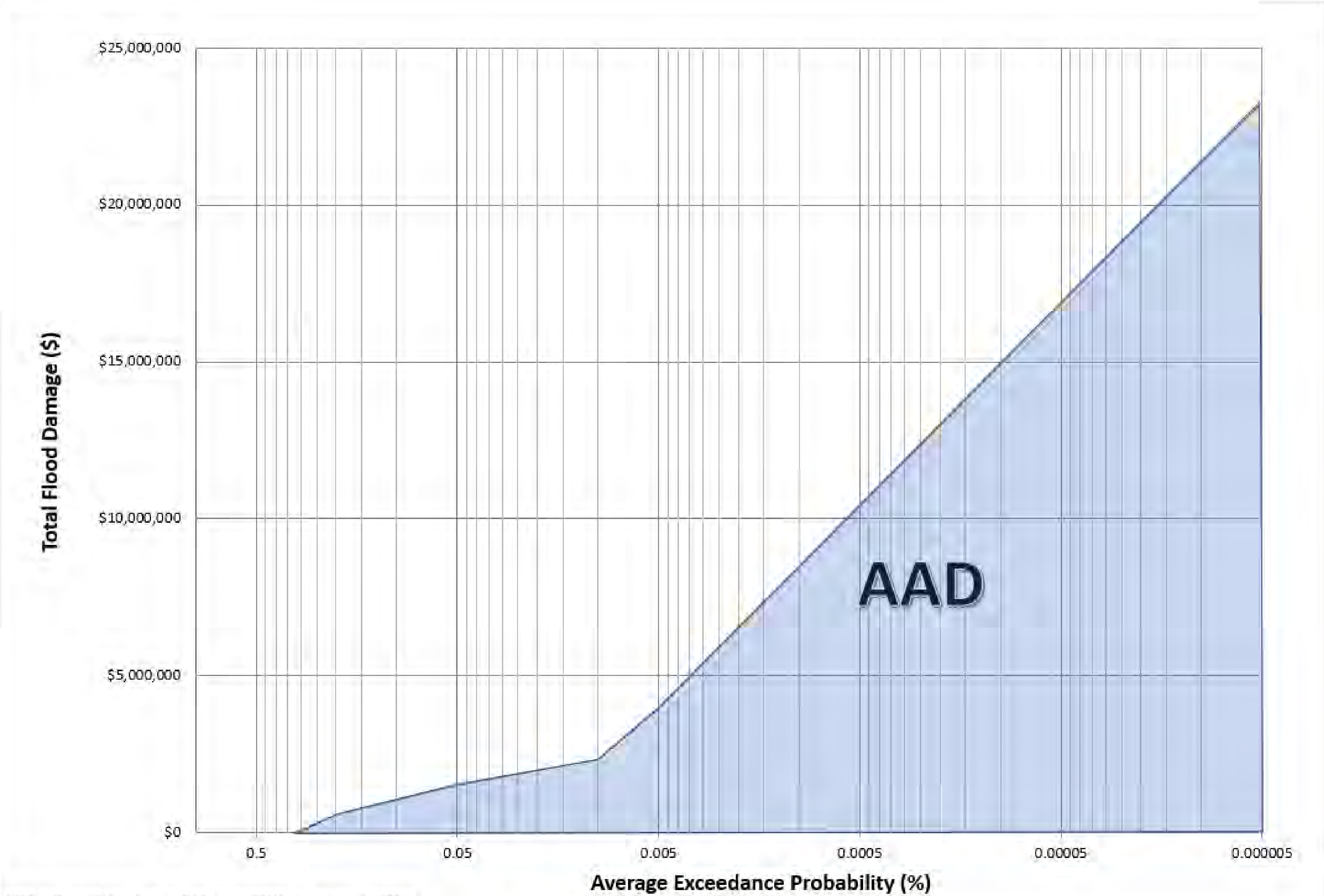
Flood Damage Component	Flood Damages (2017 dollars)				
	20% AEP	5% AEP	1% AEP	0.4% AEP	PMF
Residential	$177,313	$718,904	$1,308,167	$2,553,723	$18,083,083
Commercial.	$303,505	$566,326	$715,768	$863,723	$2,088,184
Industrial	$0	$4,783	$10,351	$15,640	$43,099
Infrastructure	$72,123	$193,502	$305,143	$514,963	$3,032,155
TOTAL	$552,941	$1,483,515	$2,339,429	$3,948,049	$23,246,521

Table 4 Number of Properties Predicted to Experience Flood Damage

Flood Event	Number of Properties Damaged		
	Residential	Commercial/ Industrial	Total Number
20% AEP	171	8	179
5% AEP	314	10	324
1% AEP	450	11	461
0.4% AEP	517	18	535
PMF	1584	37	1621

Table 5 Number of Properties Predicted to be Inundated Above Floor Inundation

Flood Event	Number of Buildings with Above Flood Inundation		
	Residential	Commercial/ Industrial	Total Number
20% AEP	1	8	9
5% AEP	12	10	22
1% AEP	26	11	37
0.4% AEP	52	18	70
PMF	331	37	368



NOTE: PMF probability is taken as 5×10^{-7} as per GSDM for a catchment < $100 km^2$

REFERENCES

- Resources and Mines, Natural (2002). *Guidance on the Assessment of Tangible Flood Damages*.
- Catchment Simulation Solutions (2017). *Draft Wyong River Floodplain Risk Management* Study. Prepared for Wyong Shire Council
- Paterson Consulting (2010). *Lower Wyong River Floodplain Risk Management Study*. Prepared for Wyong Shire Council

APPENDIX D

COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Blockage Control Structures Upstream of Wyong Road 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 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,610**
	1.01	Site Establishment (allowance only)	Lump sum	2	2,000	$4,000
	1.02	OHS&R Plan	Lump sum	1	2,000	$2,000
	1.03	Erosion and Sediment control - Geotextile Silt Fence around sites	m	340	16.50	$5,610
2		**EARTHWORKS FOR TRASH RACK ACCESS TRACK**				**$17,910**
	2.01	Excavate to remove vegetable soil average 0.15 metre near Kathleen White Crescent	m2	310	1.80	$558
	2.02	Excavate to remove vegetable soil average 0.15 metre near Hume Blvd (2 metre wide along easement)	m2	100	1.80	$180
	2.03	Crushed recycled concrete along newly constructed access roadways, 0.1 m deep (source, delivery, placement and compaction)	m3	41	93.00	$3,813
	2.04	Excavation of high volume debris storage bay near Kathleen White Cres in soft rock	m3	61	219.00	$13,359
3		**TRASH RACK**				**$26,000**
	3.01	Trash Rack supply and installed	each	2	13,000	$26,000
4		**OPERATION AND MAINTENANCE**				**$32,392**
	4.01	Trash Rack Maintenance (inpections/cleaning x 4 times per year x 50 years) **(NPV @ 7%)**	Item	1	27,601	$27,601
	4.02	Trash Rack Component Replacement at year 25 **(NPV @ 7%)**	Item	2	2,395	$4,790
					SUBTOTAL	**$87,912**
5		**ENGINEERING DESIGN**				**$8,791**
	5.01	Preparation of engineering design plans (10%)				$8,791
6		**PROJECT MANAGEMENT**				**$17,582**
	6.01	Supervision, Project Management etc (20%)				$17,582
7		**OTHER CONTINGENCIES**				**$17,582**
	7.01	General (20%)				$17,582
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$120,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
Culvert Upgrades Under Wyong Road near Kathleen White Crescent

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$178,000**
	1.01	Site Establishment (allowance only)	Lump sum	2	10000	$20,000
	1.02	Traffic/Pedestrian Management	Lump sum	1	150000	$150,000
	1.03	OHS&R Plan	Lump sum	1	8000	$8,000
2		**SERVICES**				**$15,000**
	2.01	Services investigation (water main, sewer, gas, Optus and electricity), non-destructive excavation and additional protection works during culvert installation	Lump sum	1	15000	$15,000
3		**EARTHWORKS**				**$40,471**
	3.01	Excavate roadway, base and ground along new culvert alignment from Open Channel, under Wyong Road (including backfilling/compaction) (trench of 2.8m width) (Excavate trench 1-2m deep in soft rock)	m3	185	219	$40,471
4		**DRAINAGE INFRASTRUCTURE**				**$68,468**
		Box Culverts				
	4.01	2.4m W x 1.1m H RCBC (Class 2)	m	33	2027	$66,904
		Culvert Headwall				
	4.02	Placed in-situ Concrete Culvert Headwall at Upstream and Downstream of Culverts (Filling cores of hollow blocks)	m3	2	782	$1,564
5		**ROAD WORKS**				**$8,145**
	5.01	Roadway Plates to cover open trenches during roadway opening times	Lump sum	4800	4800	$4,800
	5.02	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trenches on Wyong Rd	m2	92	36.2	$3,345
					SUBTOTAL	**$310,084**
7		**ENGINEERING DESIGN**				**$31,008**
	7.01	Preparation of engineering design plans (10%)				$31,008
8		**PROJECT MANAGEMENT**				**$62,017**
	8.01	Supervision, Project Management etc (20%)				$62,017
9		**OTHER CONTINGENCIES**				**$124,034**
	9.01	General (40%)				$124,034
				TOTAL at 7% NPV (Rounded to nearest $10,000)		**$530,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Culvert Upgrades between Hume Boulevard and Wyong Road

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

Item		Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$178,000**
	1.01	Site Establishment (allowance only)	Lump sum	2	10000	$20,000
	1.02	Traffic/Pedestrian Management	Lump sum	1	150000	$150,000
	1.03	OHS&R Plan	Lump sum	1	8000	$8,000
2		**SERVICES**				**$15,000**
	2.01	Services investigation (sewer, gas, and Optus), non-destructive excavation and additional protection works during culvert installation	Lump sum	1	15000	$15,000
3		**EARTHWORKS**				**$89,790**
	3.01	Excavate roadway, base and ground along new culvert alignment from Open Channel, under Hume Blvd, Community Park and Wyong Rd (including backfilling/compaction) (trench of 2.8m width) (Excavate trench 1-2m deep in soft rock)	m3	380	219	$83,220
	3.02	Excavation of edge of channel upstream of Hume Blvd for channel widening to house new culvert headwall	m3	30	219	$6,570
4		**DRAINAGE INFRASTRUCTURE**				**$159,545**
		Box Culverts				
	4.01	1.6m W x 1.2m H RCBC (Class 2)	m	95	1663	$157,981
		Culvert Headwall				
	4.02	Placed in-situ Concrete Culvert Headwall at Upstream and Downstream of Culverts (Filling cores of hollow blocks)	m3	2	782	$1,564
5		**ROAD WORKS**				**$8,420**
	5.01	Roadway Plates to cover open trenches during roadway opening times	Lump sum	4800	4800	$4,800
	5.02	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trenches on Hume Blvd and Wyong Rd	m2	100	36.2	$3,620
6		**LANDSCAPING**				**$810**
	6.01	Turf, layer, rolled and watered for 2 weeks in Community Park	m2	90	9.0	$810
					SUBTOTAL	**$451,565**
7		**ENGINEERING DESIGN**				**$45,156**
	7.01	Preparation of engineering design plans (10%)				$45,156
8		**PROJECT MANAGEMENT**				**$90,313**
	8.01	Supervision, Project Management etc (20%)				$90,313
9		**OTHER CONTINGENCIES**				**$180,626**
	9.01	General (40%)				$180,626
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$770,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Culvert Upgrades between The Entrance Road and the rear of The Reef Resort Motel

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

Item	Description	Unit	Quantity	Base Rate	Amount
1	**PRELIMINARY ITEMS**				**$88,000**
1.01	Site Establishment (allowance only)	Lump sum	1	10000	$10,000
1.02	Traffic/Pedestrian Management	Lump sum	1	70000	$70,000
1.03	OHS&R Plan	Lump sum	1	8000	$8,000
2	**SERVICES**				**$15,000**
2.01	Services investigation (water main, Optus and NBN), non-destructive excavation and additional protection works during culvert installation	Lump sum	1	15000	$15,000
3	**EARTHWORKS**				**$77,416**
3.01	Excavate roadway, base and ground for coring machine access point (2 access points) including backfilling (excavate pits 1-2m deep in soft rock)	m3	48.00	219	$10,512
3.02	Excavate roadway, base and ground along new culvert alignment from The Entrance Road to Motel coring hole, and from rear of Motel to grassed area (including backfilling/compaction) (trench of 3.5m width) (Excavate trench 1-2m deep in soft rock)	m3	216	219	$47,304
3.03	Excavate ground along new culvert alignment from rear of Motel to open channel (including backfilling/compaction) (trench of 3.5m width) (Excavate trench 1-2m deep in clay)	m3	280	70	$19,600
4	**CULVERT TUNNEL JACKING/BORING**				**$540,000**
4.01	Tunnel Coring under Motel and lining (3 x 0.9m diameter cores) including site establishment costs, microtunnelling, insertion of jacking culverts/lining and connections	m	60	9,000	$540,000
5	**DRAINAGE INFRASTRUCTURE**				**$210,561**
	Culverts				
5.01	0.9m W x 0.3m H RCBC (Class 2)	m	100	457	$45,700
5.02	0.9m Circular Pipe (Class 2)	m	225	600	$135,000
	Culvert Headwall				
5.03	Placed in-situ Concrete Culvert Headwall at Downstream of Culverts (Filling cores of hollow blocks)	m3	1	782	$626
	Pit Infrastructure				
5.04	Placed in-situ concrete pits for high capacity inlets within The Entrance Road and Motel Carpark	m3	14	782	$10,635
5.05	Large Grated Sag Inlet covers for high capapcity inlets (Class C galvanised cover and frame (0.9m*1.32m each))	m2	12	1,550	$18,600
6	**ROAD WORKS**				**$3,703**
	Roadway Plates to cover open trenches during roadway opening times	Lump sum	1500	1500	$1,500
6.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trenches on Wyong Rd	m2	12	30.6	$367
6.02	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering excavated trenches and coring pits within Motel grounds	m2	60	30.6	$1,836
7	**LANDSCAPING**				**$1,260**
7.01	Turf, layer, rolled and watered for 2 weeks along trech at rear of Motel to Open Channel	m2	140	9.0	$1,260
				SUBTOTAL	**$935,940**
8	**ENGINEERING DESIGN**				**$93,594**
8.01	Preparation of engineering design plans (10%)				$93,594
9	**PROJECT MANAGEMENT**				**$187,188**
9.01	Supervision, Project Management etc (20%)				$187,188
10	**OTHER CONTINGENCIES**				**$374,376**
10.01	General (40%)				$374,376
				TOTAL at 7% NPV (Rounded to nearest $10,000)	**$1,590,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Shelly Beach Golf Course Detention Basin

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,610**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	340	16.50	$5,610
2		**SERVICES**				**$0**
	2.01	Services investigation (sewer) and potential relocation prior to excavation	Lump sum	0	30000.00	$0
3		**SITE PURCHASE, DEMOLISHION AND PREPARATION**				**$0**
	3.01	Purchase of Properties in Moir St, Hart St and Victoria St	each	0	1200000	$0
	3.02	Domolishion of buildings on site and disposal/recycling of building products	each	0	60000	$0
	3.03	Transport and disposal of excavated material to Council spoil site for reuse	m3	0	3	$0
2		**EARTHWORKS AND SAFETY PROVISIONS**				**$18,220**
	2.01	Fill Material for construction of Basin crest/spillway (clay sourced locally)	m3	105	86.00	$9,030
	2.02	Constructing wall and spillway from clay (including consolidation)	m3	105	60.90	$6,395
	2.03	Labour forming sloping edge to basin crest/spillway	m	300	2.65	$795
	2.04	Basin safety mechanisms (Depth indicators, spillway/fencing signage)	Lump sum	1	2000.00	$2,000
3		**DRAINAGE INFRASTRUCTURE**				**$34,986**
		Culverts				
	3.01	0.45m Pipe (Class 2)	m	174	192	$33,321
		Headwalls				
	3.02	Basin pipe outlet headwall - to suit 3 x 0.45m diameter pipes	each	3	555	$1,665
4		**LANDSCAPING**				**$5,591**
	4.01	Turf, layer, rolled and watered for 2 weeks along basin crest and other disturbed area	m2	600	9.0	$5,400
	4.02	Placing of stabilised decomposed granite, layed and consolidated (0.15m thick) on spillway for scour protection	m3	2	85.0	$191
					SUBTOTAL	**$70,407**
5		**ENGINEERING DESIGN**				**$7,041**
	5.01	Preparation of engineering design plans (10% of non-property purchase amounts)				$7,041
6		**PROJECT MANAGEMENT**				**$3,520**
	6.01	Supervision, Project Management etc (5% of non-property purchase amounts)				$3,520
7		**OTHER CONTINGENCIES**				**$7,041**
	7.01	General (10% of non-property purchase amounts)				$7,041
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$90,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

The Bay Village Detention Basin Upgrade

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

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	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$11,610**
	1.01	Site Establishment (allowance only)	Lump sum	1	3,000	$3,000
	1.02	QA & ITP	Lump sum	1	1,000	$1,000
	1.03	Water Management Plan incl. Erosion and Sediment Control Plan	Lump sum	1	1,000	$1,000
	1.04	OHS&R Plan	Lump sum	1	1,000	$1,000
	1.05	Erosion and Sediment control - Geotextile Silt Fence around site	m	340	16.50	$5,610
2		**EARTHWORKS AND LEVEE WALL**				**$23,204**
	2.01	Fill Material for construction of Basin crest/spillway (clay sourced locally)	m3	141	86.00	$12,126
	2.02	Constructing wall and spillway from clay (including consolidation)	m3	141	60.90	$8,587
	2.03	Labour forming sloping edge to basin crest/spillway	m	940	2.65	$2,491
3		**DRAINAGE INFRASTRUCTURE**				**$15,000**
		Flood Gate				
	3.01	Flood Gate (Supply and Commission) - to suit 1.2m diameter outlet	each	1	15,000	$15,000
4		**LANDSCAPING**				**$5,400**
	4.01	Turf, layer, rolled and watered for 2 weeks along basin crest and other disturbed area	m2	600	9.0	$5,400
					SUBTOTAL	**$55,214**
5		**ENGINEERING DESIGN**				**$5,521**
	5.01	Preparation of engineering design plans (10% of non-property purchase amounts)				$5,521
6		**PROJECT MANAGEMENT**				**$2,761**
	6.01	Supervision, Project Management etc (5% of non-property purchase amounts)				$2,761
7		**OTHER CONTINGENCIES**				**$5,521**
	7.01	General (10% of non-property purchase amounts)				$5,521
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$70,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

Install Kerb and Gutter along Elsiemer Street and Pacific Street

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$29,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	Traffic/Pedestrian Management Plan	Lump sum	1	15,000	$15,000
	1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
2		**SERVICES**				**$6,000**
	2.01	Services investigation (storwater) and relocation/reconfiguration (if required) prior to excavation	Lump sum	1	6000	$6,000
3		**TRAFFIC MANAGEMENT**				**$30,000**
	3.01	Closure of one land of Pacific, Elsimer and Watkins St over a 3 week period, traffic controllers, signage, advisory, community consultation	Lump sum	1	30000	$30,000
4		**EARTHWORKS**				**$3,402**
	4.01	Break up and remove bitumen paving with basecourse under -corner of Pacific and Watkins St	m2	155	3.45	$535
	4.02	Excavate kerb and median along alignment of regrading (excavate trenches - soft rock) near Hume Blvd	m3	10	219	$2,190
	4.03	Surface treatment of exposed area to required level and grade - corner of Pacific and Watkins St	m2	155	3.55	$550
	4.04	Transport and disposal of excavated material to Council spoil site for reuse	m3	41	3.1	$127
5		**ROAD WORKS**				**$30,537**
	5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering roadway regraded area at corner of Pacific and Watkins St	m2	155	36.20	$5,611
	5.02	Formation of kerb (Extruded in situ concrete kerb, 600x225mm kerb and gutter) on Pacific St, Watkins St, Elsiemer St	m	484	51.5	$24,926
					SUBTOTAL	**$98,939**
6		**ENGINEERING DESIGN**				**$9,894**
	6.01	Preparation of engineering design plans (10%)				$9,894
7		**PROJECT MANAGEMENT**				**$19,788**
	7.01	Supervision, Project Management etc (20%)				$19,788
8		**OTHER CONTINGENCIES**				**$39,576**
	8.01	General (40%)				$39,576
			TOTAL at 7% NPV (Rounded to nearest $10,000)			**$170,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision: 1
Wyong Road Regrading	

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$24,000**
	1.01	Site Establishment (allowance only)	Lump sum	2	10,000	$10,000
	1.02	Traffic/Pedestrian Management Plan	Lump sum	1	10,000	$10,000
	1.03	OHS&R Plan	Lump sum	1	4,000	$4,000
2		**SERVICES**				**$50,000**
	2.01	Services investigation (sewer, gas, and Optus) and relocation (if required) during construction	Lump sum	2	25000	$50,000
3		**TRAFFIC MANAGEMENT**				**$280,000**
	3.01	Partial closure of Wyong Road for 3 weeks, local diversions, traffic controllers, signage, advisory, community consultation	Lump sum	1	280000	$280,000
4		**EARTHWORKS**				**$86,387**
	4.01	Break up and remove bitumen paving with basecourse under - near Hume Blvd	m2	2048	3.45	$7,064
	4.02	Excavate kerb and median along alignment of regrading (excavate trenches - soft rock) near Hume Blvd	m3	113	219	$24,747
	4.03	Surface treatment of exposed area to required level and grade - near Hume Blvd	m2	2048	3.55	$7,269
	4.04	Break up and remove bitumen paving with basecourse under - near Kathleen White Cres	m2	1887	3.45	$6,510
	4.05	Excavate kerb and median along alignment of regrading (excavate trenches - soft rock) near Kathleen White Cres	m3	100	219	$21,900
	4.06	Surface treatment of exposed area to required level and grade - near Kathleen White Cres	m2	1887	3.55	$6,699
	4.07	Transport and disposal of excavated material to Council spoil site for reuse	m3	3935	3.1	$12,197
5		**ROAD WORKS**				**$142,433**
	5.01	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering roadway regraded area near Hume Blvd	m2	2048	36.20	$74,124
	5.02	Install new pavement (40mm thick hot mix bitumen over new 300mm yellow sand basecourse) covering roadway regraded area near Kathleen White Cres	m2	1887	36.20	$68,309
					SUBTOTAL	**$582,820**
6		**ENGINEERING DESIGN**				**$58,282**
	6.01	Preparation of engineering design plans (10%)				$58,282
7		**PROJECT MANAGEMENT**				**$116,564**
	7.01	Supervision, Project Management etc (20%)				$116,564
8		**OTHER CONTINGENCIES**				**$233,128**
	8.01	General (40%)				$233,128
				TOTAL at 7% NPV (Rounded to nearest $10,000)		**$990,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

The Entrance Reef Resort Regrading

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation 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 36, 2018

Reg. Index: 1

	Item	Description	Unit	Quantity	Base Rate	Amount
1		**PRELIMINARY ITEMS**				**$14,000**
	1.01	Site Establishment (allowance only)	Lump sum	1	10,000	$10,000
	1.02	OHS&R Plan	Lump sum	1	4,000	$4,000
2		**SERVICES**				**$4,000**
	2.01	Services investigation (water main, Optus and NBN)	Lump sum	1	4000	$4,000
3		**EARTHWORKS**				**$44,129**
	3.01	Demolish Exisitng solid fence along The Entrance Road boundary (Breakup and remove brickwork)	m3	6.6	217	$1,432
	3.02	Cut away 0.1m thick reinforced concrete ground slab carpark along alignment of regrading - Reef Resort Motel	m2	616	61	$37,576
	3.03	Excavate to remove vegetable soil (0.15m)	m2	192	1.8	$345
	3.04	Surface treatment of exposed area to required level and grade - Reef Resort Motel	m2	808	3.55	$2,867
	3.05	Transport and disposal of excavated material to Council spoil site for reuse	m3	616	3.1	$1,910
4		**ROAD WORKS**				**$18,911**
	4.01	Reinforced Concrete slab (20MPa) over disturbed area within Reef Resort Motel (0.1m thick)	m3	62	307.00	$18,911
5		**LANDSCAPING**				**$5,112**
	5.01	Turf, layer, rolled and watered for 2 weeks along basin crest and other disturbed area	m2	192	9.0	$1,724
		Provision and erection of new 'open type' fencing along The Entrance Road boundary (butt jointed pailing fence, 1.5m high)	m	44	77.0	$3,388
					SUBTOTAL	**$86,152**
6		**ENGINEERING DESIGN**				**$8,615**
	6.01	Preparation of engineering design plans (10%)				$8,615
7		**PROJECT MANAGEMENT**				**$17,230**
	7.01	Supervision, Project Management etc (20%)				$17,230
8		**OTHER CONTINGENCIES**				**$34,461**
	8.01	General (40%)				$34,461
					TOTAL at 7% NPV (Rounded to nearest $10,000)	**$150,000**

APPENDIX E

ROADWAY INUNDATION INFORMATION

Impact of Flooding on Roads

Road Name	20% AEP Event				5% AEP Event				1% AEP Event				PMF Event			
	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)
ADELAIDE ST	N				N				N				N			
ADRIAN CL	N				N				N				N			
ALEXANDER AVE	N				N				N				N			
ALFRED ST	N				N				N				N			
ALTONA AVE	N				N				N				N			
AMBLER PDE	N				N				Y	0.00	0.27	0.17	Y	0.83	0.84	0.23
ANGLERS DR	N				N				N				Y	0.83	0.44	0.24
ANNE FINDLAY PL	Y	0.50	1.75	0.26	Y	0.45	2.16	0.30	Y	0.42	2.56	0.36	Y	0.83	2.24	0.74
ANNIE CL	N				N				N				N			
ANZAC RD	Y	0.58	0.19	0.19	Y	0.50	0.34	0.23	Y	0.42	0.56	0.27	Y	0.13	1.42	0.43
ARCHBOLD RD	N				N				N				Y	0.14	0.44	0.21
ARMIDALE ST	N				N				N				N			
ARMSTRONG AVE	N				N				N				Y	0.37	1.46	0.54
ASHTON AVE	N				N				Y	0.50	0.17	0.16	Y	0.13	1.19	0.45
AUBREY ST	N				N				N				Y	0.00	0.13	0.15
AUGUSTUS PL	N				N				N				N			
AURORA PL	N				N				N				N			
AVERY ST	N				N				N				N			
AVIGNON ST	N				N				N				N			
BANKS CL	N				N				N				N			
BARBARA CL	N				N				N				N			
BARD LANE	N				N				N				N			
BARRAMUNDI PL	N				Y	0.00	0.25	0.16	Y	0.50	0.76	0.18	Y	0.83	1.32	0.37
BARRY ST	N				N				N				N			
BASS AVE	N				N				N				Y	0.17	0.71	0.16
BATAAN CCT	N				N				N				N			
BATEAU BAY RD	Y	0.73	0.99	0.21	Y	0.62	1.48	0.25	Y	0.56	1.93	0.30	Y	0.13	1.88	0.57
BATTLEY AVE	N				N				N				N			
BAY RD	N				N				N				N			
BAY VILLAGE RD	Y	0.42	2.89	0.36	Y	0.33	2.92	0.39	Y	0.33	3.00	0.41	Y	0.83	2.32	0.52
BAYVIEW AVE	N				N				N				N			
BEACH ST	N				N				N				N			
BELFORD AVE	N				N				N				Y	0.17	0.46	0.16
BELLEVUE RD	N				N				N				N			
BELLEVUE ST	N				Y	0.00	0.67	0.15	Y	0.75	0.15	0.16	Y	0.16	1.28	0.33
BELSHAW PL	N				N				N				N			
BENALLA CL	N				N				N				Y	0.11	1.70	0.51
BENELONG ST	N				N				N				N			
BENT ST	Y	0.53	1.22	0.25	Y	0.49	1.69	0.30	Y	0.42	2.11	0.34	Y	0.83	1.99	0.50
BERNE ST	N				N				N				Y	0.83	1.92	0.18
BETH CL	N				N				N				N			
BIARA ST	N				N				N				N			
BIAS AVE	Y	0.43	1.97	0.29	Y	0.42	2.27	0.34	Y	0.35	2.59	0.39	Y	0.83	2.14	0.77
BLOOMFIELD ST	N				N				Y	0.92	1.47	0.19	Y	0.17	2.24	0.73
BLUE LAGOON CL	N				N				N				N			
BOLTON ST	N				N				N				N			
BONNIEVIEW ST	Y	0.50	2.33	0.37	Y	0.42	2.75	0.45	Y	0.42	2.84	0.51	Y	0.83	2.75	1.14
BOOMERANG RD	N				N				N				Y	0.83	0.90	0.17
BOONDILLA RD	N				N				N				N			
BOORANA CL	Y	0.67	0.36	0.16	Y	0.52	1.12	0.36	Y	0.48	1.43	0.46	Y	0.83	2.00	0.75
BORRODALE AVE	N				N				N				N			
BOSUN CL	Y	0.50	0.64	0.21	Y	0.50	0.91	0.23	Y	0.42	1.52	0.26	Y	0.83	1.63	0.58
BROOKE AVE	Y	0.50	1.80	0.43	Y	0.42	1.49	0.49	Y	0.42	2.58	0.54	Y	0.83	1.72	0.77
BROONARRA ST	N				N				N				N			
BURRAWONG ST	N				N				N				N			

Road Name	20% AEP Event				5% AEP Event				1% AEP Event				PMF Event			
	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)
BUSHLANDS AVE	Y	0.75	0.39	0.16	Y	0.50	0.21	0.19	Y	0.46	0.28	0.20	Y	0.83	1.49	0.43
CALOOLA CL	N				N				N				N			
CAMPBELL AVE	N				N				N				N			
CAPTAIN COOK CR	Y	0.50	1.64	0.36	Y	0.49	2.83	0.41	Y	0.42	2.53	0.46	Y	0.83	2.20	0.80
CARA ST	N				N				N				N			
CARLYON ST	N				N				N				N			
CARNATION CL	N				N				N				N			
CASTLE CL	N				N				N				N			
CASTLEREAGH CR	Y	0.42	1.64	0.46	Y	0.42	2.56	0.54	Y	0.33	2.52	0.61	Y	0.83	1.97	1.06
CENTENNIAL AVE	N				N				N				N			
CHARLOTTE CL	N				N				N				N			
CHURCHILL ST	N				N				N				N			
CLIFFORD ST	Y	0.58	2.78	0.34	Y	0.50	2.41	0.40	Y	0.50	2.75	0.45	Y	0.17	2.45	0.66
CLYDE CL	Y	0.50	0.50	0.25	Y	0.46	0.89	0.31	Y	0.42	1.34	0.36	Y	0.83	1.79	0.83
COLERIDGE RD	N				N				N				N			
COMMUNITY RD	N				N				N				Y	0.83	0.85	0.22
COMPASS CL	Y	0.54	0.59	0.28	Y	0.50	0.97	0.36	Y	0.45	1.50	0.42	Y	0.83	1.75	0.94
COOK RD	Y	0.58	0.86	0.25	Y	0.50	1.28	0.31	Y	0.47	2.00	0.37	Y	0.83	2.00	0.83
COOMBS LANE	Y	0.25	3.17	0.19	Y	0.25	3.17	0.19	Y	0.17	3.17	0.19	Y	0.83	2.67	0.34
COPNOR AVE	N				N				N				Y	0.86	0.63	0.22
CORAL ST	Y	0.33	3.16	0.38	Y	0.33	3.17	0.41	Y	0.38	3.19	0.43	Y	0.83	3.35	0.56
CORNISH AVE	N				N				N				N			
COTTON ST	N				N				N				N			
CRAIG CL	Y	0.57	0.42	0.34	Y	0.50	0.76	0.41	Y	0.42	1.83	0.44	Y	0.83	1.59	0.60
CRANBROOK CR	N				N				N				N			
CRESTHAVEN AVE	N				N				N				N			
CROSBY CR	N				N				N				Y	0.17	0.87	0.40
CUNNINGHAM RD	Y	0.54	0.95	0.36	Y	0.50	1.33	0.46	Y	0.42	1.86	0.56	Y	0.12	1.80	0.97
CURZON AVE	N				N				N				N			
CUTHBERT RD	N				N				N				N			
CYNTHIA ST	N				N				N				N			
DAMPIER BVD	N				Y	0.50	0.14	0.16	Y	0.50	0.23	0.17	Y	0.17	1.20	0.26
DANIEL CL	Y	0.34	3.24	0.53	Y	0.33	3.25	0.57	Y	0.31	3.27	0.60	Y	0.83	3.42	0.88
DARRIN CL	N				N				N				N			
DAVIDSON AVE	Y	0.58	2.17	0.38	Y	0.50	2.67	0.47	Y	0.50	2.75	0.54	Y	0.16	2.93	0.95
DEBRA ANNE DR	N				N				N				N			
DENING ST	N				N				N				N			
DUFFYS LANE	Y	0.43	2.29	0.43	Y	0.33	2.64	0.47	Y	0.33	2.94	0.50	Y	0.83	2.53	0.67
DUNCAN ST	N				Y	0.58	0.86	0.17	Y	0.48	0.22	0.21	Y	0.14	1.28	0.49
DUNNING AVE	N				N				N				N			
EARL ST	N				N				Y	0.50	0.14	0.16	Y	0.87	1.23	0.38
EASTERN RD	Y	1.00	0.29	0.16	Y	0.50	0.88	0.25	Y	0.47	1.42	0.31	Y	0.17	1.79	0.60
ELEWA AVE	Y	0.65	0.33	0.20	Y	0.56	0.52	0.26	Y	0.50	0.73	0.35	Y	0.14	1.46	0.80
ELGATA ST	N				N				N				N			
ELOORA RD	Y	0.50	3.00	0.23	Y	0.50	3.83	0.25	Y	0.42	3.17	0.27	Y	0.83	3.33	0.33
ELSIEMER ST	N				N				N				Y	0.95	1.32	0.38
ENDEAVOUR DR	N				Y	0.75	0.37	0.18	Y	0.67	1.42	0.25	Y	0.17	2.22	0.83
EPSOM PL	N				N				N				N			
FAIRPORT AVE	N				N				N				N			
FAIRVIEW AVE	N				N				N				Y	0.83	0.42	0.18
FARRAR RD	N				N				N				N			
FARRELL LANE	N				N				N				Y	0.83	0.83	0.23
FAYE CL	N				N				N				N			
FERNDALE ST	Y	0.50	2.50	0.48	Y	0.50	2.75	0.56	Y	0.42	2.83	0.63	Y	0.83	3.25	1.05
FINCH PL	N				N				N				N			
FIONA CL	Y	0.50	0.59	0.37	Y	0.41	1.16	0.42	Y	0.34	1.82	0.45	Y	0.83	1.66	0.72
FISHERMENS BEND	Y	0.42	1.77	0.36	Y	0.33	1.35	0.39	Y	0.33	1.99	0.41	Y	0.83	1.66	0.52

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FLINDERS AVE	N				N				Y	0.00	0.59	0.10	Y	0.17	1.88	0.30
FRANCES ST	N				N				N				N			
FRASER RD	N				N				N				N			
FRIENDSHIP CL	N				N				N				N			
GALLIPOLI RD	N				N				N				Y	0.00	0.24	0.15
GARDEN GR	N				N				N				N			
GARLAND AVE	N				N				N				Y	0.00	0.28	0.16
GATELEIGH CR	N				N				N				N			
GEORGE EVANS RD	Y	0.50	0.28	0.16	Y	0.42	0.35	0.18	Y	0.37	0.38	0.21	Y	0.83	1.27	0.40
GEORGE HELY CR	N				N				N				N			
GERMAINE AVE	N				N				N				Y	0.17	0.17	0.18
GILBERT ST	N				Y	0.33	0.53	0.17	Y	0.25	0.84	0.20	Y	0.83	1.50	0.45
GLADSTAN AVE	Y	0.57	0.82	0.26	Y	0.50	1.23	0.30	Y	0.49	1.71	0.34	Y	0.13	1.79	0.53
GLEESONS LANE	N				N				N				N			
GLENBROOK ST	N				Y	0.85	1.93	0.42	Y	0.52	2.41	0.42	Y	0.12	2.89	1.27
GORDON RD	Y	0.50	0.84	0.18	Y	0.49	0.24	0.22	Y	0.43	0.34	0.25	Y	0.83	1.34	0.43
GOSFORD AVE	Y	0.50	0.69	0.29	Y	0.47	0.94	0.41	Y	0.42	1.44	0.49	Y	0.83	1.63	1.16
GOSSIMER CL	N				N				N				N			
GRAHAM ST	N				Y	0.93	1.76	0.36	Y	0.65	2.43	0.45	Y	0.84	2.77	1.51
GRANDIS PL	N				N				N				N			
GRANDVIEW ST	N				Y	0.65	0.14	0.18	Y	0.54	0.33	0.23	Y	0.17	1.31	0.63
GUMTREE LANE	N				N				N				Y	0.83	0.34	0.18
GUYAGAL ST	N				N				N				N			
GWYDIR ST	Y	0.47	0.23	0.21	Y	0.39	0.36	0.25	Y	0.33	0.51	0.28	Y	0.83	1.45	0.54
HARBOUR ST	Y	0.00	0.61	0.16	Y	0.54	0.73	0.19	Y	0.50	0.93	0.21	Y	0.14	1.47	0.38
HAROLD CL	N				N				N				N			
HAWKESBURY CL	Y	0.48	1.88	0.60	Y	0.42	2.21	0.71	Y	0.42	2.55	0.81	Y	0.83	1.93	1.30
HELEN ST	Y	0.54	2.16	0.33	Y	0.47	2.51	0.37	Y	0.42	2.82	0.41	Y	0.83	2.20	0.66
HENRICKS RD	N				N				N				N			
HIBISCUS CL	N				N				N				N			
HIGHCLERE ST	N				N				N				N			
HILLCREST AVE	N				N				N				N			
HILLTOP ST	N				N				N				N			
HINEMOA AVE	N				N				N				N			
HUME BVD	Y	0.50	1.45	0.42	Y	0.45	1.93	0.53	Y	0.42	2.31	0.63	Y	0.83	1.89	1.04
IRELAND DR	N				N				N				N			
ITHACA ST	N				Y	0.50	0.12	0.15	Y	0.47	0.20	0.17	Y	0.83	1.20	0.29
JEAN ALBON PL	N				N				N				Y	0.25	1.37	0.52
JESSICA ST	N				N				N				N			
JONATHON CL	N				N				N				N			
JONQUIL CL	N				N				N				N			
KAROOAH AVE	N				N				N				N			
KATHLEEN WHITE CR	Y	0.50	2.92	0.49	Y	0.50	3.83	0.57	Y	0.42	3.17	0.64	Y	0.83	3.33	1.06
KATUNGAL ST	N				N				N				N			
KAYSTONE CL	N				N				N				N			
KEATS AVE	N				N				N				N			
KEDGE LANE	N				N				N				N			
KILLARNEY ST	N				N				N				N			
KINDARUN CL	Y	0.42	3.17	0.29	Y	0.33	3.25	0.32	Y	0.33	3.25	0.42	Y	0.83	3.42	0.76
KIPLING DR	N				N				N				N			
KIRRANG ST	N				N				N				Y	0.17	1.43	0.60
KITCHENER RD	Y	0.50	0.96	0.15	Y	0.42	0.19	0.18	Y	0.46	0.36	0.19	Y	0.83	1.22	0.29
KOONAH AVE	N				N				N				N			
KOORINDA AVE	N				N				Y	0.75	0.63	0.15	Y	0.83	1.17	0.36
KYWONG CL	N				N				N				N			
LADY PENRHYN CL	N				N				N				N			
LAIRD CL	Y	0.50	2.32	0.42	Y	0.43	2.72	0.52	Y	0.39	2.84	0.60	Y	0.83	2.73	1.21

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LAKE ST	Y	0.49	2.34	0.42	Y	0.42	2.78	0.45	Y	0.49	2.85	0.48	Y	0.83	2.95	0.73
LAKESIDE PDE	Y	0.50	0.30	0.19	Y	0.47	0.47	0.26	Y	0.42	0.67	0.31	Y	0.83	1.49	0.54
LAKIN ST	N				N				Y	0.00	0.14	0.17	Y	0.25	1.19	0.32
LAMB CL	N				N				N				N			
LANCASTER PDE	N				N				N				N			
LENTARA WALK	N				N				N				Y	0.17	1.64	0.44
LIDDELL ST	N				N				N				Y	0.19	0.77	0.23
LINCOLN CL	N				N				N				N			
LINDSAY ST	N				N				Y	0.67	0.53	0.17	Y	0.14	1.25	0.38
LISA CL	N				N				N				N			
LONGS RD	N				N				N				N			
LORD ST	N				N				N				Y	0.83	0.62	0.27
LUCINDA AVE	Y	0.35	3.24	0.41	Y	0.33	3.25	0.47	Y	0.33	3.25	0.49	Y	0.83	3.42	1.19
LUMBY DR	N				N				N				N			
LYNCH CR	N				N				N				Y	0.17	1.76	0.26
LYNWOOD AVE	N				N				N				N			
MACARTHUR ST	Y	0.58	0.21	0.20	Y	0.50	0.46	0.31	Y	0.50	0.65	0.40	Y	0.12	1.57	0.82
MACAULEY RD	N				N				N				N			
MACINTYRE ST	Y	0.50	0.28	0.22	Y	0.42	0.78	0.25	Y	0.37	1.19	0.29	Y	0.83	1.67	0.88
MAIN ST	N				N				N				N			
MALANA AVE	N				N				N				Y	0.17	1.35	0.35
MANNING RD	Y	0.50	2.43	0.43	Y	0.49	2.75	0.49	Y	0.42	2.83	0.54	Y	0.83	2.68	0.75
MAREE BVD	N				N				N				N			
MARGHERITA AVE	N				N				N				Y	0.00	0.15	0.21
MARINE PDE	Y	0.42	2.56	0.40	Y	0.40	2.78	0.43	Y	0.33	2.92	0.46	Y	0.83	2.27	0.74
MARLOWE RD	N				N				N				N			
MARQUIS CL	Y	0.59	0.88	0.51	Y	0.54	1.29	0.67	Y	0.50	1.94	0.78	Y	0.83	1.83	1.34
MASEFIELD AVE	N				N				N				N			
MAWSON DR	N				N				N				N			
MAYFAIR ST	N				N				N				Y	0.17	1.66	1.10
MCGIRR AVE	N				N				N				Y	0.17	1.86	0.26
MCLACHLAN AVE	Y	0.44	2.58	0.31	Y	0.44	2.69	0.35	Y	0.35	2.85	0.39	Y	0.83	2.77	0.93
MCLEAN ST	Y	0.00	0.14	0.15	Y	0.66	1.95	0.21	Y	0.50	2.67	0.23	Y	0.15	3.32	1.14
MELALEUCA ST	Y	0.42	3.73	0.24	Y	0.42	3.16	0.28	Y	0.33	3.24	0.38	Y	0.83	3.32	0.71
MELISSA CL	N				N				N				N			
MERMAID DR	N				N				N				Y	0.83	0.67	0.16
MINTO AVE	N				N				N				Y	0.15	1.96	0.57
MOLLY CL	N				N				N				N			
MONTANA PL	N				N				N				N			
MOORAH AVE	N				N				N				N			
MOORLAN AVE	N				N				N				Y	0.83	0.77	0.22
MORLEY AVE	N				N				N				N			
MORONGA ST	N				Y	0.82	0.63	0.18	Y	0.57	1.58	0.23	Y	0.17	1.76	0.43
MORRIS PL	N				N				N				N			
MORT ST	N				N				N				Y	0.17	0.38	0.21
MOSSMAN AVE	N				N				N				N			
MURRAY ST	N				N				N				N			
MURRUMBIDGEE CR	Y	0.42	1.65	0.60	Y	0.33	2.73	0.68	Y	0.33	2.41	0.75	Y	0.83	1.91	1.03
NAELCM AVE	N				N				N				Y	0.19	0.92	0.23
NAMOI CL	Y	0.50	0.24	0.24	Y	0.43	0.39	0.30	Y	0.37	0.57	0.35	Y	0.83	1.42	0.51
NEALE ST	Y	0.50	0.33	0.23	Y	0.50	0.48	0.28	Y	0.42	0.80	0.33	Y	0.83	1.50	0.58
NEPEAN ST	Y	0.17	3.00	0.46	Y	0.17	3.00	0.49	Y	0.17	3.83	0.51	Y	0.83	1.67	0.62
NEVILLE CL	N				N				N				N			
NEWHAVEN PL	N				N				N				N			
NEWLING LANE	N				N				N				N			
NIMBIN ST	Y	0.42	0.40	0.19	Y	0.42	0.55	0.20	Y	0.33	0.85	0.21	Y	0.83	1.38	0.25
NIRVANA ST	Y	0.50	0.67	0.18	Y	0.42	0.83	0.20	Y	0.40	1.45	0.22	Y	0.83	1.44	0.33

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NISIC CL	N				N				N				N			
NOELENE CL	N				N				N				N			
NORAH HEAD CL	N				N				N				N			
NORAHVIEW ST	N				N				N				N			
NORBERTA ST	N				N				N				N			
NORFOLK ST	N				N				N				N			
NORTHVIEW DR	Y	0.50	0.54	0.23	Y	0.33	0.67	0.26	Y	0.33	0.88	0.29	Y	0.83	1.42	0.50
NORTON AVE	N				N				N				Y	0.16	0.78	0.23
OAKEHAMPTON CT	N				N				N				N			
OAKLAND AVE	N				Y	0.00	0.13	0.10	N				Y	0.83	1.84	0.84
OAKS AVE	Y	0.37	2.64	0.29	Y	0.34	2.78	0.32	Y	0.33	2.92	0.35	Y	0.83	2.41	0.58
OCEAN PDE	N				N				N				Y	0.83	0.54	0.16
OCEANSIDE CL	N				N				N				N			
OXLEY RD	N				N				Y	0.58	0.15	0.10	Y	0.17	1.33	0.46
OZONE ST	N				N				N				N			
PACIFIC ST	Y	0.58	0.19	0.19	Y	0.50	0.37	0.22	Y	0.42	0.54	0.24	Y	0.15	1.52	0.35
PACKARD CL	N				N				N				N			
PAMELA CL	N				N				N				N			
PAPALA AVE	N				N				Y	0.58	0.62	0.17	Y	0.17	1.53	0.36
PARK RD	N				N				N				N			
PARKLANDS CL	N				N				N				N			
PARKSIDE AVE	Y	0.50	0.66	0.24	Y	0.43	0.96	0.29	Y	0.42	1.44	0.33	Y	0.16	1.58	0.62
PARKVIEW PL	N				N				N				N			
PASADENA AVE	N				N				N				N			
PASSAGE RD	N				N				N				N			
PATRICIA ST	N				N				N				N			
PATSTONE ST	N				N				N				N			
PEAK ST	N				N				N				N			
PENDANT PDE	N				N				N				N			
PENTON PL	N				N				N				Y	0.83	0.78	0.26
PETA CL	N				N				N				N			
PHEASANT AVE	N				N				N				N			
PHILLIP ST	N				N				N				Y	0.31	1.52	0.39
PLAYFORD RD	N				N				N				N			
POINT ST	Y	0.58	0.33	0.17	Y	0.50	0.58	0.18	Y	0.59	0.99	0.20	Y	0.17	1.50	0.40
POPLARS AVE	N				N				N				N			
PREMIER WAY	N				N				N				N			
PRINCE OF WALES ROAD	N				N				N				N			
PROMENADE AVE	N				N				N				Y	0.83	0.17	0.21
RAINBOW CL	N				N				N				N			
RAWSTHORNE CT	N				N				N				N			
RAYS RD	N				N				Y	0.50	0.17	0.19	Y	0.83	1.35	0.43
REDGUM CL	N				N				N				N			
REDMYRE ST	Y	2.83	0.65	0.17	Y	1.20	1.83	0.25	Y	0.98	2.27	0.33	Y	0.83	2.85	1.07
RESERVE DR	Y	0.50	2.57	0.38	Y	0.48	2.75	0.43	Y	0.42	2.83	0.47	Y	0.83	2.26	0.76
RHODIN DR	Y	0.58	0.70	0.22	Y	0.52	0.99	0.27	Y	0.46	1.45	0.32	Y	0.84	1.66	0.63
RICHMOND CL	Y	0.50	0.56	0.15	Y	0.50	0.11	0.17	Y	0.43	0.18	0.18	Y	0.83	1.22	0.44
RICKARD ST	N				N				N				N			
ROBERT BOURKE ST	N				N				N				N			
ROBERT PL	N				N				N				N			
ROBERTSON RD	N				N				Y	0.42	0.33	0.16	Y	0.83	1.33	0.27
ROBYN LANE	N				N				N				N			
ROTHERHAM ST	N				N				N				N			
RUSHBY ST	Y	0.42	1.32	0.37	Y	0.41	1.91	0.44	Y	0.33	2.40	0.48	Y	0.83	1.84	0.84
RUSKIN ROW	N				N				N				N			
RUTH PL	N				N				N				N			
SABRINA AVE	Y	0.50	1.86	0.33	Y	0.44	2.15	0.36	Y	0.42	2.49	0.39	Y	0.83	1.74	0.63

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SANCTUARY PL	N				N				N				N			
SARAH CL	N				N				N				N			
SCARBOROUGH PL	N				N				N				N			
SEABROOK AVE	N				N				N				N			
SEASPRAY CL	N				N				N				N			
SHAKESPEARE AVE	N				N				N				N			
SHANE CL	N				N				N				N			
SHAW ST	N				N				N				Y	0.17	1.16	0.46
SHELLY BEACH RD	N				N				Y	1.17	0.60	0.16	Y	0.34	1.73	1.10
SHERRY ST	N				N				N				N			
SHERWOOD CL	N				N				N				N			
SHORT ST	N				N				N				N			
SHORTLAND AVE	Y	0.75	0.25	0.22	Y	0.67	0.50	0.32	Y	0.58	0.77	0.38	Y	0.17	1.58	0.59
SIERRA AVE	Y	0.58	0.13	0.18	Y	0.50	0.26	0.21	Y	0.42	0.35	0.24	Y	0.83	1.34	0.40
SIR JOSEPH BANKS DR	N				N				N				N			
SIRIUS AVE	N				N				N				N			
SOLANDER PL	N				N				N				Y	0.17	1.32	0.32
SOUTH ST	N				N				N				Y	0.00	0.18	0.18
STAR ST	N				N				Y	0.50	0.95	0.16	Y	0.13	1.78	0.49
STELLA ST	Y	0.50	0.43	0.18	Y	0.57	0.78	0.24	Y	0.48	1.13	0.27	Y	0.12	1.80	0.42
STEPHENSON RD	N				N				N				N			
STRICKLAND RD	N				N				N				N			
STURT ST	N				N				N				Y	0.17	0.49	0.21
SUPPLY CL	N				N				N				N			
SURF ST	Y	0.64	0.53	0.23	Y	0.58	0.84	0.27	Y	0.50	1.22	0.31	Y	0.17	1.71	0.47
SUTTON AVE	N				N				N				N			
SWADLING ST	Y	0.57	0.90	0.23	Y	0.46	1.38	0.26	Y	0.42	1.79	0.28	Y	0.93	1.73	0.48
SYCAMORE AVE	N				N				N				Y	0.17	0.57	0.20
TALARA AVE	N				Y	0.50	0.92	0.17	Y	0.42	0.15	0.19	Y	0.83	1.74	0.43
TAYLOR ST	N				N				N				Y	0.83	0.84	0.21
THE ENTRANCE ROAD	Y	0.55	0.67	0.63	Y	0.49	1.00	0.98	Y	0.42	1.29	1.19	Y	0.83	1.75	2.21
THE PENINSULA	N				N				N				N			
THEATRE LANE	N				N				N				Y	0.83	0.16	0.15
THELMA ST	N				N				N				N			
THOMAS MITCHELL RD	N				N				N				N			
THOMPSON ST	N				N				N				Y	0.16	0.93	0.31
TIMS LANE	N				N				N				N			
TOONGARA AVE	N				N				N				N			
TOOWOON BAY RD	N				N				N				Y	0.83	0.55	0.20
TORRENS AVE	N				N				N				Y	0.17	0.30	0.22
TORRES ST	N				N				N				N			
TOWER ST	N				N				N				N			
TRELAWNEY ST	N				Y	0.17	3.42	0.34	Y	0.17	3.42	0.34	Y	0.83	3.42	0.35
TRUDY CL	Y	0.42	1.23	0.28	Y	0.36	1.70	0.31	Y	0.33	2.47	0.33	Y	0.83	1.65	0.46
TUGGERAH PDE	N				Y	0.50	0.20	0.15	Y	0.50	1.30	0.24	Y	0.99	2.45	0.97
TURANA ST	N				N				N				N			
TWEED CL	Y	0.42	2.49	0.60	Y	0.34	2.86	0.73	Y	0.33	2.91	0.81	Y	0.83	2.67	1.22
TYRRELL PL	N				N				N				Y	0.83	1.00	0.23
VALLEY VIEW RD	N				N				N				N			
VAUGHAN CL	N				N				N				N			
VENICE ST	N				Y	0.67	0.27	0.15	Y	0.50	0.49	0.18	Y	0.14	1.66	0.42
VENTURA AVE	N				N				Y	0.00	0.93	0.10	Y	0.17	0.64	0.28
VICTORIA AVE	N				N				N				Y	0.83	0.67	0.18
VIEW ST	N				N				N				Y	0.83	0.33	0.16
VILLAGE LANE	N				N				N				Y	0.83	0.78	0.22
VISCOUNT CL	N				N				N				Y	0.83	1.40	0.61
VISTA PDE	N				N				N				Y	0.83	0.17	0.15

Road Name	20% AEP Event				5% AEP Event				1% AEP Event				PMF Event			
	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)	Access Cut?	Access First Cut (Hours)	Duration Cut (Hours)	Max Depth (m)
WADI RD	N				N				N				N			
WAIKIKI CL	N				N				N				N			
WAITE ST	N				N				N				N			
WALCH AVE	N				N				N				N			
WANDELLA AVE	N				N				N				Y	0.00	0.44	0.19
WARATAH ST	N				N				N				N			
WARRATTA RD	N				N				N				N			
WARRIGAL ST	N				N				Y	0.73	0.88	0.18	Y	0.83	1.95	0.45
WATERVIEW ST	N				N				Y	0.50	0.12	0.17	Y	0.83	1.14	0.36
WATKINS ST	N				N				N				Y	0.17	0.75	0.22
WERONA PL	N				N				N				N			
WHALANS RD	N				N				N				N			
WILFRED BARRETT DR	Y	0.50	2.86	0.30	Y	0.47	2.99	0.35	Y	0.42	3.38	0.38	Y	0.83	3.29	0.55
WILLOW ST	N				N				N				N			
WOODSIDE CT	N				N				N				N			
WORDSWORTH AVE	N				N				N				N			
WYONG RD	N				N				Y	0.73	2.14	0.18	Y	0.17	2.56	0.53
YAKALLA ST	Y	0.50	3.53	0.72	Y	0.42	3.83	0.84	Y	0.42	3.17	1.01	Y	0.12	3.33	2.18
YAMBA ST	N				N				N				N			
YANGOORA ST	Y	0.17	3.42	1.37	Y	0.17	3.42	1.45	Y	0.17	3.42	1.52	Y	0.83	3.50	2.49
YARUGA ST	N				N				N				N			
YEDDENBA AVE	N				N				N				N			
YIMBALA ST	N				N				N				N			
YINGA LANE	N				N				N				N			
YORK ST	N				N				N				N			
YULONG ST	N				N				N				N			
ZORA PL	N				N				N				N			

APPENDIX F

PROPERTY INUNDATION INFORMATION

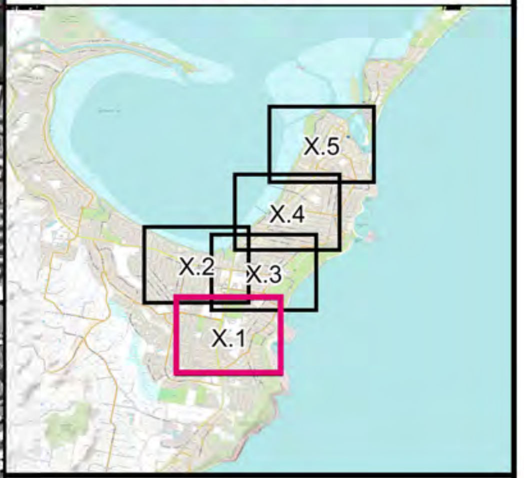
Number of Properties with above floor flooding				
Location	**20% AEP Event**	**5% AEP Event**	**1% AEP Event**	**PMF Event**
Anzac Rd	0	0	0	1
Armstrong Ave	0	0	0	5
Bateau Bay Rd	0	0	0	1
Bloomfield St	0	1	1	13
Bonnieview St	0	0	0	35
Brooke Ave	0	0	0	1
Campbell Ave	0	0	0	1
Captain Cook Cr	0	0	0	1
Castlereagh Cr	0	0	1	13
Compass Cl	0	0	1	6
Coral St	0	0	0	1
Craig Cl	0	0	0	4
Crosby Cr	0	0	0	1
Elewa Ave	0	0	1	9
Elsiemer St	0	0	0	6
Farrar Rd	0	0	0	2
Ferndale St	0	0	1	10
Fishermens Bend Ave	0	0	0	4
Flinders Ave	0	0	0	1
Glenbrook St	0	0	0	6
Gosford Ave	0	0	0	1
Graham St	0	0	0	9
Grandview St	1	1	3	7
Harbour St	0	0	0	1
Hume Bvd	0	0	0	5
Jean Albon Pl	0	0	0	1
Kathleen White Cr	0	0	0	16
Kirrang St	0	0	0	8
Laird Cl	0	0	1	10
Lakin St	0	1	1	2
Lindsay St	0	0	0	2
Malana Ave	0	0	0	5
Marquis Cl	0	1	3	10
Mclachlan Ave	0	0	0	1
Mclean St	0	0	0	7
Murrumbidgee Cr	0	0	0	3
Neale St	0	0	0	3
Oakland Ave	0	0	1	2
Oaks Ave	0	0	0	1
Papala Ave	0	0	1	7
Redmyre St	0	0	0	12
Rhodin Dr	0	0	0	1
Shelly Beach Rd	0	1	1	19
Sierra Ave	0	2	2	4
Solander Pl	0	0	0	1
Surf St	0	0	0	2
Sycamore Ave	0	2	2	2
Tasman Ave	0	0	0	18
The Entrance Road	1	2	4	28
Thompson St	0	0	0	1
Toongara Ave	0	2	2	2

Number of Properties with above floor flooding				
Location	**20% AEP Event**	**5% AEP Event**	**1% AEP Event**	**PMF Event**
Tuggerah Pde	0	0	0	1
Ventura Ave	0	1	1	2
Viscount Cl	0	0	0	9
Wandella Ave	0	0	0	3
Wyong Rd	6	8	9	36
Yakalla St	0	0	0	4
Description of Flood Impacts	Local overland flooding resulting in shallow inundation along local roads. Over 50 roads are cut (For complete list, please refer to Appendix E - Road Inundation Information)	Local overland and mainstream flooding resulting in shallow inundation along some local roads. Additional access cut along Barramundi Pl, Endeavour Dr, Moronga St, and Venice St (For complete list, please refer to Appendix E - Road Inundation Information)	Local overland and mainstream flooding resulting in moderate inundation along local roads. Additional access cut along Ambler Pde, Bloomfield St, Koorinda Ave, Rays Rd, Shelly Beach Rd, Ventura Ave, and Waterview St (For complete list, please refer to Appendix E - Road Inundation Information)	Local overland and mainstream flooding resulting in high inundation depth along most local roads. Additional access cut along Anglers Dr, Bass Ave, Crosby Cr, Fairview Ave, Garland Ave, Liddell St, Moorlan Ave, Penton Pl, Promenade Ave, Shaw St, Thompson St, and Vista Pde (For complete list, please refer to Appendix E - Road Inundation Information)

APPENDIX G

VARIABLE FREEBOARD MAPS

Central Coast Council



LEGEND

- Catchment Boundary

Recommended Freeboard Allowances

- 0.5m freeboard
- 0.3m freeboard

Notes:

Aerial photograph date: 2013

N W E S

Scale 1:6,000 (at A3)

0 0.15 0.3 Km

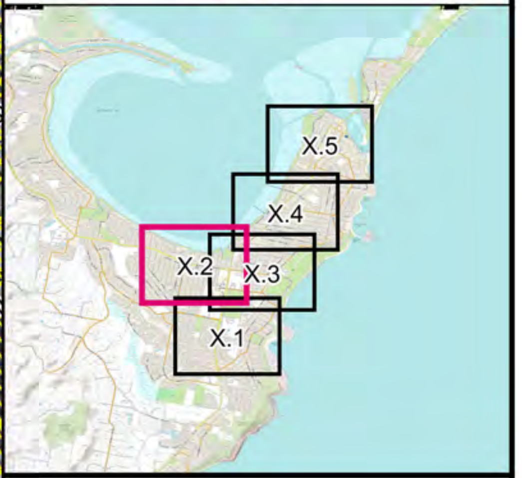
Figure G.1
Variable Freeboard Map

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

Appendix G Variable Freeboard Map.wor

Central Coast Council



LEGEND

Catchment Boundary

Recommended Freeboard Allowances

0.5m freeboard

0.3m freeboard

Notes:

Aerial photograph date: 2013

N W E S

Scale 1:6,000 (at A3)

0 0.15 0.3 Km

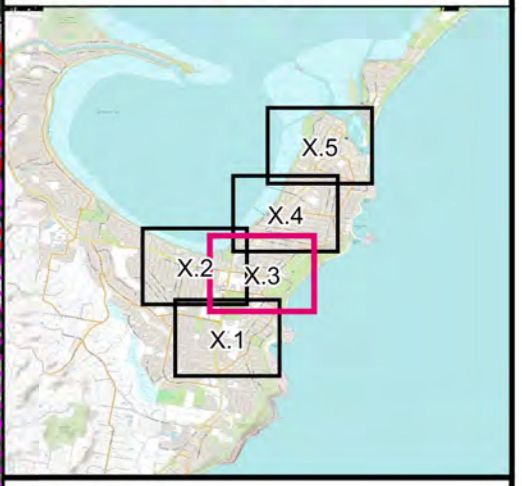
Figure G.2
Variable Freeboard Map

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

Appendix G Variable Freeboard Map.wor

Central Coast Council



LEGEND

Catchment Boundary

Recommended Freeboard Allowances

0.5m freeboard

0.3m freeboard

Notes:

Aerial photograph date: 2013

N
W E
S

Scale 1:6,000 (at A3)

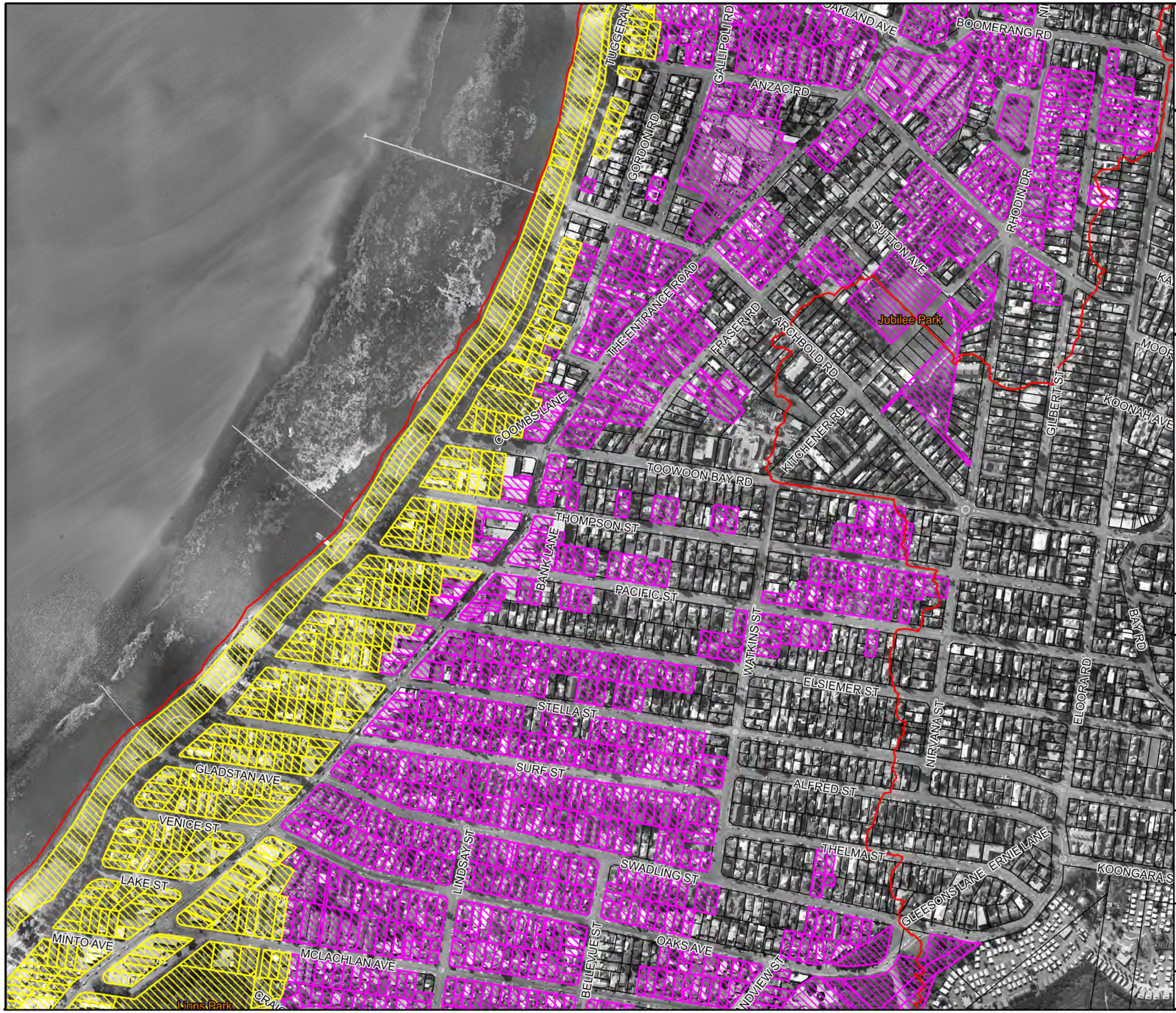
0 0.15 0.3
Km

Figure G.3
Variable Freeboard Map

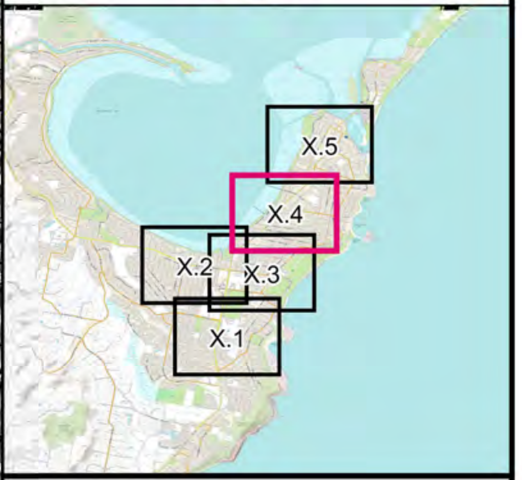
Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

Appendix G Variable Freeboard Map.wor



Central Coast Council



LEGEND

Catchment Boundary

Recommended Freeboard Allowances

0.5m freeboard

0.3m freeboard

Notes:

Aerial photograph date: 2013

N
W
E
S

Scale 1:6,000 (at A3)

0 0.15 0.3

Km

Figure G.4
Variable Freeboard Map

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

Appendix G Variable Freeboard Map.wor

Central Coast Council

LEGEND

Catchment Boundary

Recommended Freeboard Allowances

0.5m freeboard

0.3m freeboard

Notes:

Aerial photograph date: 2013

N S W E

Scale 1:6,000 (at A3)

0 0.15 0.3 Km

Figure G.5
Variable Freeboard Map

Prepared By:

Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

Appendix G Variable Freeboard Map.wor