Central Coast Council

Wallarah Creek Catchment
Floodplain Risk Management Study & Plan

Final Report
Volume 1 of 2: Report Text & Appendices

Revision 3
March 2021

Flood Focus Consulting

Catchment Simulation Solutions

Wallarah Creek Catchment

Floodplain Risk Management Study & Plan

Final Report

REVISION / REVIEW HISTORY

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

DISTRIBUTION

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1	Central Coast Council	23/4/2019	PDF
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Central Coast Council

Ordinary Council Meeting

Held in the Council Chamber
2 Hely Street, Wyong

9 March 2021

MINUTES

Present

Dick Persson AM

In Attendance

Rik Hart	Acting Chief Executive Officer
Malcolm Ryan	Chief Operating Officer
Natalia Cowley	Acting Director Corporate Affairs
Boris Bolgoff	Director Infrastructure Services
Julie Vaughan	Director Connected and Recreation Communities
Scott Cox	Director Environment and Planning
Daniel Kemp	Acting Director Water and Sewer

4.5 Adoption of Wallarah Creek Catchments Floodplain Risk Management Study and Plan

Time commenced: 7.55pm

Moved: Mr Persson AM

51/21 Resolved

That Council adopt the draft Wallarah Creek Catchment Floodplain Risk Management Study and Plan (Links to Report – Link 1, Link 2, Link 3) amended as follows:

a) *Inclusion in Section 9.5 of a recommendation that Council pursue the preparation of a management plan for the sewerage system as per the recommendations detailed in the 'Tuggerah Lakes Floodplain Risk Management Study 2014'.*
b) *Inclusion in Section 9.6.2 of a recommendation that future upgrade of Birdwood Drive, Blue Haven provide an opportunity to upgrade the local stormwater system and install kerb and guttering.*
c) *Amendment of Table 1 such that the implementation responsibility for FM1 (Doyalson Link Road Basin) be shared between RMS and Council.*

Executive Summary

Overview

The Wallarah Creek catchment is located within the Central Coast Council LGA. The catchment comprises a mix of urbanised and rural land uses and includes the suburbs of Blue Haven, Wallarah and Bushells Ridge as well as part sections of Doyalson, San Remo, Charmhaven and Woongarrah. The extent of the catchment is shown in **Figure 1**, which is enclosed in Volume 2 of this report.

During periods of heavy rainfall there is potential for flooding across parts of the catchment. Flooding may occur as a result of major watercourses overtopping their banks or from overland flooding when the capacity of the local stormwater system is exceeded. Flooding across the catchment has been experienced in February 2007, August 2014 and most recently in August 2015.

Although a significant proportion of the catchment is currently undeveloped, development pressure in the area will likely lead to the expansion of the existing urban areas. This urban expansion may increase the existing flood risk (associated with additional runoff) and has the potential to introduce more people into flood liable areas (resulting in a potential increase in the future flood risk).

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

The Existing Flooding Problem

The nature and extent of the existing flooding problem was quantified using computer flood models that were originally developed as part of the *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016). Flood hazard mapping was prepared using the flood modelling outputs based upon the Australian Government's *"Technical Flood Risk Management Guideline: Flood Hazard"* (2014) to quantify 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) for the Blue Haven area are provided in **Figure ES1** and **Figure ES2**.

The outcomes of the modelling determined that:

- 2 properties would likely experience above floor flooding in a 20% AEP flood. During a 1% AEP flood, 46 properties are predicted to experience above floor inundation and during the probable maximum flood (PMF), over 500 properties are likely to experience above floor inundation.

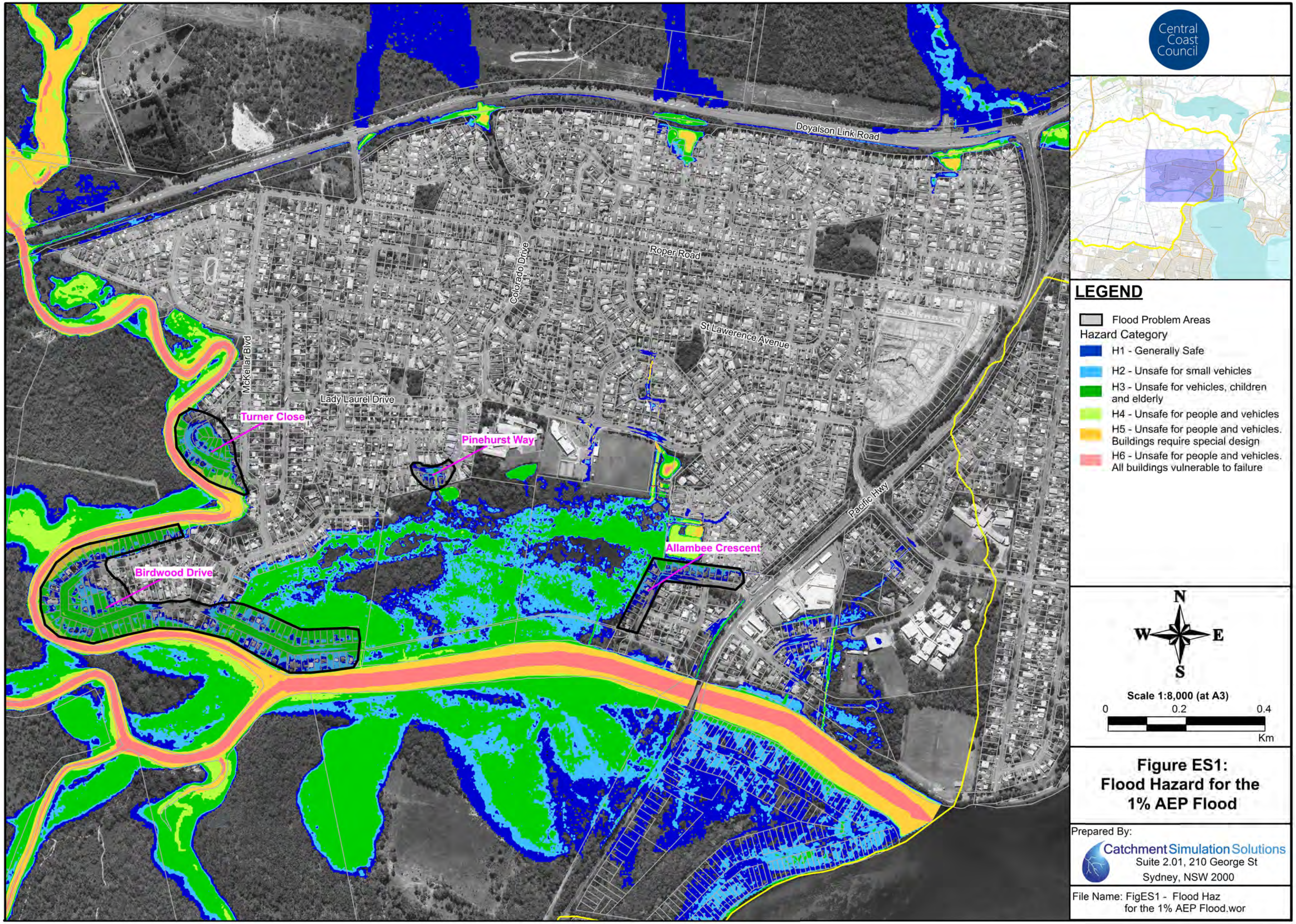

Figure ES1: Flood Hazard for the 1% AEP Flood

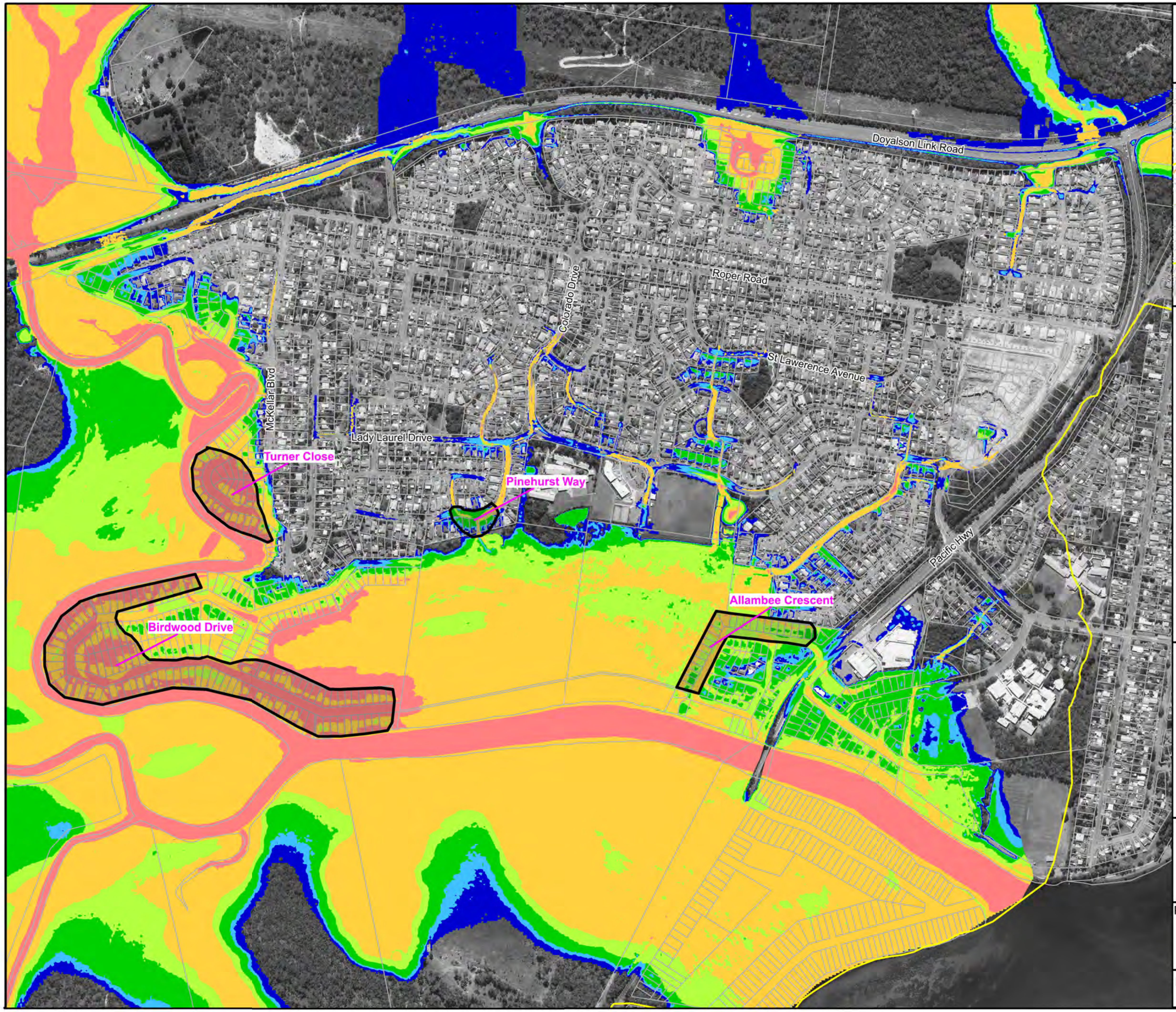

Figure ES2: Flood Hazard for the PMF

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File Name: FigES2 - Flood Haz for the PMF.wor

- A number of roadways are predicted to be cut by floodwaters. This includes Turner Close and Birdwood Drive, which would cut be during floods as frequent as the 20% AEP flood. During the 1% AEP event, floodwaters are predicted to cut several major roadways including the Pacific Highway.
- The average annual flood damage cost for existing catchment conditions would be about $371,000. Properties located in the following areas are expected to suffer the highest flood damage costs (these areas are also shown on **Figure ES1** and **Figure ES2**):
  - Birdwood Drive, Blue Haven
  - Turner Close, Blue Haven
  - Pinehurst Way, Blue Haven
  - Allambee Crescent, Blue Haven

Impacts of Future Catchment Development

Although most of the upstream catchment areas are currently undeveloped, a significant proportion of this area is currently zoned for industrial uses. If these areas were fully developed in the future it has the potential to increase existing flood flows, levels, depths and extents across parts of the catchment. More specifically, flood flows/discharges are predicted to increase by 30 to 50% across most locations and peak flood levels/depths are predicted to increase by over 0.3 metres at some locations. The increases in flood flows, levels and depths are predicted to increase existing 20% AEP damages by $15,000 (a 40% increase over existing damages) and 1% AEP damages by around $500,000 (a 20% increase over existing damages).

Impacts of Climate Change

Increases in rainfall associated with climate change also has the potential to increase the existing flood risk. More specifically, a 15% increase in rainfall intensity has the potential to increase peak 1% AEP discharges by 18% and increase flood levels/depths by 0.07 metres (on average). A 30% increase in rainfall intensity has the potential to increase peak 1% AEP discharges by 39% and peak flood levels/depths by 0.15 metres (on average). Accordingly, climate change induced rainfall intensity increases do have the potential to significantly increase the existing flood risk across the catchment.

Options Considered for Better Managing the Flood Risk

A range of flood modification, property modification and response modification measures were considered to help manage the existing and future flood risk across the catchment. 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

Floodplain Risk Management Plan

Based upon the outcomes of the detailed evaluation, the options outlined **Table 1** are recommended for implementation as part of the Floodplain Risk Management Plan for the Wallarah Creek catchment. 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**.

The total capital cost to implement the structural components of the Plan is expected to be about $2.9 million. The most significant contributors to this cost are the Doyalson Link Road detention basin ($2 million) and the Birdwood Drive upgrades ($600,000). In addition to the capital costs, some options will require an investment in time from various agencies including Central Coast Council and the State Emergency Service in addition to monetary contributions.

It needs to be recognised that implementation of the structural/flood modification options will not eliminate the potential for flooding within the catchment and the options may take a number of years before they are fully implemented. Therefore, implementation of the remaining, property and response modification options, as well as those aimed at reducing the future flood risk are considered essential for ensuring the existing flood risk is not increased in the future and the continuing flood risk is minimised during particularly severe floods.

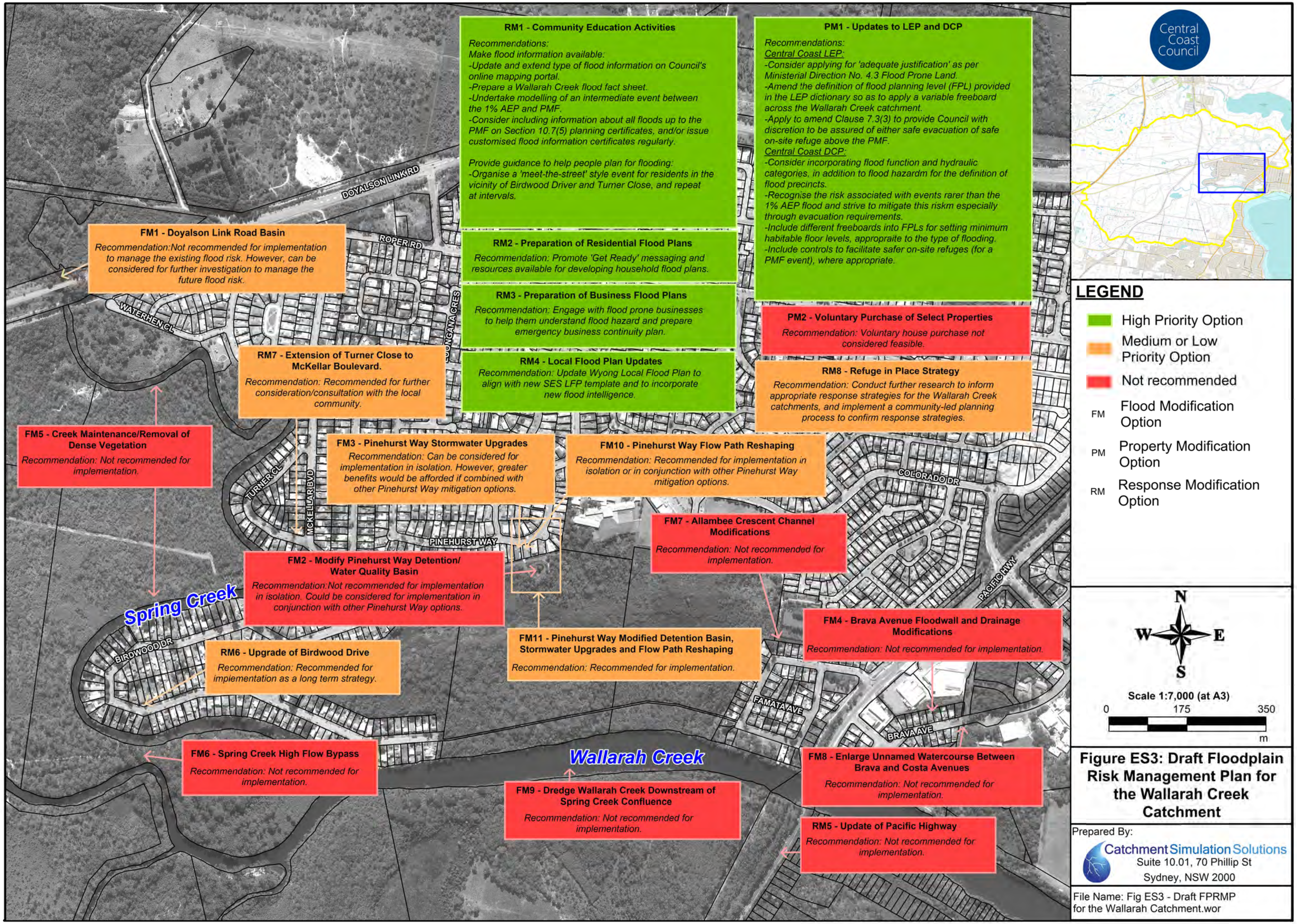

Figure ES3: Draft Floodplain Risk Management Plan for the Wallarah Creek Catchment

Table 1 Recommended Floodplain Risk Management Options for the Wallarah Creek catchment

#	Option Description	Report Section	Cost	Implementation Responsibility	Priority
Flood Modification Options					
FM10	Pinehurst Way Flow Path Reshaping	7.5.1	$100,000	Council	Medium
FM11	Pinehurst Way Modified Detention Basin, Stormwater Upgrades and Flow Path Reshaping	7.6.1	$310,000	Council	Medium
Property Modification Options					
PM1	LEP Amendments	8.2	Council Time	Council	High
	DCP Amendments		Council Time	Council	High
Response Modification Options					
RM1	Community Education Activities	9.2	Council & SES Time	SES & Council	High
RM2	Preparation of residential flood plans	9.3	Residents, SES & Council time	Individual residents with assistance from SES & Council	High
RM3	Preparation of business flood plans	9.4	Business owners, SES & Council time	Individual business owners with assistance from SES & Council	High
RM4	Local Flood Plan Updates	9.5	SES time	SES	High
RM6	Upgrade of Birdwood Drive	9.6.2	$600,000	Council	Medium
RM7	Extension of Turner Close to McKellar Boulevard	9.6.3	unknown	Council	Medium
RM8	Refuge in Place Strategy	9.7	Council & SES time	Council & SES	Medium
Options for Reducing the Future Flood Risk					
FM1	Doyalson Link Road Basin	7.2.1	$2 million	Council & RMS	Low

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1 INTRODUCTION

1.1 Background

The Wallarah Creek catchment is located on the Central Coast of New South Wales and occupies an area of 33 km^2. The extent of the catchment is shown in **Figure 1**.

As shown in **Figure 1**, the catchment is drained by two major watercourses (Spring Creek and Wallarah Creek) as well as a number of unnamed tributaries which carry runoff in an easterly direction into Budgewoi Lake. Although the catchment is largely undeveloped, a number of urban settlements are scattered across the area including Blue Haven, Wallarah and Bushells Ridge as well as part sections of Doyalson, San Remo, Charmhaven and Woongarrah. The urban sections of the catchment are typically drained by a stormwater system which conveys runoff below ground and into one of the receiving watercourses. The watercourses ultimately drain into Budgewoi Lake which forms the eastern boundary of the catchment.

During periods of heavy rainfall across the Wallarah Creek catchment, there is potential for water to overtop the banks of the various creeks and waterways and inundate adjoining properties. There is also the potential for the capacity of the stormwater system to be exceeded across the urban areas leading to overland flooding. Flooding has been experienced across the catchment on a number of occasions in the past including 2007 as well as more recently in 2015.

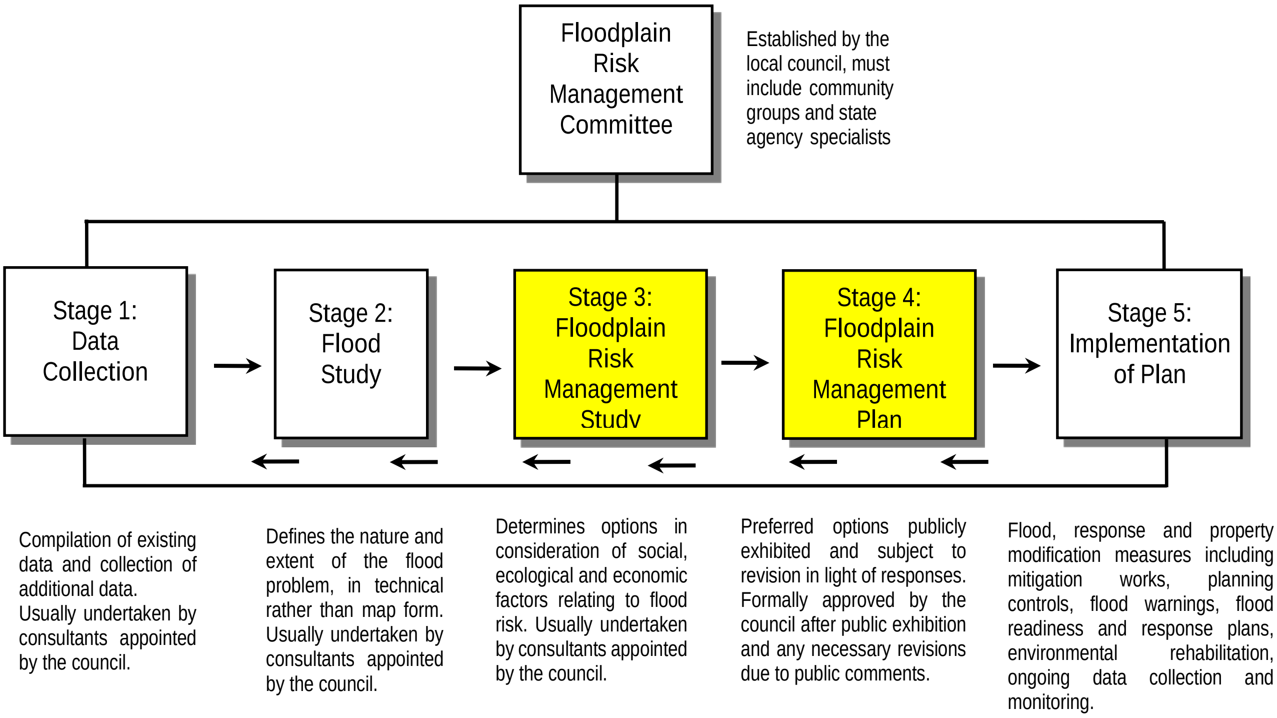
In recognition of the damage and inconvenience that has been caused by past flooding across the catchment, Central Coast Council resolved to prepare a Floodplain Risk Management Plan for the Wallarah Creek catchment.

1.2 The Floodplain Risk Management Process

The Wallarah Creek Catchment Floodplain Risk Management Study and Plan (FPRMS) 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 *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016).

Central Coast Council engaged Catchment Simulation Solutions to prepare the *Wallarah Creek Catchment Floodplain Risk Management Study and 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 and assess various options for managing the flood risk across the catchment. The *Floodplain Risk Management Plan* draws on the outcomes of the *Floodplain Risk Management Study* and provides a set of recommended options that will outline how to best manage the existing, future and continuing flood risk across the Wallarah Creek catchment.

It should be noted that the Wallarah Creek catchment drains into Budgewoi Lake. Accordingly, inundation of the study area can occur as a result of elevated water levels within Budgewoi Lake as well as from runoff from the local catchments. 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 Budgewoi Lake was 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 following report forms the Floodplain Risk Management Study and Plan for the Wallarah Creek catchment. It is divided into the following sections:

- <u>Section 2 - Catchment Information</u>: Provides general information regarding the catchment, including past flooding investigations.

- 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 catchment.
- Section 5 – Existing Emergency Management Protocols: provides an overview of emergency management measures that are currently implemented across the catchment to assist in managing the flood risk. Opportunities to improve these existing protocols are also discussed.
- Section 6 - Options for Managing the Flood Risk: Outlines options that could be potentially employed to manage the existing, future and continuing flood risk across the study area.
- S Section 6 – Options for Managing the Flood Risk: Outlined the options that were considered to assist in better managing the flood risk across the Wallarah Creek catchment.
- 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 –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 Catchment Description

The Wallarah Creek catchment is located on the Central Coast of New South Wales and occupies a total area of 33 km^2. The extent of the catchment is shown in **Figure 1**.

The catchment is largely undeveloped. However, a number of urban settlements are concentrated within the eastern sections of the catchment including Blue Haven, Wallarah and Bushells Ridge as well as part sections of Doyalson, San Remo, Charmhaven and Woongarrah.

The catchment is drained by two major watercourses (Spring Creek and Wallarah Creek) as well as a number of unnamed tributaries which carry runoff in an easterly direction into Budgewoi Lake. The urban sections of the catchment are typically drained by a stormwater system which conveys runoff below ground and into one of the receiving watercourses.

Three major transportation links extend across the catchment. These include (refer to **Figure 1**):

- Pacific Highway;
- Pacific Motorway; and
- Main Northern Railway.

The catchment is also home to major infrastructure including the Charmhaven wastewater treatment works.

A Digital Elevation Model (DEM) showing ground surface elevations across the study area is shown in **Figure 2**. It indicates that the ground elevations vary from over 75 mAHD to less than 1 mAHD along the Budgewoi Lake foreshore.

2.2 Previous Studies

The most recent flood study for the area is the *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016). This study provides the most contemporary description of flood behaviour across the Wallarah Creek catchment. 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 Wallarah Creek Flood Investigation (1992 & 1993)

The *'Wallarah Creek Flood Investigation'* was prepared by Gutteridge Haskins & Davey for Wyong Shire Council. The study was completed in three separate stages:

- Stage 1 (December 1992) involved defining flood behaviour along Wallarah and Spring Creeks under current (i.e., 1992) conditions as well as 'fully developed' catchment conditions.
- Stage 2 (June 1993) looked at options for mitigating the predicted increases in peak catchment flows and flood levels associated with the full development of the catchment (as defined in the Stage 1 report). The report determined that a detention basin located on Spring Creek (upstream of the Doyalson Link Road) afforded the most benefits in terms of reducing flood impacts across residential areas adjoining Spring and Wallarah Creeks.
- Stage 3 (May 1993) involved defining the potential impacts associated with failure of the detention basin on Spring Creek recommended as part of the Stage 2 investigations. It utilised the DAMBRK software to undertake the detention basin failure simulations.

The detention basin on Spring Creek that was recommended as part of these investigations has not been constructed.

2.2.2 Tuggerah Lakes Floodplain Risk Management Plan (November, 2014)

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 Lake 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 Wallarah Creek. Nevertheless, it does provide useful information regarding flooding mechanisms across Budgewoi Lake. As shown in **Figure 1**, the Wallarah Creek catchment drains into Budgewoi Lake. Accordingly, the prevailing water levels in Budgewoi Lake can influence flood behaviour along the downstream reaches of the catchment.

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 (as 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 0.4mAHD with no apparent tidal fluctuation.

The study includes a summary of peak lake water levels for significant historic floods, which is reproduced in **Table 2**.

Table 2 Summary of Peak Historic Lake Water Levels
(Source: 'Tuggerah Lakes Floodplain Risk Management Plan' (WMAwater, 2014))

Rank	Date	Peak Lake Water Level (mAHD)
1	18th June 1949	2.10
2	Easter 1946	1.90
3	2nd May 1964	1.90
4	1927	1.80
5	1931	1.80
6	10th June 2007	1.65
7	4th February 1990	1.60
8	4th March 1977	1.60
9	1963	1.50
10	1953	1.50

As shown in **Table 2**, the highest recorded historic water level within the Tuggerah Lake system occurred in 1949 and generated a peak water level of 2.1mAHD. Another significant event occurred in 1946, which is known to have caused significant inundation across the lower sections of Wallarah Creek (refer to **Plate 1**). The 1990 and 2007 events have produced the highest lake levels over the last 30 years. As the major urban areas contained within the catchment were established over the last 30 years, it is likely that these floods are the events that most residents and business owners within the catchment will be familiar with.

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 to **Table 3**). The design flood levels listed in **Table 3** are based on an entrance breach model that was calibrated against historic floods.

Table 3 Summary of Peak Design Flood Levels for Tuggerah Lake
(Source: Tuggerah Lakes Flood Study' (Lawson & Treloar, 1994))

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).

CREEK FLOODS PACIFIC HIGHWAY

For the first time on record backwater from the flooded Wallarah Creek flowed across the Pacific Highway, about 200yd. from the southern approach to the bridge. Unsuspecting motorists who entered the water at speed spent some minutes drying out ignition parts.

Plate 1 Article showing floodwater extending across the southern approach to the Pacific Highway bridge crossing of Wallarah Creek during April 1946
(Source: Newcastle Morning Herald and Miners' Advocate issue dated Thursday 18 April 1946 p.3)

The study notes that "structural" mitigation options were largely ineffective owing primarily to the large contributing catchment areas. Structural options that were explored but found to be not feasible included:

- Levees, flood gates and pumps;
- Dams/flood detention basins;
- Entrance management/dredging; and
- 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 floodplain risk management plan are summarised in **Table 4**.

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 4** 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, these options may not afford benefits across the Wallarah Creek catchment. Therefore, it is important that the Wallarah Creek catchment is independently investigated, which is the focus of the current study.

Table 4 Flood Risk Management Measures Recommended as Part of the 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		

2.3 Plans

2.3.1 Work as Executed Survey

At the time the *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016) was being prepared, a part section of Blue Haven was still being developed (i.e., the area located immediately west of the Pacific Highway and south of Roper Road). A representation of the proposed terrain and drainage system across this area was included in the hydraulic model based on information contained in design plans.

This area is now fully developed and work-as-executed (WAE) survey was collected for the stormwater drainage system. The WAE survey was compared with the "design" drainage information that was included in the hydraulic model. This review determined that there were small differences between the design and WAE invert elevations for some pits and pipes. Therefore, the stormwater pit and pipe inverts were updated based on the WAE survey information to ensure the hydraulic model provided the best possible representation of "as built" conditions. The location of stormwater pits and pipes that were updated are shown in red in **Plate 2**.

Plate 2 Stormwater Pits and Pipes that Were Updated based Upon WAE Survey (red)

2.4 Local Environment

2.4.1 Vegetation

The Wallarah Creek catchment contains a significant amount of vegetation. This includes significant areas of Endangered Ecological Communities (ECC). The location of ECC based on Council's vegetation mapping is shown in **Figure 3**.

As shown in **Figure 3**, the ECC is distributed throughout the catchment, however, it is most concentrated in areas adjoining Wallarah and Spring Creeks.

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

2.4.2 Acid Sulfate Soils

Acid sulfate risk mapping is presented in **Figure 3**. It shows that there is a high probability of acid sulfate soils across areas adjoining Wallarah and Spring Creeks (typically areas located below 2mAHD). Across most of the elevated sections of the catchment, the potential for acid sulfate soils is low.

Further detailed soil investigations will be required when assessing the potential for structural mitigation measures in areas with high probability of acid sulfate soils (as shown in **Figure 3**). If it is determined that acid sulfate soils exist, the implementation of structural works and excavation in these areas will be limited due to the potential for disturbed soil to release acid into the air, damaging built structures and harming or killing animals and plants.

2.4.3 Aboriginal Land Claims and Heritage Sites

There are 23 aboriginal heritage sites located within the catchment. The location of the heritage sites is shown in **Figure 3**. A detailed summary of these sites is listed below in **Table** 5.

Table 5 Summary of Aboriginal Heritage Sites

ID (refer **Figure 3**)	Site Name	Site Features
1	Halloran ISO 1	Artefact:
2	WC-IF1	Artefact:
3	WC-ST1	Modified Tree (Carved or Scarred): -
4	WC-OS1	Artefact:
5	Wallarah Creek Open Site 2	Artefact: 1
6	Restricted-Cultural Tree	Modified Tree (Carved or Scarred): -
7	CASAR Park IF 1	Artefact: -
8	PAD 4 - Munmorah (not a PAD)	Potential Archaeological Deposit (PAD): -
9	Wyee 3	Stone Arrangement: -
10	B14	Artefact:
11	BR13	Artefact:
12	BR12	Artefact:
13	B11	Artefact:
14	BR10	Artefact:
15	B9, Bushells Ridge	Artefact: 2
16	B;1	Artefact :
17	B8, Bushells Ridge	Artefact: 1
18	B4, Bushells Ridge	Artefact: 1
19	B3, Bushells Ridge	Artefact: 1
20	B7	Artefact: 1
21	B5, Bushells Ridge	Artefact: 2
22	B2	Modified Tree (Carved or Scarred)
23	PAD 3 - Munmorah	Potential Archaeological Deposit (PAD)

Therefore, the location of Aboriginal heritage sites shown in **Figure 3** will need to be considered in the assessment of potential flood modification options in order to minimise potential for disturbance at aboriginal heritage sites and prevent damage to heritage items.

There are also several parcels within the catchment that are the subject of Aboriginal land claims. The location of these parcels is also included in **Figure 3**. Consent of the Local and NSW Aboriginal Land Councils would be required for any proposed work on land subject to Aboriginal land claims.

2.5 Demographics

Understanding 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 the internet, the primary language spoken at home and the availability of a motor vehicle can have a strong bearing on the feasibility of different education, flood warning and evacuation strategies.

In this regard, the Australian Bureau of Statistics (ABS) provides a range of information for the Wallarah Creek catchment 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 6**. Also included in **Table 6** are the associated information for the state of NSW, for comparison purposes.

The information presented in **Table 6** shows that:

- The majority of residential properties in the catchment are "standalone" houses.
- The majority (i.e. >85%) of households only speak English at home. This is significantly higher than the state average of 69%.
- More than 80% of households have an internet connection.
- The median age of residents within the study area is around 33-38.
- Less than 29% of the population rents their place of residence. That is, just under 30% of the population may be considered transient and, therefore, have a lower level of flood awareness.
- Nevertheless, more than 50% of residents have resided at the same address for at least 5 years, which would likely indicate that more than half of the population would have been in the area during the 2015 flood (discussed in more detail in the following section). Although the 2015 flood was not a particularly severe event it may indicate a proportion of the population has at least some awareness of the potential for flooding.
- More than 90% of households have at least 1 motor vehicle.
- Approximately 20% of the population would be considered less mobile and, therefore, more susceptible to the impacts of flooding (e.g., the elderly or children under the age of 15).

Table 6 Summary of Demographics for the Wallarah Creek Catchment

Statistic[#]			Blue Haven	Charmhaven	Wallarah	NSW
Population Statistics	Age	Median Age	33	37	38	38
		<15 years of age	24.6%	20.5%	21.7%	18.5%
		>65 years of age	13.0%	16.5%	15.1%	16.3%
		Proportion of population that volunteers	12.1%	14.1%	11.4%	18.1%
	Education	Year 12 or equivalent	13.1%	11.5%	12.0%	53.9%
		Year 10 or equivalent	20.5%	21.2%	16.8%	26.2%
		Did not Complete Year 10	12.2%	11.0%	11.7%	11.1%
Dwelling Statistics	Motor Vehicle	Dwellings with no vehicles	3.2%	5.6%	0.0%	9.2%
		Dwellings with ≥ 1 vehicle	93.0%	91.4%	91.0%	87.1%
		Average persons per dwelling	2.9	2.7	3.3	2.6
	The language is spoken at home	Speaks English only	91.4%	90.4%	85.7%	68.5%
		Other	Spanish 0.5%	Thai 0.4%	Arabic 2.8%	Mandarin 3.2%
			Italian 0.5%	Tongan 0.4%	Italian 1.7%	Arabic 2.7%
			Maltese 0.3%	Japanese 0.3%	Greek 0.8%	Cantonese 1.9%
		Proportion of renters	29.2%	28.7%	23.5%	31.8%
	Same address	As one year ago	79.5%	76.8%	75.1%	77.4%
		As five years ago	54.0%	54.2%	59.4%	53.8%
	Dwelling Type	Separate house	98.2%	94.0%	91.8%	66.4%
		Semi-detached, row or terrace house, townhouse	1.5%	6.0%	8.2%	12.2%
		Flat, unit or apartment:	0.1%	0.0%	0.0%	19.9%
		Other dwelling (cabin, caravan):	0.1%	0.0%	0.0%	0.9%
Income		Median total household income ($/weekly)	$1,331	$1,194	$1,562	$1486
		Median Rent ($/weekly)	$370	$340	$510	$380
Internet Statistics		No Internet connection	14%	16.1%	14.6%	14.7%
		Access to Internet connection	83.5%	81.0%	81.6%	82.5%
		Not Stated	2.6%	2.9%	3.9%	2.8%

2.6 Community Consultation

2.6.1 Overview

Community consultation is an important component of the floodplain risk management study based on the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005).* Central Coast Council also recognises that the community is an important part in the development of the floodplain risk management study and plan for the Wallarah Creek catchment. Therefore, the community was consulted throughout the preparation of the flood study as well as the floodplain risk management study.

Consultation with the community aimed to satisfy the following objectives:

- Inform the community about the development of the study and its potential outcomes;
- Identify community concerns and attitudes;
- Collect information from the community including their flood experience; and
- Develop and maintain community confidence in the study results.

Outcomes of the community consultation are summarised below.

2.6.2 Flood Study

A community information brochure and questionnaire were prepared and distributed to over 900 households and businesses. 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 90 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 likely experienced the 2007 flood.
    - Approximately 63% of respondents have experienced some form of disruption as a result of flooding in the study area. This includes:
    - 16 respondents have experienced traffic disruptions;
    - 29 respondents have had their front or back yard inundated;
    - 11 respondents have had their garage inundated; and,
    - 1 respondent has had their house inundated.
    - The following streets/areas were identified by several respondents as being particularly susceptible to flooding problems:
    - Birdwood Drive, Blue Haven;
    - Turner Close, Blue Haven;
    - Allambee Crescent, Blue Haven; and
    - Costa Avenue/Brava Avenue, San Remo.
- 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:
    - Upstream development/increase in impervious surfaces;
    - Lack of routine maintenance/blockage of stormwater pipes and culverts;
    - Inadequate stormwater system; and
    - Lack of kerb and gutter.

A number of respondents provided photos of past flood events. A selection of these photographs is provided in **Plates 3** to **5**.

Plate 3 Inundation Across the Back Yard of 20 Turner Close, Blue Haven

Plate 4 April 2015 Flood Showing Water Extending Across Birdwood Drive (near Penguin Road) at Blue Haven

Plate 5 Floodwaters Extending Across Allambee Crescent, Blue Haven During April 2015 Event

The photos generally show water extending across a number of roadways as well as front and back yards. The photos also show inundation occurring as a result of Spring Creek and Wallarah Creek overtopping their banks (**Plates 3** and **4**) as well as from local stormwater runoff (**Plate 5**). The findings of the *'Wallarah Creek Catchment Flood Study'* (CSS, 2016) indicate that the April 2015 rainfall event, as shown in **Plates 4** and **5**, was approximately equal to a 20% AEP design rainfall event.

2.6.3 Floodplain Risk Management Study

Questionnaire

Consultation with the community has also been undertaken at various stages throughout the preparation of the floodplain risk management study. A questionnaire was distributed to over 2,900 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 total of 182 questionnaire responses were received. A copy of the questionnaire is included in **Appendix A**.

Detailed responses to the questionnaire are included in **Appendix A** as **Tables A1** to **A4**. Key outcomes are provided below:

- Flood Impacts (refer to **Table A1** in **Appendix A**):
    - 67% of the questionnaire respondents had not been experienced previous floods in this area.

  - 31% 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 flooding of garages/sheds followed by lost access due to flooding of roads. Five respondents reported above floor inundation of their house.
- Flood Awareness (refer to **Table A1** in **Appendix A**):
  - 13% of respondents acknowledged that their home or business could be flooded.
  - 51% of respondents did not know whether their property could be potentially flooded or not.
  - 36% of respondents claimed that their property could not be flooded. However, 17% of these properties are located within the Probable Maximum Flood (PMF) extent. When combined with the 51% of respondents who don't know whether their property could be flooded, it highlights a relatively low level of flood awareness and the need for community education.
- Evacuation (refer to **Table A2** in **Appendix A**):
  - During a future flood, the majority of residents would seek information on the radio or television. Only 2 respondents would search for information online only and 6% of respondents did not know where to search for flooding information. This also indicates that education may be beneficial to help ensure the wider community can act proactively during future floods.
  - During a future flood, 49% of respondents said that they would remain at home. Only 25% said they would evacuate to an official evacuation centre (refer to **Figure A2** in **Appendix A**). The primary reason for people choosing to stay at home was a concern for the security of their property should they evacuate. Moreover, some of the residents believe that their house cannot be flooded, or they can cope with isolation. The need to care for animals, discomfort, inconvenience and cost of evacuating are also cited as reasons for staying at home.
- 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 (refer to **Table A3** in **Appendix A**):
    - Provides safety to the community during floods
    - Reduced flood damages to the community
    - Raises community awareness and understanding of the local flood risk
    - Does not result in negative flood impacts to other areas
    - Does not disadvantage individual members of the community
  - The following potential flood risk management options were the most favoured by the community (refer to **Table A4** in **Appendix A**):
    - Stormwater upgrades
    - Flood forecasting/warning system
    - Regular maintenance and clearing of the creeks
    - SES local flood plan updates

  - Culvert/bridge upgrades
  - Community education
  - Enlarging channels
- The following potential flood risk management options were the least favoured by the community (refer **Table A4** in **Appendix A**):
  - Voluntary house purchase
  - Levees
  - Voluntary house flood proofing

Public Exhibition

The draft 'Wallarah Creek Catchment Floodplain Risk Management Study & Plan' was placed on public exhibition from 25 June 2020 until 5 August 2020. Due to the COVID-19 situation, it was not possible to complete the public exhibition in a traditional manner (e.g., face-to-face community information sessions). Instead, the following mechanisms were employed to allow the community to review the draft report, ask questions and provide comments on the draft report in a safe manner:

- A Your Voice Our Coast website was established for the exhibition period. The website included the following features:
  - A digital copy of the draft report
  - Frequent-asked-questions and answers
  - Interactive map showing flooding "problem spots" and locations where flood risk mitigation measures are recommended
  - Contact details to allow community members to ask questions and speak directly to Council staff (either via email or telephone)
- For those without internet/computer access, a "hard copy" of the report was available for viewing at the Lake Haven Library
- Virtual meetings could be booked by the community which would allow them to speak one-on-one with a representative from Catchment Simulation Solutions and Council.

The Your Voice Our Coast website was visited on 571 occasions during the exhibition period. There were 3 questions posted to the online question and answer board and 19 phone calls and virtual meetings were also completed.

A total of three submissions were received during the exhibition period. The following themes were observed in the submissions:

- insufficient drainage infrastructure to deal with frequent rainfall events
- the lack of kerb and guttering can result in a more frequent inundation of front yards
- king tides exacerbate the flooding problem across areas adjoining Spring and Wallarah Creeks
- dredging The Entrance channel and Tuggerah Lakes should be considered as a flood risk management option.

A summary of the submissions that were received is provided in **Appendix H**. Also included in **Appendix H** are the actions that were taken to address each submission when preparing the final report.

3 DEFINING THE EXISTING FLOOD RISK

3.1 Overview

In order to identify and evaluate potential options for managing the flood risk, it is necessary to identify 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 (PMF). The former Wyong Shire Council commissioned the *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016) 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 Australian Rainfall & Runoff 2016 Assessment

Flood behaviour across the Central Coast Council LGA for the past three decades has been defined based on guidance contained in the 1987 version of *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (Engineers Australia) (in this report refer to as ARR1987). This included the '*'Wallarah Creek Flood Study'* (Catchment Simulation Solutions, 2016).

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (referred to herein as ARR2016). Therefore, for this study investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the catchment prior to undertaking any revised design flood simulation.

The outcomes of the assessment are presented in **Appendix B**. The assessment determined that application of ARR2016 hydrologic procedures to the Wallarah Creek catchment is predicted to reduce flood discharges across the vast majority of subcatchments during smaller design floods (e.g., 20% and 5% AEP events), and produce slightly higher discharges and flood levels for larger floods (e.g., 1% AEP event). Therefore, the potential impacts of adopting ARR2016 over ARR1987 (and vice versa) are dependent on the size of the flood under consideration.

Application of ARR2016 does require additional work effort to implement and the difference in design flows and flood levels were typically minimal relative to ARR1987. Therefore, ARR1987 was retained for application as part of the current study and forms the basis for the existing flood assessment presented in the following sections.

3.2.2 TUFLOW Model Updates

The former Wyong Shire Council commissioned the *'Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016) to describe existing flood behaviour. The flood study utilised an XP-RAFTS hydrologic model to define the rainfall-runoff process and a TUFLOW hydraulic model to define key flood characteristics such as floodwater depths and velocities.

The models developed as part of the flood study are still considered to be the best available tools for defining existing flood behaviour across the Wallarah Creek catchment. However, as noted in Section 2.3.1, the work-as-executed survey was provided for a part section of Blue Haven that provides an improved description of the stormwater drainage system. Accordingly, the TUFLOW model was updated to reflect this new survey information.

The updated TUFLOW model was used to re-simulate the design 20% AEP, 5% AEP and 1% AEP floods as well as the PMF. The outputs from the TUFLOW model were used to prepare a range of flood maps, which are described in more detail in the following sections.

3.2.3 Floodwater Depths and Velocities

Peak floodwater depths were extracted from the results of the 20% AEP, 5% AEP, 1% AEP and PMF simulations and are presented in **Figures 4** to **7**. Flow velocities were also extracted and are presented in **Figures 8** to **11**. Also included in **Figures 4** to **7** are the corresponding water levels at the Wallarah Creek bridge gauge (relative to mAHD) for each AEP.

It should be noted that the "raw" TUFLOW model results were filtered to only display areas where there is a significant flood risk/hazard. To ensure consistency with other studies being completed across the Central Coast LGA, only those areas subject to an inundation depth of at least 0.15 metres are displayed in the flood mapping.

The results of the design flood modelling show that:

- Floodwaters are largely contained in close proximity to the main watercourses across the largely undeveloped upper sections of the catchment.
- The most significant flooding impacts are predicted across low lying land adjoining Spring Creek and Wallarah Creek. This includes properties located in the following areas:
    - Turner Close, Blue Haven
    - Birdwood Drive, Blue Haven
    - Allambee Crescent, Blue Haven
    - Costa Avenue, San Remo
    - Woods Avenue, Sam Remo
    - Brava Avenue, Sam Remo
- Flooding across the more elevated sections of Blue Haven and San Remo is typically contained to roadways and drainage reserves. Nevertheless, overland flooding is predicted across some properties. In most cases, the maximum inundation depths during the 1% AEP flood are less than 0.3 metres.

- Although inundation across most of the urban areas is shallow, some areas (most notably roadways) are predicted to be exposed to velocities of more than 2 m/s. This is sufficient to cause a significant hazard to cars as well as people regardless of the depth of water (flood hazard categories are discussed further in Section 3.2.6).

3.2.4 Design Rainfall Depths and Gauge Heights

Design rainfall depths for the Wallarah Creek catchment 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 *'Wallarah Creek Catchment Flood Study'* indicate that rainfall over a 1.5 to 2 hour periods typically produced the worst case flooding across the urban sections of the catchment (highlighted in yellow in **Table 7**). Across mainstream areas (e.g., Wallarah Creek and Spring Creek), rainfall over a 6 to 9 hour period generally produced the most significant flooding (highlighted in orange in **Table 7**).

Table 7 Design Rainfall Intensities

DURATION	Rainfall Depth (mm)			
	20% AEP	5% AEP	1% AEP	PMP
10 mins	18.3	23.8	31.0	N/A
20 mins	26.8	35.0	45.7	N/A
30 mins	32.8	42.9	56.0	200
1 hour	45.1	59.1	77.6	310
1.5 hours	53.7	70.7	93.0	390
2 hours	60.8	80.0	105	460
3 hours	72.3	95.4	126	549
4.5 hours	86.0	113	150	N/A
6 hours	96.6	128	170	738
9 hours	115	152	202	N/A
12 hours	130	172	228	N/A
24 hours	171	228	305	N/A
48 hours	218	293	393	N/A
72 hours	246	332	446	N/A

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

Peak design flood levels at the Wallarah Creek Bridge gauge were also extracted from the results of the flood modelling and are provided in **Table 8**. However, it should be noted that the Wallarah Bridge gauge is influenced by the prevailing water level in Budgewoi Lake at the time of the flood. Furthermore, due to the differing flooding mechanisms across urban versus mainstream areas, flooding may be experienced across the urban and areas and not along Wallarah Creek (and vice versa).

Table 8 Wallarah Creek Gauge Levels for each design flood

Design Flood	Level at Wallarah Creek Bridge Gauge (mAHD)
20% AEP	0.95
5% AEP	1.19
1% AEP	1.42
PMF	2.95

The rainfall information in **Table 7** can be potentially combined with the design water levels in **Table 8** and the road/property impacts information provided in **Appendix F** and **G** to assist with emergency response planning (e.g., determining what rainfall depths may "trigger" the need to evacuate certain areas).

3.2.5 Performance of Stormwater System

The TUFLOW modelling completed as part of the *'Wallarah Creek Catchment Flood Study'* (CSS, 2016) 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 catchment.

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 20% AEP event and 100% full during the 5% AEP event, the pipe capacity would be defined as "20% 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 12**. As shown in **Figure 12**, 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 12** shows that a significant number of pipes in Blue Haven and San Remo typically has a capacity of less than the 20% AEP (i.e., 1 in 5-year ARI). Accordingly, overland flooding is predicted to occur relatively frequently.

The capacity mapping also indicates that it is lack of pipe capacity rather than lack of pit capacity that is the major limitation in the drainage system (i.e., the pipes are predicted to fail before the pits). However, it also shows that a number of pits are predicted to surcharge during relatively frequent events (frequently as the 20% AEP flood). In such instances, these pits may be increasing the flooding problem by releasing water from the drainage system rather than removing it from the local area. Again, it appears that the surcharging pits are a result of a lack of downstream pipe capacity (i.e., the water that cannot be accommodated within the pipes, begins to “spill” out of the pipe system via the stormwater pits). Areas with pits that are predicted to surcharge in frequent events include:

- Pinehurst Way/near to the ADA intersection;
- Colorado Drive;
- Dunlop Road;
- Scribbly Gum Close;
- Menindee Avenue;
- Birdwood Drive at different locations;

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 (a 20% blockage factor was adopted for on grade pits and 50% blockage was adopted for sag pits). 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 catchment.

3.2.6 Flood Hazard Categories

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

It is noted that flood precinct definitions specified by Council within the *Wyong Development Control Plan 2013* (Wyong DCP 2013) 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) (NSW Government, 2005). However, for this study, the variation in flood hazard across the catchment was defined using flood hazard vulnerability curves presented in the *Australian Disaster Resilience Handbook Collection Guideline 7-3 Flood Hazard* (AIDR, 2017). This approach was selected over the hazard categorisation defined in the FDM (2005) as it is believed to represent the latest approach to flood hazard definition and provides a better correlation between risk to life and flood hazard. The hazard curves are reproduced in **Plate 6** and are also described in **Table 9**.

Table 9 Description of Adopted Flood Hazard Categories (AIDR, 2017)

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

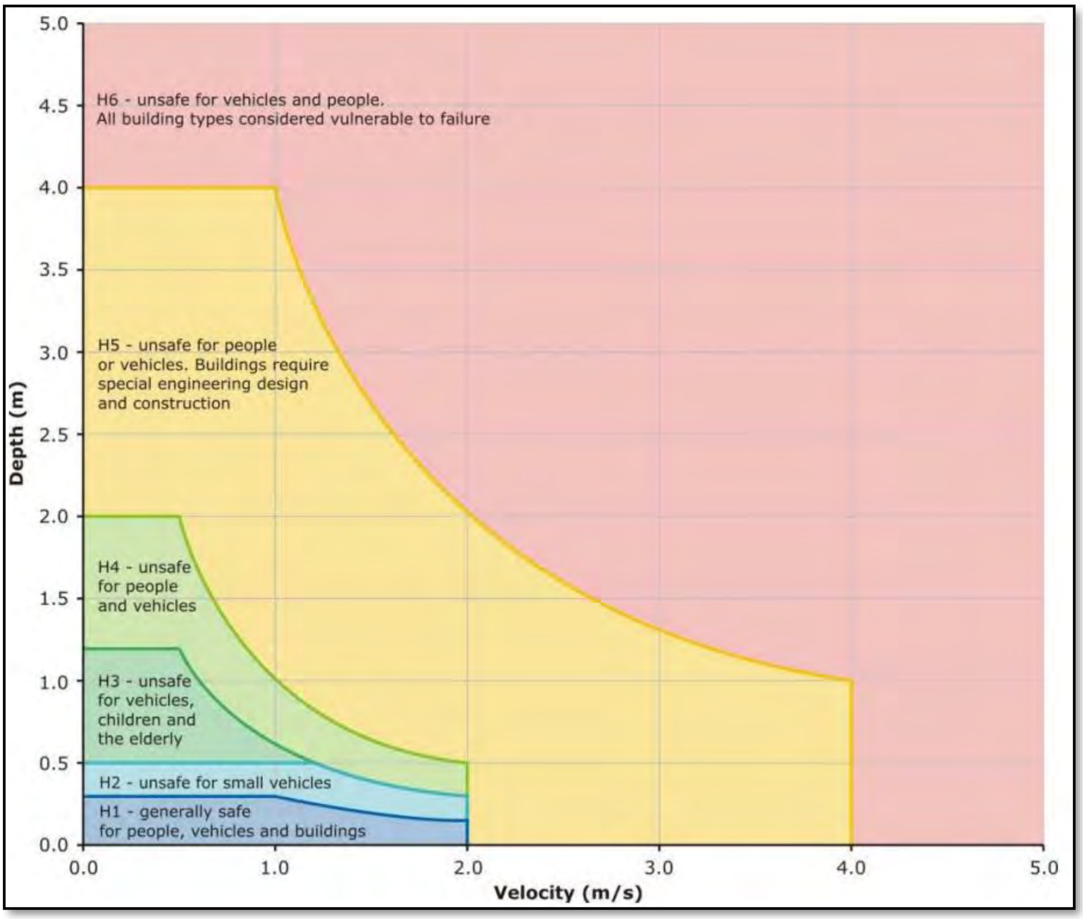


Plate 6 Flood Hazard Vulnerability Curves (AIDR, 2017)

As shown in **Plate 6**, the hazard curves assess the potential vulnerability of people, cars and structures based upon the depth and velocity of floodwaters at a particular location. Peak depth, velocity and velocity-depth product outputs generated by the TUFLOW model were used to map the variation in flood hazard across the Wallarah Creek catchment based on the hazard criteria shown in **Plate 6** for the 1% AEP flood as well as the PMF. The resulting hazard category maps are shown in **Figures 13** and **14**.

Figure 13 indicates that during the 1% AEP flood, the hazard across most urban areas is predicted to be contained within the H1 category, which indicates that the water would not present a significant hazard to people or vehicles. Nevertheless, there are some localised areas (most notably roadways) where the hazard is predicted to exceed H3. This would be hazardous to vehicles and potentially also for people. In general, H5 and H6 areas are restricted to the main watercourses.

Figure 14 shows that during the PMF, more extensive areas of H5 and H6 are predicted. This includes some residential areas fronting Birdwood Close and Turner Close. This hazard category indicates that there is potential for structural failure of buildings in these areas should a flood of PMF magnitude occur. Many more roadways would also experience hazards of H3 or above including the Pacific Highway which would be exposed to H5 conditions.

3.2.7 Hydraulic Categories

The *'Floodplain Development Manual'* also subdivides flood prone land into one of three hydraulic categories, which are summarised in **Table 10**. The hydraulic categories define areas that are important for the conveyance and storage of floodwaters and, at the same time, highlight areas where development (e.g., filling) has the potential to adversely impact on flood behaviour.

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, quantitative criteria were developed as part of the *'Wallarah Creek Catchment Flood Study'* and are reproduced in **Table 10**. These criteria were retained as part of the current study and the resulting hydraulic category maps for the 1% AEP and PMF events are shown in **Figure 15** and **16**.

Figure 15 shows that during the 1% AEP flood, floodways are typically contained within close proximity to defined waterways. Nevertheless, there are some roadways that would function as floodways at the peak of the 1% AEP flood (most notably Pinehurst Drive, Blue Haven).

Figure 16 shows that during the PMF floodways are predicted to cover a much larger area. This includes residential areas fronting Spring and Wallarah Creeks (e.g., Turner Close, Birdwood Drive, Blue Haven). Many more roadways across Blue Haven and San Remo would also function as floodways at the peak of the PMF.

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 flowchart shown in **Plate 7** (AIDR, 2017). 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 is useful in emergency response planning.

Table 10 Qualitative and Quantitative Criteria for Hydraulic Categories

Hydraulic Category	Definition	Adopted Criteria*
Floodway	those areas where a significant volume of water flows during floods often aligned with obvious natural channels and drainage depressions they are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flowpaths resulting in the development of new flowpaths. they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	Area where 80% of the total flow is conveyed
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 metres

Each allotment within the Wallarah Creek catchment 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 17** and **18**. 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 3.3.3.

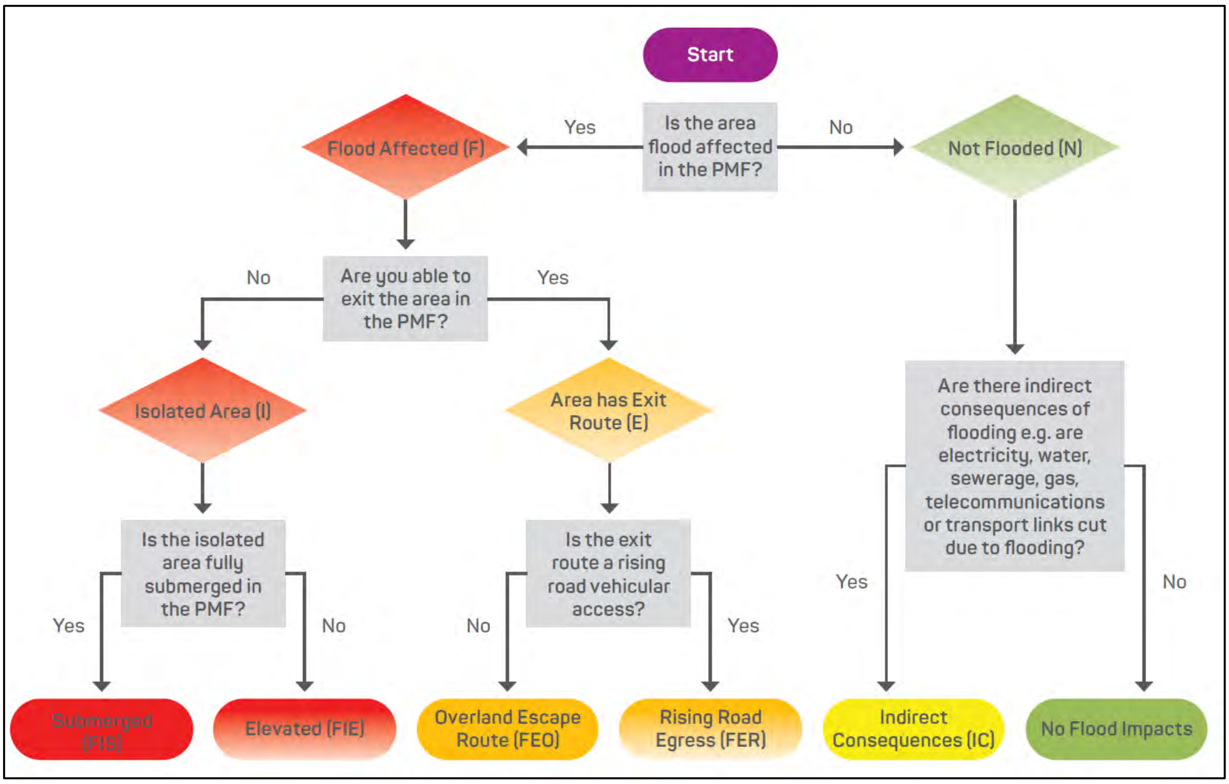


Plate 7 Flow Chart for Determining Flood Emergency Response Classifications (AIDR, 2017).

Figure 17 shows that during the 1% AEP flood, the most common ERP classification is "Rising Road Egress", which indicates that an evacuation route grade up and out of the floodwaters is available. However, there are some "flooded isolated submerged" areas (i.e., low flood islands), which indicates that evacuation routes are likely to be cut before inundation of the property itself. This includes sections of Birdwood Drive and Turner Close.

Figure 18 shows that during the PMF, the number of "flooded isolated submerged" areas increase, particularly for areas adjoining Spring and Wallarah Creeks. Accordingly, if a particularly large flood was to occur, there is potential for a significant number of lots to become isolated, which can be very dangerous if people become trapped and floodwaters rise to inundate their floors or threaten building structures.

3.3 Impacts of Flooding

3.3.1 Key Infrastructure

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

Critical and vulnerable facilities located within the Wallarah Creek catchment are summarised in **Table 11** and a more detailed discussion is provided below.

Table 11 Impact of Flooding on Key Infrastructure

Key Infrastructure		Inundated During 20% AEP Flood?	Inundated During 5% AEP Flood	Inundated During 1% AEP Flood	Inundated During PMF
Fire Stations	*NSW Rural Fire Service – The Lakes Fire Control Centre* (105 Arizona Rd, Charmhaven)				
	Doyalson Fire Station (Pacific Highway, Doyalson)				
Police Stations		There are no police stations located within the catchment			
State Emergency Service		There are no SES buildings located within the catchment			
Ambulance Stations		There are no ambulance stations located within the catchment			
Hospitals		There are no hospitals located within the catchment			
Aged Care Facilities		There are no aged care facilities located within the catchment			
Schools	*Blue Haven Public School* (Colorado Drive, Blue Haven)				☑
	Northlakes Public School (Goorama Avenue, San Remo)				
	Northlakes High School (Goorama Avenue, San Remo)	☑	☑	☑	☑

Key infrastructure and vulnerable facilities located within the catchment includes:

- **Fire Stations**: There are two fire stations located within the catchment;
  - **NSW Rural Fire Service – The Lakes Fire Control Centre** (105 Arizona Rd, Charmhaven): This fire control centre is generally located on elevated land and is not predicted to be inundated during any of the simulated design floods. However, access along Arizona Road may be cut at the peak of the PMF.
  - **Doyalson Fire Station** (Pacific Highway, Doyalson): the fire station is located close to the catchment boundary and is not predicted to be inundated during any design flood up to and including the PMF.
- **Police Stations**: There are no police stations located within the catchment;
- **State Emergency Service**: There are no SES buildings located within the catchment;
- **Ambulance Stations**: There are no ambulance stations located within the catchment;
- **Hospitals**: There are no hospitals located within the catchment;
- **Aged Care Facilities:** There are no aged care facilities located within the catchment;
- **Schools**: There are three schools located within the catchment:
  - **Blue Haven Public School** (Colorado Drive, Blue Haven): Some minor inundation is predicted at the peak of the 1% AEP event. However, this is generally located away

from buildings and infrastructure. However, school buildings are predicted to be inundated during the PMF.

- **Northlakes Public School** (Goorama Avenue, San Remo): This school is located close to the catchment boundary. Accordingly, no inundation of the school is predicted during any of the simulated design floods. However, access along Goorama Avenue may be cut during the 1% AEP flood and PMF.
- **Northlakes High School** (Goorama Avenue, San Remo): Some inundation of the Northlakes High School is predicted during all design floods up to and including the PMF. However, the inundation is generally restricted across sporting field located at the southern end of the school. Access along Goorama Avenue may be cut during the 1% AEP flood and PMF.

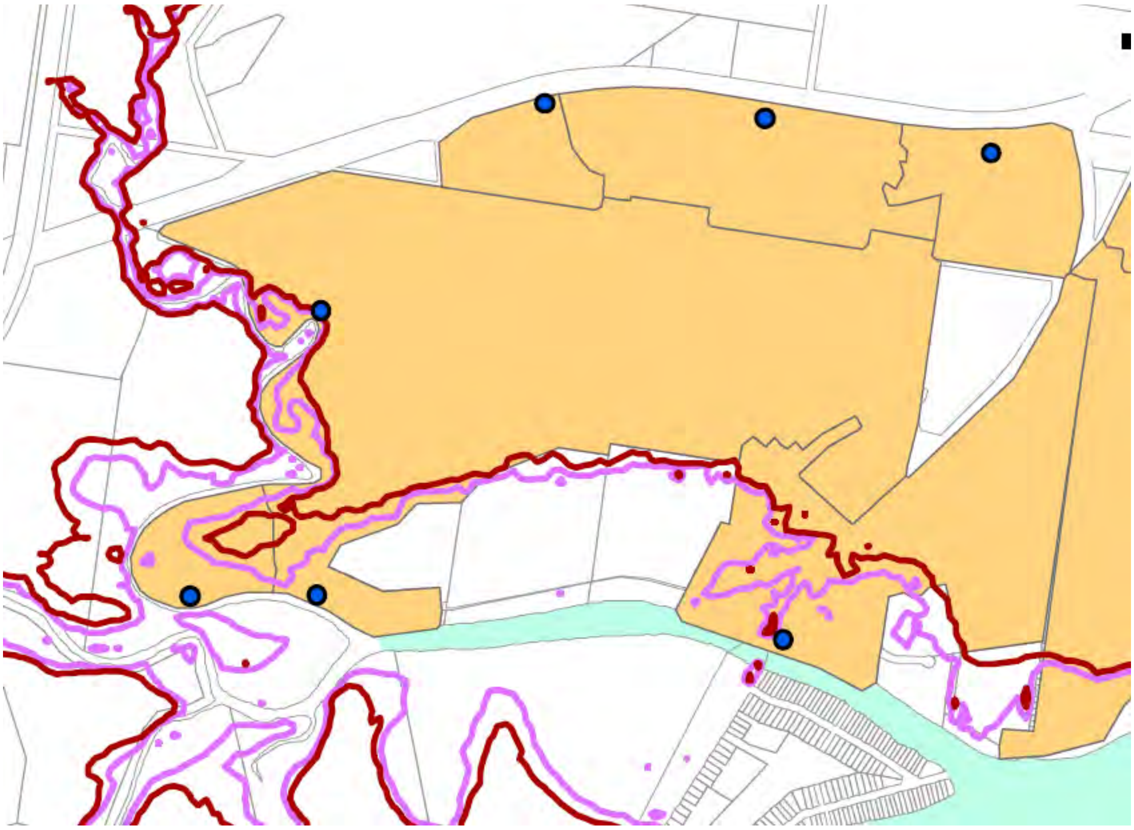
No official evacuation centres are currently nominated for the catchment to service residents of Blue Haven who may need to evacuate and have no local family or friends to stay with. Blue Haven Public School or the Blue Haven Seventh Day Adventist Church may be suitable in this regard as they are centrally located and not impacted in floods up to and including the PMF.

3.3.2 Impacts on Sewerage System

The *'Tuggerah Lakes Floodplain Risk Management Study'* (WMAwater, 2014) notes that areas adjoining Tuggerah Lakes (including the lower reaches of the Wallarah Creek catchment) can be impacted by sewer overflows. Sewer overflows can occur when floodwaters enter the sewerage system at "gully" points resulting in the capacity of the system being exceeded. This can result in floodwaters being contaminated with sewage that cannot be accommodated in the sewage system.

Although the sewage is often diluted by the floodwaters, the presence of raw sewerage in floodwaters still presents a significant health issue. Furthermore, the sewage system is often "turned off" during floods in particularly vulnerable areas to reduce the potential for sewer overflow. This does mean that multiple properties would not be serviced by an active sewerage system should they choose to remain at home during floods.

There are 7 sewer pumping stations located in the Wallarah Creek catchment



3.3.3 Transportation Impacts

There are a number of roadways across Wallarah Creek catchment 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.

An assessment of the location where roadways are first predicted to be overtopped was completed as part of the Flood Emergency Response Precinct classifications discussed in Section 3.2.8. The locations where roads are first overtopped were established by comparing peak design water levels against road centreline elevations. The locations where roadways are predicted to be first cut by floodwater during the 1% AEP and PMF events are shown as yellow dots in **Figure 17** and **Figure 18,** respectively. Also included on **Figure 17** and **Figure 18** are labels for each roadway overtopping location that provides the following information:

- The time at which each roadway is first inundated relative to the start of rainfall (red label); and,
- The duration of inundation (green label).

A summary of the predicted impacts of flooding on key roadways contained within the catchment is discussed below. A complete list of roadway inundation information is also included in **Appendix F**.

- ***Pacific Motorway:*** Pacific Motorway is predicted to be inundated from Wallarah Creek overtopping during the 1% AEP and PMF events. This ranges from 0.1 m during the 1% AEP flood to more than 1 m during the PMF. Inundation is predicted to first occur about

15 minutes after the onset of rainfall during the 1% AEP flood. During the PMF, overtopping and inundation would first occur after about 5 minutes. The Pacific Motorway would be cut for about 75 minutes during the PMF. Therefore, this section of the motorway would likely remain trafficable during the 1% AEP, but access would be cut during the PMF event.

- ***Doyalson Link Road:*** Doyalson Link Road is predicted to stay flood free during both the 1% AEP and PMF events. It is just predicted to be inundated during the PMF for five minutes. Depths of inundation are predicted to be less than 0.2 m during the PMF. Therefore, Doyalson Link Road would likely remain trafficable during the both 1% AEP and PMF events.
- ***Pacific Highway:*** Pacific Highway is predicted to be inundated from Wallarah Creek overtopping during both 1% AEP and PMF events. Depths of inundation are predicted to range from 0.2 m during the 1% AEP event to more than 1 m during the PMF. Inundation is predicted to occur about 65 minutes after the onset of rainfall during the 1% AEP flood. During the PMF, inundation would first occur after about 15 minutes, and the highway would be cut for about 65 minutes. Accordingly, while the highway might possibly remain trafficable during the 1% AEP, access to this section of the highway would be cut in rarer floods.
- ***Birdwood Drive:*** Birdwood Drive is predicted to be inundated during both 1% AEP and PMF events. Depths of inundation are predicted to range from 0.5 m to more than 1 m during the 1% AEP event and to more than 3 m during the PMF. Inundation is predicted to occur about 10 minutes after the onset of rainfall during the 1% AEP flood. During the PMF, inundation would first occur after about 5 minutes, and last for about 75 minutes. For these design events, Birdwood Drive would be cut in both the 1% AEP and PMF events.
- ***Turner Close:*** Turner Close is predicted to be inundated during both 1% AEP and PMF events. Depths of inundation are predicted to range from 0.2 m to about 1 m during the 1% AEP event and to more than 3 m during the PMF. Inundation is predicted to occur about 25 minutes after the onset of rainfall during the 1% AEP flood, and after about 5 minutes during the PMF. Turner Close would be cut for about 75 minutes during the PMF. For these design events, Turner Close would be cut in both the 1% AEP and PMF events.
- ***Brava Avenue:*** Brava Avenue is predicted to be inundated during the PMF event. Depths across Brava Avenue are predicted to exceed 1 m, inundation would first occur about 5 minutes after the onset of rainfall, and the road would be cut for about 75 minutes.
- ***Costa Avenue:*** Costa Avenue is predicted to be inundated during the PMF event. Depths across Costa Avenue are predicted to exceed 1 m, inundation would first occur about 5 minutes after the onset of rainfall, and the road would be cut for about 60 minutes.

It should be noted that the roadway inundation information is based on “design” flood information, with single temporal patterns. No two floods are the same and future floods will likely exhibit different characteristics. Nevertheless, the information provides a good indication of the relative susceptibility of transportation links in different parts of the study area to inundate and can assist emergency services in evacuation planning. It should be also noted that under no circumstances should vehicles attempt to drive through floodwaters regardless of the floodwater depth or the type of vehicle they are driving.

3.3.4 The Cost of Flooding

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

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

- Residential properties;
- Commercial properties;
- Industrial properties; and
- Infrastructure.

As part of the damage cost calculations, the number of properties predicted to be subject to inundation (and therefore incur flood damages) as well as the number of buildings predicted to be subject to above floor inundation (and therefore incur more significant flood damages) were determined and are summarised in **Table 12**. During the 1% AEP event, 123 properties are predicted to suffer inundation, 46 of which to above floor inundation. During the PMF, 614 properties are predicted to experience inundation, 539 of which to above floor inundation.

The frequency of above floor flooding (i.e., the design event at which above floor flooding was first predicted to occur) was also mapped and is shown in **Figure 19**.

The frequency of above floor flooding (i.e., the design event at which above floor flooding was first predicted to occur) was also mapped and is shown in **Figure 19**. Additional information on property impacts during each design flood is provided in **Appendix G**.

Table 12 Number of Properties Subject to Property Inundation and Above Floor Inundation

Flood Event	Number of Properties inundated or Subject to Above Floor Inundation					
	Residential		Commercial/Industrial		Total Number	
	Property Inundation	Above Floor Inundation	Property Inundation	Above Floor Inundation	Property Inundation	Above Floor Inundation
20% AEP	17	2	0	0	17	2
5% AEP	78	15	1	1	79	16
1% AEP	122	45	1	1	123	46
PMF	602	527	12	12	614	539

The final flood damage estimates for each design flood are summarised in **Table 13** for existing topographic, development and climate conditions. It indicates that if a 1% AEP flood was to occur, over $2 million worth of damage could be expected across Wallarah Creek catchment. Most of the damage would be incurred across residential properties. **Table 13** shows that damage to industrial properties is not predicted to occur until the PMF. **Table 13** also shows a significant increase in flood damage costs between the 1% AEP and PMF events.

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for the study area for existing conditions. 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 AAD for the Wallarah Creek catchment was determined to be **$371,000**. Accordingly, if the "status quo" was maintained, residents and business owners within the study area as well as infrastructure providers, such as Council, would likely be subject to flood damage costs of approximately **$371,000** per annum (on average).

Table 13 Summary of Flood Damage Costs for Existing Conditions

Flood Damage Component	Flood Damages (2018 dollars)			
	20% AEP	5% AEP	1% AEP	PMF
Residential	$87,508	$792,195	$1,981,262	$38,280,804
Commercial.	$0	$15,274	$20,612	$687,025
Industrial	$0	$0	$0	$2,548
Infrastructure	$13,126	$121,120	$300,281	$5,845,557
TOTAL	$100,634	$928,589	$2,302,155	$44,815,934

3.4 Impacts of Future Catchment Development

Although the Wallarah Creek catchment comprises some urban areas (most notably Blue Haven and San Remo), the majority of the catchment is currently undeveloped. However, the current LEP zoning would potentially permit significant sections of the catchment to be developed in the future. This future development has the potential to alter existing flood behaviour which may impact on the existing flood risk across the catchment. Accordingly, additional simulations were completed to quantify the potential impacts that future development may have on the results of the modelling.

Those areas that are currently undeveloped but are likely to be developed in the future (based upon current LEP zoning) were identified. This was completed by reviewing land use zoning information relative to contemporary aerial imagery. The extent of the land that was identified as having the potential for future urban development is shown on **Figure 20**.

As the future "make up" of these areas is not known, assumptions were made regarding the likely land use composition. This information, in turn, was used to calculate weighted average impervious and pervious "n" values for each land use that were used as the basis for updating the XP-RAFTS hydrologic model (refer **Table 14**).

The updated impervious and pervious "n" values were applied to an updated "future catchment development" version of the XP-RAFTS model. The updated model was used to re-simulate the 20% AEP and 1% AEP storms under potential future catchment development conditions. Peak discharges extracted from the results of the revised hydrologic assessment are presented in **Appendix D**. Peak 20% AEP and 1% AEP discharges for current catchment development conditions are also included in **Appendix D** for comparison.

Table 14 Adopted land use information for future development assessment

Future Land Use Zone	Zone Description	Impervious	Pervious "n"
IN1	General Industrial	95%	0.018
RU6	Transition	25%	0.045

The discharge comparison indicates that future catchment development is predicted to generate localised increases in peak design discharges. More specifically:

- 20% AEP Event: Discharges are predicted to increase by 52%;
- 1% AEP Event: Discharges are predicted to increase by 39%;

More significant increases (>200%) are predicted at some locations within the catchment. Accordingly, future development does have the potential to produce notable increases in current peak design discharges across the catchment.

To quantify the impact that the increases in design discharges are predicted to have on future flood behaviour, the hydrographs generated by the future catchment conditions XP-RAFTS model were subsequently applied to the TUFLOW model. It should be noted that only flood hydrology was modified and that no updates were completed to the terrain representation to reflect the potential future development (as the future land forms cannot be precisely defined at this point).

Flood level difference mapping was prepared to quantify the impact that future catchment development is predicted to have on "existing" design flood levels across the catchment. The difference mapping is presented in **Plate 8** and **Plate 9** for the 20% and 1% AEP events respectively.

Plate 8 indicates that during the 20% AEP flood, future development is generally predicted to generate increases in mainstream flood levels across most of the catchment. The flood level increases are most commonly between 0.05 and 0.15 metres. However, increases of up to 0.3 metres are predicted along Spring Creek upstream of Doyalson Link Road.

The flood level differences shown in **Plate 9** indicate that during the 1% AEP event flood level increases are typically in the order of 0.05 to 0.2 metres. Increases of more than 0.2 metres are predicted along Spring Creek upstream of Doyalson Link Road, as well as upstream of the Pacific Motorway.

The majority of the flood level increases are contained in close proximity to the main watercourses and are contained to land that is currently not developed. Nevertheless, across some of the more problematic flooding areas (e.g., Turner Close and Birdwood Drive), the flood level increases are predicted to be 0.05 to 0.1 metres.

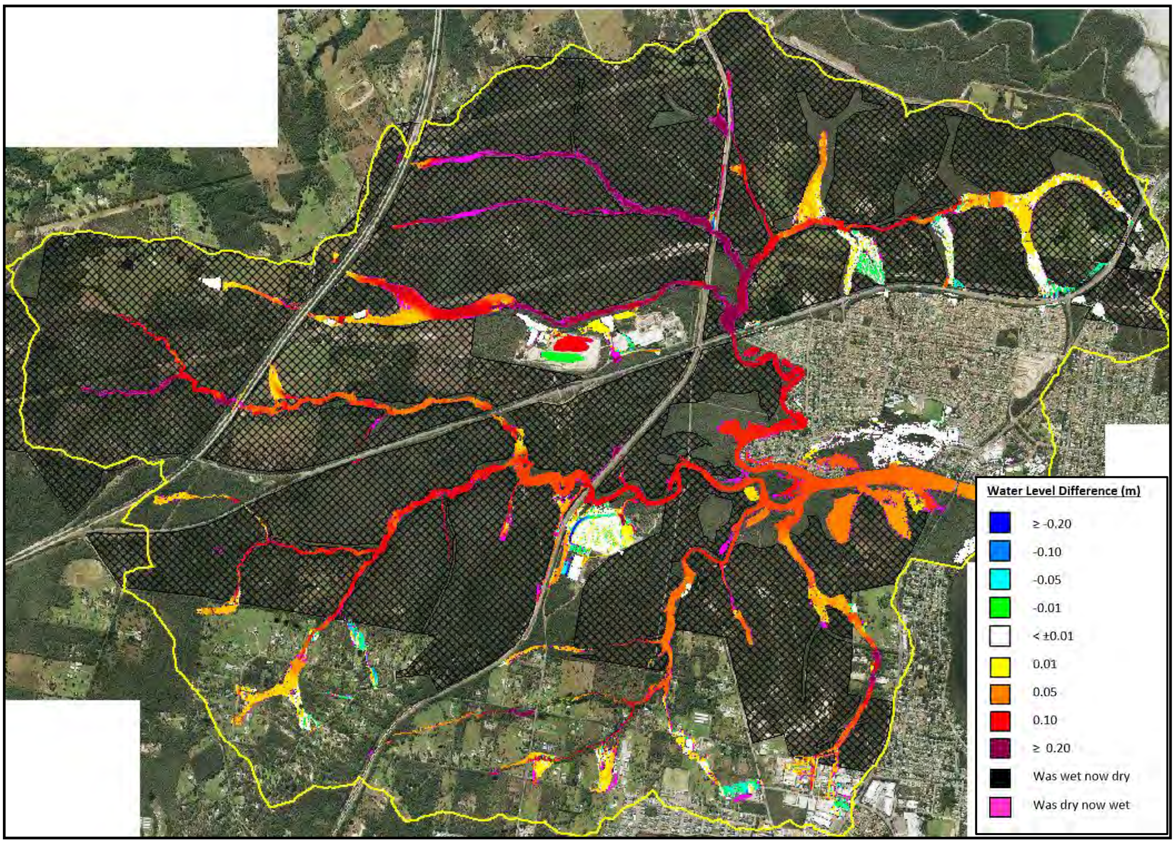


Plate 8 Flood Level Difference Map for the 20% AEP future catchment development scenario

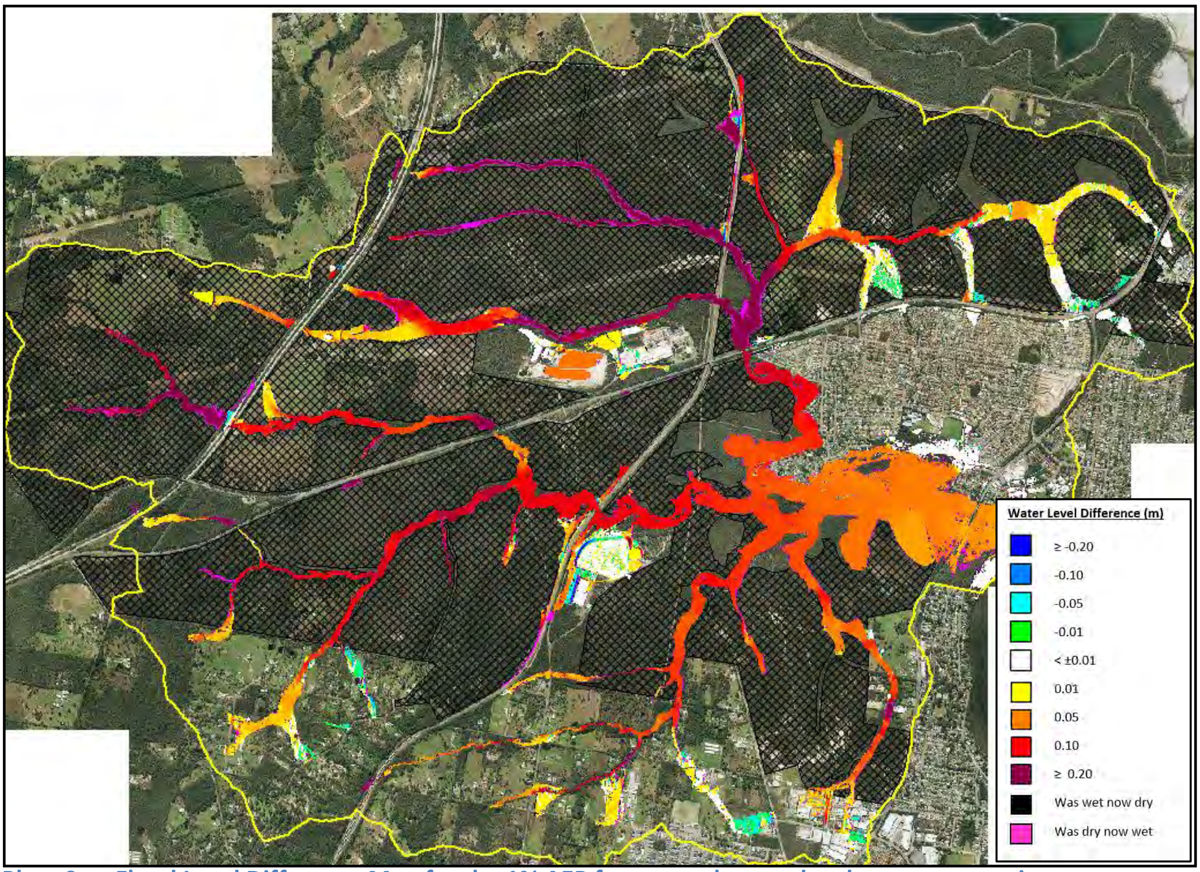


Plate 9 Flood Level Difference Map for the 1% AEP future catchment development scenario

A revised damage assessment was also completed to determine the impacts that potential future development may have on existing flood damage estimates. This determined that future catchment development has the potential to increase existing 20% AEP damages by $15,000 (a 40% increase over existing damages) and 1% AEP damages by around $500,000 (a 20% increase over existing damages).

A review of the revised flood damage estimates shows that a total of 45 buildings are predicted to be exposed to an increase in flood damage during the 1% AEP flood as a result of future catchment development. These properties are shown in **Plate 10**.

Plate 10 **Predicted increase in 1% AEP flood damages associated with future development**

As shown in **Plate 10**, the increase in flood damages tends to most significant along Birdwood Drive where many properties are predicted to experience flood damage increases of more the $10,000. Several properties in Turner Close are also predicted to be exposed to significant increases in flood damage costs.

Accordingly, future catchment development does have the potential to cause increases in flood discharges and levels at various locations across the catchment. This has the potential to increase the flood exposure and flood damage potential across some existing properties. Most of the adverse impacts are predicted along Birdwood Drive and Turner Close.

3.5 Impacts of Climate Change

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.

A climate change assessment was completed as part of the 'Wallarah Creek Flood Study' (CSS, 2016). This included an assessment of the impacts that 15% and 30% increases in 1% AEP rainfall intensities would have on flood behaviour across the catchment.

The outcomes of the assessment showed that a 15% increase in rainfall intensity has the potential to increase peak 1% AEP discharges by between 4% and 28%, with the average increase being 18%. A 30% increase in rainfall intensity has the potential to increase peak 1% AEP discharges by between 8% and 57% with the average increase being 39%. Accordingly, increases in rainfall intensities of between 15% and 30% do have the potential to significantly increase runoff and, consequently, peak discharges across the catchment.

The revised 1% AEP flows were also applied to the TUFLOW model to determine the impact that the rainfall increases may have on peak 1% AEP water levels. The results of the TUFLOW model simulations showed that a 15% increase in rainfall has the potential to increase 1% AEP flood levels by over 0.3 metres at some locations. The median increase in flood level is predicted to be 0.07 metres.

If 1% AEP rainfall intensities were to increase by 30%, it would potentially increase flood levels by over 0.5 metres at some locations (e.g., upstream of Pacific Motorway). The median increase in 1% AEP flood level is predicted to be 0.15 metres.

Accordingly, it can be concluded that if climate change was to increase rainfall intensities by 15% to 30%, it has the potential to significantly increase the severity of flooding across the catchment.

3.6 Summary of Flooding "Trouble Spots"

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

- Turner Close, Blue Haven
- Birdwood Drive, Blue Haven
- Pinehurst Way, Blue Haven
- Allambee Crescent, Blue Haven
- Costa Avenue, San Remo
- Woods Avenue, Sam Remo
- Brava Avenue, Sam Remo

The average annual flood damage cost is expected to be in the order of $370,00 per annum. Most of the flood damage cost is predicted to be incurred across residential properties.

Future development has the potential to increase the existing flood discharges and flood risk within the Wallarah Creek catchment. This is predicted to result in an increase in flood damages along Birdwood Drive and Turner Close by more the $10,000 for some properties.

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 2016 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 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 buildings of Classes 1, 2, 3, 4 (residential), 9a (health-care) and 9c (aged-care). These Performance Requirements require a building in an 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 Deemed-to-Satisfy (DTS) provisions of Volume One, B1.6 and Volume Two, 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 DFE, which typically will correspond to the level of the 1% AEP flood plus 0.5 m 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.

4.1.2 Flood Information to Support Land Use Planning

Australian Disaster Resilience Handbook 7 *Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017) identifies the essential role of land-use planning in limiting the growth in flood risk associated with new land uses and development in the floodplain. Guideline 7-5, *Flood Information to Support Land Use Planning*, sets out a method for translating products from flood studies into Flood Planning Constraint Categories (FPCCs) to better inform land-use planning activities. This guideline delineates flood liable land into one of four major "constraint" categories (with several subcategories) based upon key flooding considerations such as flood hazard, flood function and emergency response. The resulting categories can serve to inform land use planning activities. The guideline notes that the categorisation is intended to support community/precinct scale decisions where flow paths and flood extents can be readily defined and was not developed to support change of land use or development at the lot/site scale.

The Guideline's Flood Planning Constraint Categories are set out in **Table 15**. A FPCC of "1" implies a more flood constrained section of land relative to FPCC category "2", and so on. FPCC mapping for the Wallarah Creek catchment is presented in **Figure 21**. For this catchment, the defined flood event (DFE) is the 1% AEP flood. Where FPCCs overlap, only the more constrained category is mapped.

Significant numbers of properties in Turner Close and Birdwood Drive, Blue Haven, fall within FPCC1a, which is defined as a flood conveyance and storage area within the 1% AEP event. Many other properties fall within FPCC2a, which conveys flows during events larger than the defined flood event.

Table 15 Flood Planning Constraint Categories (AIDR, 2017)

FPCC	Description	Discussion
1a	Flow conveyance and storage areas in the DFE	Majority of development and uses vulnerable to failure and/or likely to have adverse flood impacts. Most development in these areas should be limited and any development must be designed to maintain the current flood function.
1b	H6 hazard in the DFE	
2a	Flow conveyance in events larger than the DFE	Many uses in these areas will be vulnerable to high flood hazard during large floods and/or have the potential to be isolated leading to evacuation difficulties. Vulnerable land uses not suitable for these areas and new development of any new development should be limited to those compatible with higher hazard conditions (i.e., special development conditions should be applied).
2b	Flood hazard H5 in the DFE	
2c	Emergency response—isolated and submerged areas	
2d	Emergency response—isolated but elevated areas	
2e	Flood hazard H6 in floods larger than the DFE	
3	Outside FPCC2 — generally below the DFE and the freeboard	Compatible with most development types/land uses subject to appropriate development controls being applied to reduce potential for flood damage/exposure. Generally, not suitable for vulnerable land uses.
4	Outside FPCC3, but within the probable maximum flood	Compatible with most development types. Vulnerable facilities may still require development controls

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 *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; and
- 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 (FPL, 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 Wallarah Creek catchment warrants the imposition of flood related development controls above the residential FPL is considered in Section 4.2.3.

At the time of preparing this report (November 2018), the NSW Department of Planning and Environment was reviewing the Direction related to Flood Prone Land.

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 FPL, unless 'adequate justification' has been satisfied), 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' under the Codes SEPP 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 (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 11**).

(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 11 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 Local Environmental Plan (LEP) and Development Control Plan (DCP), which shape the flood planning area.
- 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 Wallarah Creek catchment have been developed as part of the current 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' in the SEPP is not clear. If based on the *Floodplain Development*

[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.

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' flood hazard is not explicitly defined (in this study, taken as inclusive of H4–H6 categories for the 1% AEP flood). 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.

SEPP (Coastal Management) 2018

SEPP (Coastal Management) 2018 aims to promote an integrated and co-ordinated approach to land use planning in the coastal zone. For areas mapped as 'coastal wetland and littoral rainforests' – including a 4.3-hectare coastal wetland in the Wallarah Creek catchment – development consent is required for the clearing of native vegetation, and for earthworks, construction of a levee, draining the land and environmental protection works, and for any other development. For areas mapped as 'coastal environment areas' – including the floodplains of Wallarah and Spring Creeks downstream of the Sydney-Newcastle Railway – development consent must not be granted unless the consent authority has considered whether the proposed development is likely to cause an adverse impact on "the integrity and resilience of the biophysical, hydrological (surface and groundwater) and ecological environment" amongst other factors. The development must be designed, sited and managed to either avoid, minimise or managed to mitigate adverse impacts.

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 preparing 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.

At the time of preparing this report, the Guideline is being reviewed.

In considering whether a case for 'exceptional circumstances' should be made for the Wallarah Creek catchment, 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. For Spring Creek downstream of the Doyalson Link Road – adjacent to land zoned for residential use, the difference is up to about 2.1 metres. Higher differences are observed upstream of hydraulic obstructions – about 3.8 metres in Spring Creek immediately upstream of the Doyalson Link Road, and over 5 metres in Wallarah Creek immediately upstream of the Doyalson Link Road.

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. Many properties zoned "R2" (Low Density Residential) in the Birdwood Drive and Turner Close areas of Blue Haven are subject to these high hazard conditions in the PMF. Importantly, not all of these properties fall within a flood planning area formed by the addition of a 0.5 metre freeboard to the 1% AEP flood level (see Section 0). This suggests that in the interests of community safety during floods, development controls would be desirable for some residential properties which are not currently able to subject to such controls given the constraints of the Guideline, and that there would be merit in preparing an application for 'exceptional circumstances', which if successful would permit the application of suitable controls when properties are redeveloped. 'Exceptional circumstances' would also make it unambiguous that controls relevant to safety in the PMF could be applied to dwellings within the (standard) flood planning area.

4.3 Local Provisions

In NSW, local government councils are responsible for managing flood risk with their Local Government Areas (LGAs). A Local Environmental Plan (LEP) is used to establish what land uses are permissible and/or prohibited on land within the 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. At the time of preparing this report (November 2018), development applications within the study area continue to be assessed based on the former Wyong Shire planning controls. A draft Consolidated Central Coast LEP and DCP were subsequently placed on public exhibition from December 2018 to February 2019.

This section briefly describes and reviews the flood-related controls within the Wyong Shire policies as at November 2018, with a view to flood behaviour in the Wallarah Creek catchment 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 m freeboard'.

The appropriateness of the *existing Wyong LEP* 2013 for managing flood risk in the Wallarah Creek catchment is considered under the following headings:

- Flood planning area definition;
- Compatibility of existing land use zones with flood hazard; and
- 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 over residential development. For those areas contained within the FPA, the FPLs are frequently used to establish the elevation of key 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 (residential) FPL is considered generally appropriate for the Wallarah Creek catchment. A more frequent design flood would expose communities to too great a risk. The flood height range between the 1% AEP flood and the PMF is up to about 2.1 m adjacent to areas zoned for residential use, which is fairly typical for many NSW coastal catchments where the 1% AEP flood forms the basis of the residential FPL as per the 2007 Guideline. But even if the FPA is based on the 1% AEP flood, there is arguably still a need for controls beyond this area (see Section 4.2.3).

The '*Wallarah Creek Catchment Flood Study'* (Catchment Simulation Solutions, 2016) assessed modelling sensitivities and uncertainties to inform selection of freeboards for incorporation into the FPL. It recommended that Council's standard 0.5 m freeboard be retained for defining mainstream FPLs across the Wallarah Creek catchment. However, for overland flow style inundation in urban parts of the catchment, it recommended that a reduced freeboard of 0.3 m be adopted. This would provide a 0.2 m allowance for modelling uncertainty plus a 0.1 m allowance for other uncertainties that cannot be explicitly represented in the modelling (e.g., wind and wave action), in line with the mainstream freeboard.

However, the model LEP clause taken up in *Wyong* LEP 2013 – stipulating only a 0.5 m 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 FPAs.

It is therefore recommended that Council seek to amend the definition of FPL 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.'*

There is currently no industry standard for defining the FPA 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) and *'Killarney Vale & Long Jetty Catchments Floodplain Risk Management Study* (CSS, 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 the 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 across the urban areas of Blue Haven and San Remo was defined by re-simulating the 1% AEP flood with a 30% increase in rainfall to account for uncertainties. For the remainder of the catchment where mainstream flooding dominates, the FPA was defined by extending the FPL (i.e., 1% AEP level +0.5m freeboard) laterally until it intersected higher ground. The urban and mainstream FPAs were subsequently combined to form the final FPA for the subcatchment which is shown in **Figure 22**.

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 national flood hazard categories was undertaken. The results of this assessment for the 1% AEP and PMF events are presented in **Table 16**.

Of most interest in reviewing the information presented in **Table 16** is land zoned for urban development within flood hazard H5 and H6 as the depth and velocity of floodwater in these areas is sufficient to cause structural failure of buildings. H4 is also of interested as it would be unsafe for people. The results indicate that the current zoning is broadly compatible with the flood hazard, with less than 1% of residential "R1" and R2", commercial "B1", B2" and "B4" and industrial "IN1 and "IN2" being exposed to a H5 or H6 during the 1% AEP flood and less than 3% of these habitable land uses being exposed to H4 hazard areas.

A greater area is subject to H4, H5 and H6 hazard during the PMF. This includes over 20% of the residential zoned areas and over 10% of industrial zoned land. Most of the high hazard industrial land is currently undeveloped but the zoning may allow development in the future, which is discussed in more detail on the following section.

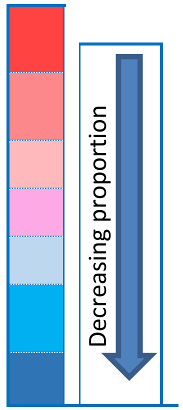
Residential zoned land exposed to H4, H5 or H6 hazard conditions during the PMF is primarily contained to the western edges of Blue Haven. This includes properties adjoining Turner Close, Penguin Drive and Birdwood Drive as well as part sections of properties fronting Olney Drive. It is also noted that many of the residential property boundaries in this area extend right to the edge of the creek or in some cases into the creek, which is also not ideal given this area is mapped as a 'coastal environment area' for the purposes of the *Coastal Management Act 2016* (Section 4.2.2). However, although an environmental zone such as "E3" (Environmental Management) or "E4" (Environmental Living) would better reflect the ecological values identified for this area, the reality is that the floodplain adjacent to the creek is already developed, so changing the zoning would appear to have little practical benefit unless Council wishes to signal an intention to backzone highly hazardous areas, and that voluntary purchase of affected properties is a genuine prospect.

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 FPL (in particular, those locations highlighted above), should be discouraged.

As noted, there are a few areas within the Wallarah Creek catchment that are currently undeveloped. However, their current zoning may permit new development or intensification of development in the future. These areas are discussed in more detail below.

Table 16 Compatibility of Current Land Use Zones with National Flood Hazard Categories During the 1% AEP and PMF

Land Zone	Area (Ha)	Hazard Category													
		PMF							1%AEP						
		No Hazard	H1	H2	H3	H4	H5	H6	No Hazard	H1	H2	H3	H4	H5	H6
B1 (Neighbourhood Centre)	0.4	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B2 (Local Centre)	10.0	91%	4.0%	1.3%	1.9%	1.9%	0.3%	0.0%	99%	0.3%	0.4%	0.2%	0.0%	0.0%	0.0%
B4 (Mixed Use)	3.3	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
E2 (Environmental Conservation)	334	25%	5.9%	3.8%	6.7%	12.7%	37.1%	9.2%	51%	16.4%	8.8%	13.4%	3.7%	6.1%	0.3%
E3 (Environmental Management)	2.9	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
IN1 (General Industrial)	630	84%	4.7%	1.4%	1.8%	2.4%	4.7%	1.2%	92%	3.8%	0.9%	1.1%	1.1%	0.6%	0.0%
IN2 (Light Industrial)	20.0	81%	15.7%	1.0%	0.4%	0.4%	1.5%	0.0%	89%	10.7%	0.4%	0.0%	0.0%	0.0%	0.0%
R1 (General Residential)	166	88.9%	3.0%	1.9%	2.2%	1.1%	2.5%	0.4%	98.2%	0.7%	0.3%	0.4%	0.1%	0.2%	0.01%
R2 (Low Density Residential)	84.1	57.3%	2.2%	2.1%	8.2%	7.4%	13.3%	9.5%	82.4%	4.3%	4.2%	6.6%	1.6%	0.9%	0.01%
RE1 (Public Recreation)	32.3	75%	2.8%	2.2%	2.5%	2.6%	12.5%	2.2%	89%	2.9%	1.9%	3.4%	1.9%	0.4%	0.0%
RU1 (Primary Production)	1.9	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RU6 (Transition)	1722	85%	4.3%	1.5%	2.5%	2.3%	4.0%	0.6%	94%	3.5%	0.9%	1.0%	0.4%	0.5%	0.0%
SP2 (Infrastructure)	237	62%	12.4%	3.5%	2.9%	4.2%	10.6%	4.1%	84%	9.4%	1.1%	1.1%	0.7%	1.2%	2.7%
W1 (Natural Waterways)	24.6	1.3%	0.0%	0.0%	0.0%	0.7%	10.6%	87.4%	1.7%	0.5%	1.0%	2.7%	4.0%	38.8%	51.3%
W2 (Recreational Waterways)	0.4	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%



Compatibility of intensified development with flood hazard

An assessment of the compatibility of areas that have the potential to be developed in the future was completed. The areas shown in **Plate 13** formed the basis for the assessment

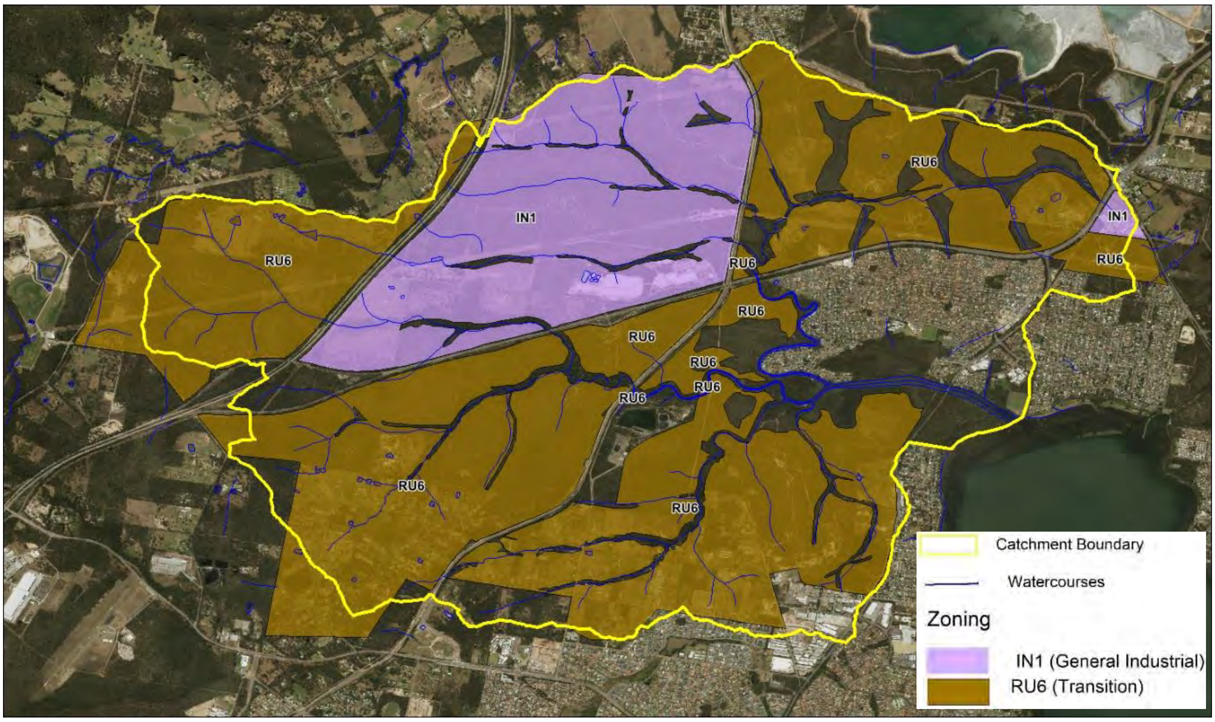
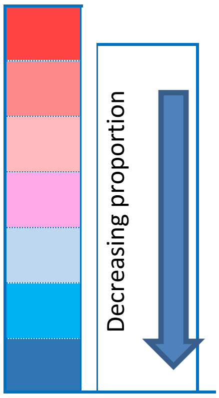


Plate 13 Land use zones that have the potential to be developed in the future

The results of the assessment for the 1% AEP and PMF are presented in **Table 17**.

Table 17 Compatibility of currently undeveloped areas that have the potential to be developed in the future with National Flood Hazard Categories During the 1% AEP and PMF

Flood Hazard Category	RU6 (Transition)		IN1 (General Industrial)	
	PMF	1%AEP	PMF	1%AEP
No Hazard	84.6	93.6	83.8	92.5
H1	3.8	3.5	4.1	4.1
H2	1.9	0.8	2.0	0.9
H3	2.7	1.6	1.6	1.9
H4	1.9	0.4	2.4	0.5
H5	4.5	0.0	4.9	0.0
H6	0.5	0.0	1.2	0.0



The information in **Table 17** shows that the land use zonings are compatible with the flood hazard, with the majority of the land (i.e., >80%) being located outside of the PMF extent

For the general industrial area (IN1) located between Scenic Drive and the Pacific Highway (i.e., located in the far east of the catchment) more than half of the undeveloped area is predicted to be flood free. Only a small area in the vicinity of the watercourse is predicted to fall within the H1 to H3 hazard categories during the 1% AEP flood and PMF. Therefore, new development across this area is considered feasible.

The results also show that most of the general industrial area (IN1) and 'transition' areas (RU6) are predicted to remain flood free during the 1% AEP and PMF events. The national hazard category mapping indicates that there are high hazard areas, however, they typically coincide with defined waterways where development would not be appropriate. Therefore, considering only the flood hazard of the land, intensification of development across this area may be feasible in areas away from the defined waterways.

Evacuation challenges

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

- Excluding flooding from the lake, the worst flooding in most of the catchment results from short storms – from 90 to 120 minutes in the 1% AEP event. Along the major watercourses, rainfall over a period in excess of 6 hours will typically produce the worst flooding.
- Some roads may be cut less than 20 minutes after the commencement of a storm, limiting opportunity for safe evacuation.
- Some roads may be impassable for approximately 140 minutes, which means a relatively short period of isolation.

Clause 7.3 of Wyong LEP 2013 is focussed on the evacuation of land subject to flooding in events exceeding the FPL. If this clause is strictly applied, development applications for the listed land uses in the Wallarah Creek catchment may fail because in some areas 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

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

A detailed review of the Wyong DCP was provided as part of the '*Wyong River Catchment Floodplain Risk Management Study & Plan'* (Catchment Simulation Solutions, 2018). A shorter review was provided as part of the *Killarney Vale/Long Jetty Catchments Floodplain Risk Management Study & Plan* (Catchment Simulation Solutions, 2018), focussing on controls suitable for local overland flow catchments. Flooding in the Wallarah Creek catchment is a combination of mainstream flooding and local overland flooding (as well as flooding from Budgewoi Lake, which is outside the scope of this study). This section discusses controls that may be appropriate to manage inundation risks in the Wallarah Creek catchment, for consideration for inclusion in the floodplain risk management chapter of a new Central Coast DCP currently under development.

Flood precinct categorisation

In general, the variability of modelled flood behaviour in the Wallarah Creek catchment suggests that having a single matrix of controls for this entire catchment would be inappropriate. What may be appropriate controls for mainstream inundation with significant depths and velocities might be inappropriate for shallow local overland flooding, and vice versa. Adopting provisional hydraulic hazard (based on the national H1 to H6 categorisation) is expected to be a profitable means for demarcating combinations of depths and velocities associated with various consequences to people and buildings. This approach has been adopted for the draft consolidated Central Coast DCP 2018, based on the flood planning level (FPL, typically 1% AEP flood) for residential and commercial uses, and the PMF for critical or sensitive facilities, land subdivision, tourist development and caravan parks.

For the next iteration of Central Coast DCP, consideration could also be given to incorporating flood function (hydraulic categories) and the constraints of topography and road networks for evacuation (flood emergency response precincts), in a manner similar to Flood Planning Constraint Categories (see Section 4.1.2).

It is vital that consideration be given to managing the risk to life and enhancing resilience in events rarer than the 1% AEP flood. Under current controls, a new house subject to H3 conditions in a 1% AEP flood might be given development approval subject to meeting the required controls for the FPL. However, this same house might be subject to dangerous H5 or H6 flood hazard conditions in rarer floods. Such locations are apparent in the Wallarah Creek floodplain. Extreme floods do occur in Australia, and best practice requires that the consequences of such floods be understood and the risks (especially to life) be mitigated as far as is practical.

Floor level

Given the different styles of inundation in the Wallarah Creek catchment – from mainstream flooding, local overland flow in urban areas, and lake flooding – different freeboards are appropriate for addition to design flood peak levels to identify minimum floor levels for new dwellings. The standard 0.5 m freeboard is judged to be suitable for areas subject to mainstream flooding, whilst a 0.3 m freeboard is suitable for areas subject only to shallow local overland flows.

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' rooms, 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).*

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

Given a provision in the Codes SEPP for houses to be able to withstand the forces of floodwater up to the FPL (or up to the PMF if the building serves as an on-site refuge), it is appropriate for such a requirement in the DCP too. Such a control is still considered desirable even with a shift in the draft consolidated Central Coast DCP 2018 to basing flood precincts on flood hazard criteria and discouraging development in H4-H6 hazard categories.

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 (and safe road access) are important for properties subject to mainstream flooding, where early evacuation is required.

Evacuation

As noted in the DCP review for the *Wyong River Catchment Floodplain Risk Management Study & Plan* (Catchment Simulation Solutions, 2018), in some cases people will need an ability to safely evacuate in events *rarer* than the 1% AEP flood, which is not currently required. The DCP should also recognise the desirability of ensuring access to an appropriate area of refuge located above the PMF, not just the FPL.

Currently, Wyong DCP 2013 does not promote on-site refuge. The merits of evacuation and on-site refuge as strategies for managing risk to life are assessed in Section 5.3.2. In some parts of Wallarah Creek catchment subject to mainstream inundation where it is possible for access roads to be flooded before houses are flooded to depths and velocities that would pose a very high hazard, early evacuation will be the safest emergency response. There are many other parts of the catchment subject to relatively shallow overland flow style inundation where it may well be safer to stay within houses rather than attempt to evacuate along roads which sometimes convey flows making it unsafe for vehicles. Given the diversity of flood conditions, having controls for the entire study area – let alone the whole LGA – that *require* evacuation may be inappropriate.

Although not desirable, community consultation suggests that a significant proportion of the population who need to evacuate will fail to evacuate (see Section 2.6.3). This may be because they are not aware of an emerging threat, noting that Wallarah Creek does not receive formal flood warnings from the Bureau of Meteorology. Many questionnaire respondents indicated they would not evacuate due to concerns for the security of their property. Some people may be unable to self-evacuate even if aware of the need. For whatever reason people fail to evacuate, there is an opportunity to facilitate increased safety during floods by providing a 'Plan B', when redevelopment of existing housing stock from such areas is proposed.

Among the required DCP controls for facilitating on-site refuge would be requirements for a portion of habitable floor area above the PMF (and not in an enclosed roof space but with opportunity for boat rescue from the refuge) and for the building to withstand the forces of floodwater, buoyancy and debris in a PMF. (Whether Department of Planning and Environment approval for 'exceptional circumstances' is needed for the application of such controls to dwellings located on land within the Flood Planning Area requires clarification).

Redevelopment and additional occupancies

One of the issues identified for the Wallarah Creek catchment is the problem of existing housing stock in locations that are undesirable from a flood risk perspective. Several dwellings, particularly near Spring Creek in Blue Haven, are located in areas of flow conveyance in the 1% AEP flood and in areas of very high hazard (H6) in the PMF. If it is not possible to voluntarily purchase these properties, what policies should be adopted for extensions or redevelopment? It is understood that Council's current approach is to allow replacement dwellings on a one for one basis. Secondary dwellings or dual occupancies are prohibited in these areas. This would seem to be a sensible precaution to prevent an increase in risk. If replacement dwellings are built to more resilient standards, possibly including a PMF refuge, the risk could reduce from current conditions.

The draft consolidated Central Coast DCP 2018 has a new prescriptive criterion (10*) that applies to low density residential development in H2-H3 areas below the FPL:

> *'In addition to meeting other relevant requirements, additional occupancies will only be supported if the proposal:*
> *(a) Is located in an area with less than 0.8m flood depth*
> *(b) has a safe low hazard evacuation route with less than 0.8m flood depth and of less than 200m length in flood waters'*

This new criterion would appear to provide the means to formally implement the policy of not allowing an increase in the number of dwellings where the flood hazard poses a serious threat to adult pedestrians either in situ or evacuating.

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 Wallarah Creek catchment.

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 Catchment Floodplain Risk Management Study & Plan* (Catchment Simulation Solutions, 2018). Further comments relating specifically to the Wallarah Creek catchment study area are provided in **Table 18**.

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 sites for active reconnaissance during floods.

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 could expand on flood behaviour in the Wallarah Creek catchment. There is also potential to include more specific community education activities, with a particular focus on properties adjoining Birdwood Drive and Turner Close.

Volume 3 was last updated in December 2007. It describes response arrangements including flood warning systems and evacuation protocols. The appropriate emergency response(s) for Wallarah Creek catchment are not articulated. Considerable effort is needed to provide the detail consistent with the new NSW SES LFP template.

Table 18 Comments on Current Wyong Shire Local Flood Plan

Section	Description	Comment
Volume 1		
3.8.4	List of problem areas for active reconnaissance during flooding	Turner Close and Birdwood Drive, Blue Haven, have a significant flood risk and should be added to the list of problem areas for active reconnaissance during floods.
3.18.42	List of evacuation centres	There does not appear to be an evacuation centre to service residents of Blue Haven who may need to evacuate and have no local family or friends to stay with. Blue Haven Public School or the Blue Haven Seventh Day Adventist Church may be suitable in this regard
Volume 2 Hazard and Risk in Wyong		
1.1	Landforms and River Systems	Wallarah Creek's catchment area is recorded as 33 km^2 in the *Wallarah Creek Catchment Flood Study*.
1.2	Storage Dams	Not relevant to Wallarah Creek catchment.
1.3	Weather Systems and Flooding	Needs to describe role of short-duration (1-2 hours' burst) rainfall for flooding in the Wallarah Creek urban catchment, which may be caused by short-lived thunderstorms.
1.4	Characteristics of Flooding	Needs to amplify description of flooding in Spring and Wallarah Creeks that can precede lake flooding and describe characteristics of overland flow inundation in the urban catchment, including degree of hazard.
1.5	Flood History	Historical floods in the Wallarah Creek catchment should be added, especially Jun 2007, as well as Apr 2015 (see the *Wallarah Creek Catchment Flood Study*).
1.6	Flood Mitigation Systems	The detention basins within the Wallarah Creek catchment should be added (Blue Ridge Drive Basin, Newton Place Basin, Myall Close Basin).
1.7	Extreme Flooding	Information in the *Wallarah Creek Catchment Flood Study* and this FPRMS should be used to describe what happens in the PMF.
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	Birdwood Drive and Turner Close could be described.
2.5	Public Education	Suggested that Birdwood Drive and Turner Close properties could be specifically identified for education activities
2.7	Road Closures	The current LFP does not include such a list. This information is available in the *Wallarah Creek Catchment Flood Study* and this FPRMS.
2.8	Summary of Isolated Communities and Properties	Isolated properties could be described using the mapped Flood Emergency Response classification. It is noted that isolation of properties as a result of local overland flows only is likely to be of short duration.
Volume 3 SES Response Arrangements		

Section	Description	Comment
Ch. 1	Flood Warning Systems and Arrangements	It is noted that Wallarah Creek Bridge gauge is listed. It might be possible to prepare a flood intelligence card for this gauge based on flood modelling inputs. As flood levels for this gauge are reported on the bom.gov.au website (even though flood warnings are not issued for this gauge), this could be useful for emergency responders. However, it is noted that this gauge is influenced by lake levels so may not provide a true indication of flooding across upstream areas.
Ch. 2	SES Locality Response Arrangements	The current LFP breaks down Wyong Shire into six evacuation sectors. Wallarah Creek catchment is included within Sector B (Wyong Town). However, Wallarah Creek is not explicitly described in the text and strategies (evacuation/on-site refuge) are not clear. This should be clarified in the text.
Ch. 3	SES Dam Failure Arrangements	Not relevant to Wallarah Creek catchment.
Ch. 4	SES Caravan Park Arrangements	Not relevant to Wallarah Creek catchment.

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 Wallarah Creek catchment 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; and
- 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 Wallarah Creek Catchment Practice

It is noted that the current Wyong Local Flood Plan (Volume 3 Annex F clause 10, and map 3, dated 2007) appears to endorse shelter-in-place (i.e., on-site refuge) as the appropriate strategy for areas north of Wyong subject to flash flooding. This is a pragmatic approach given:

- The worst flooding across much (but not all) of the catchment results from short storms of about 2 hours duration. 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 water on roads and 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 10 minutes after the commencement of a storm, leaving very little opportunity for evacuation triggered by environmental cues.
- Roads may be impassable for approximately 150 minutes, which means a relatively short period of isolation.

Nonetheless, early 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.
- Sites where the national hazard rating exceeds H4 could be unsafe for buildings and their occupants. This includes many dwellings in Birdwood Drive and Turner Close in the PMF. Because the magnitude of flooding will probably not be able to be predicted prior to flooding, only in dwellings where a place of refuge above the PMF level is provided *and* where the dwelling is known to be capable of surviving the PMF should people in areas subject to high hazard flooding contemplate not evacuating before flooding. For these areas, the safest course of action is likely to be evacuating *prior to* flooding, as difficult as that behaviour may be to engender.
- 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 are 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 study area are predicted to be exposed to a significant flood risk and/or significant financial impacts during major floods within the catchment. The following chapters outline options that could be potentially implemented to build upon current emergency response protocols to better manage this flood risk.

6.2 Potential Options for Managing the Flooding Risk

6.2.1 Types of Options

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

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across flood liable areas. Flood modification measures will generally benefit a number of properties and are primarily aimed at reducing the existing flood risk.
- **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 are 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 initial list of risk management measures was developed based upon consideration of the following factors:

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

A total of 33 options were initially identified and these options are summarised in **Table 19** (flood modification options), **Table 20** (property modification options) and **Table 21** (response modification options).

Table 19 Preliminary List of Flood Modification Options Considered for Managing the Flood Risk

Potential Flood Modification Options	Description of Option
Detention Basins	
Doyalson Link Road Basin	Create a detention basin upstream of Doyalson Link Road to temporarily store water from the upstream catchment and reduce downstream flows/water levels
Modify Newton Place detention basin	Modify Newton Place detention basin to increase storage volume and/or modifying the outlet to reduce potential for inundation of adjoining properties
Spring Creek Basin	Create a detention basin/storage area on western side of Spring Creek downstream of Doyalson Link Road to store water from the upstream catchment and reduce downstream flows/water levels
Modify Pinehurst Way detention/water quality basin	Modify basin located on southern side of Pinehurst Way to reduce potential for water to "backup" into Pinehurst Way properties.
Drainage Upgrades	
Doyalson Link Road culvert upgrades	Upgrade of existing Doyalson Link Road culverts located north of Roper Road to allow detention basins to more freely drain
Newton Place stormwater upgrades	Upgrade stormwater system near Newton Place to allow water to drain into detention basin
Pinehurst Way stormwater upgrades	Upgrade stormwater system at low point in Pinehurst Way to reduce potential for inundation of adjoining properties (including potential regrading)
Colorado Drive stormwater upgrades	Upgrade stormwater system near Colorado Drive and Apsley Ct intersection
Scribbly Gum Close stormwater upgrades	Upgrade stormwater system of Scribbly Gum Close in the area pipes and pits have a capacity equal or less than the 20% AEP to allow water to drain more readily from the area
Install kerb & guttering and new stormwater system in Brava Avenue	Install kerb & guttering and new stormwater system in areas around Brava Avenue particularly in residential areas between Costa Avenue and the watercourse to allow floodwater to drain readily
Upgrade stormwater system adjacent to Callaghan Drive and Botham Close	Upgrade stormwater system near Callaghan Drive and Botham Close to allow water drain more readily from the area
Channel Modification	
Creek maintenance/removal of dense vegetation	Creek maintenance including removal of dense vegetation to provide additional flow carrying capacity
Spring Creek high flow bypass	Reshaping of terrain to create additional flow path from Spring Creek to Wallarah Creek when capacity of Spring Creek channel is exceeded
Modify Spring Creek channel	Increase Spring Creek channel width and depth from Turner Close to Wallarah Creek confluence
Allambee Crescent channel modifications	Increase capacity of existing channel along north side of Allambee Crescent properties
Enlarge unnamed watercourse between Brava and Costa Avenues	Increase size of existing watercourse between Brava and Costa avenues to allow water to drain more readily and prevent overtopping

Potential Flood Modification Options	Description of Option
Dredge Wallarah Creek downstream of Spring Creek confluence	Lower bed elevation of Wallarah Creek downstream of Spring Creek confluence to provide additional flow carrying capacity
Earthworks/Levees	
Birdwood Drive levee	Construct levee around rear of Birdwood Drive properties to reduce potential for water to spill from Spring Creek and inundate area.
Allambee Crescent levee	Construct levee around north-western side of Allambee Crescent properties to reduce potential for water to spill from Wallarah Creek and inundate area.
Pinehurst Way flow path reshaping	Reshaping of existing overland flow path between 28 and 30 Pinehurst Way to increase overland flow capacity

Table 20 Preliminary List of Property Modification Options Considered for Managing the Flood Risk

Potential Property Modification Options	Description of Option
Planning Modifications	
Updates to LEP and DCP	Update Council LEP and DCP to reflect the detailed review completed as part of the current study
Residential Property Modifications	
Voluntary house raising program	Voluntary raising of select houses subject to frequent above floor inundation
Voluntary flood proofing	Flood proofing of select residential properties
Voluntary house purchase program	Voluntary purchase of select properties in high hazard / floodway areas

Table 21 Preliminary List of Response Modification Options Considered for Managing the Flood Risk

Potential Response Modification Options	Description of Option
Education	
Community education activities	Various community education activities to increase flood awareness and allow residents to be more self-sufficient during future floods
Flood Plans	
Preparation of residential flood plans	Preparation of flood plans by residential property occupiers to identify actions to be taken before, during and after a flood
Preparation of business flood plans	Preparation of flood plans by business owners to identify actions to be taken before, during and after a flood
Local flood plan updates	Update NSW SES local flood plan to take advantage of updated flood information generated as part of the current study
Evacuation Route Upgrades	
Upgrade of Pacific Highway	Elevated Pacific Highway on southern side of Wallarah Creek to provide greater flood immunity
Upgrade of Birdwood Drive	Elevate sections of Birdwood Drive to allow increased evacuation times

Potential Response Modification Options	Description of Option
Extension of Turner Close to McKellar Blvd	Join Turner Close to McKellar Blvd to allow properties at southern end of Turner Close to evacuate directly to McKellar Boulevarde
Miscellaneous	
Flood warning system	Development of a flood warning system for the catchment to provide additional evacuation time
Refuge in place strategy	Develop a strategy to allow for safe refuge in place at suitable locations within the catchment

It was not considered feasible to undertake a detailed assessment of all options in **Table 19, Table 20** and **Table 21**. Therefore, a relative 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 22** and the outcomes of the assessment are provided in **Table 23**, **Table 24** and **Table 25**.

Table 22 Adopted Evaluation Criteria and Scoring System for Qualitative Assessment of Flood Risk Management Options

Score:	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance
-2	Significant increases in levels/extents	Significant disbenefit to emergency services	Significant technical challenges	Significant impacts	Costs significantly outweigh benefits	Majority of community opposed
-1	Minor increases in levels/extents	Slight disbenefit to emergency services	Some technical challenges	Minor impacts	Costs outweigh benefits	Some opposed
0	Negligible changes in levels/extents	No impact on emergency services	Minor technical challenges	No impacts	Benefits and costs approximately equal	Neutral
1	Minor decreases in levels/extents	Slight benefit to emergency services	Negligible technical challenges	Some benefits	Benefits outweigh costs	Some support
2	Significant decreases in levels/extents	Significant benefit to emergency services	No technical challenges	Significant benefits	Benefits significantly outweigh costs	Majority of community support

Table 23 Qualitative Assessment of Preliminary List of Flood Modification Options

Potential Flood Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Detention Basins							
Newton Place detention basin modifications	1	1	1	-1	-1	0	**1**
Pinehurst Way detention basin Modifications	1	1	1	-1	-1	0	**1**
Doyalson Link Road detention Basin	1	1	0	-1	-1	0	**0**
Spring Creek detention Basin	1	1	0	-1	-1	0	**0**
Drainage Upgrades							
Doyalson Link Road culvert upgrades	0	0	-1	0	-1	1	**-1**
Newton Place stormwater upgrades	1	0	0	0	-2	2	**1**
Pinehurst Way stormwater upgrades	1	0	0	0	-1	2	**2**
Colorado Drive stormwater upgrades	0	0	-1	0	-2	2	**-1**
Dunlop Road stormwater upgrades	0	0	0	0	-2	2	**0**
Scribbly Gum Close stormwater upgrades	0	0	-1	0	-1	2	**0**
Install kerb & guttering and new stormwater system in Brava Avenue	1	0	-1	0	-1	2	**1**
Upgrade stormwater system adjacent to Callaghan Drive and Botham Close	1	0	-1	0	-1	2	**1**
Channel Modifications							
Creek maintenance/removal of dense vegetation	1	1	-1	-1	-1	2	**1**
Create formalised channel on the western side of Arizona Road and Chelmsford Road intersection	1	1	-1	-1	-1	1	**0**
Spring Creek high flow bypass	2	1	-1	-1	-1	1	**1**
Modify Spring Creek channel	1	0	0	-1	-1	1	**0**
Allambee Crescent channel modifications	2	1	-1	-1	-1	1	**1**

Potential Flood Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Enlarge unnamed watercourse between Brava and Costa Avenues	1	1	-1	0	-1	1	**1**
Dredge Wallarah Creek downstream of Spring Creek confluence	2	1	-1	-2	-1	2	**1**
Earthworks/Levees							
Birdwood Drive levee	2	1	-1	-1	-1	-1	**-1**
Allambee Crescent levee	2	1	-1	-1	-1	-1	**-1**
Pinehurst Way flow path reshaping	1	1	-1	-1	0	1	**1**

Note: # refer to **Table 19** for a detailed description of each option

Table 24 Qualitative Assessment of Preliminary List of Property Modification Options

Potential Property Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Planning Modifications`							
Updates to LEP and DCP	0	0	2	0	1	1	**4**
Residential Property Modifications							
Voluntary purchase of select properties	0	2	1	1	-2	-1	**1**
Voluntary flood proofing of select properties	0	0	1	0	-1	-1	**-1**
Voluntary raising of select residential properties	0	0	1	0	0	-1	**0**

Note: # refer to **Table 20** for a detailed description of each option

Table 25 Qualitative Assessment of Preliminary List of Response Modification Options

Potential Response Modification Options#	Evaluation Criteria/Score						
	Change in Flood Levels/Extents	Emergency Response	Technical Feasibility	Environmental Impacts	Economic Feasibility	Community Acceptance	Overall Score
Education							
Community education activities	0	2	1	0	1	1	**5**
Flood Plans							
Preparation of residential flood plans	0	2	1	0	1	1	**5**
Preparation of business flood plans	0	2	1	0	1	0	**4**
Local flood plan updates	0	2	0	0	1	2	**5**
Evacuation Route Upgrades							
Upgrade of Pacific Highway	-1	2	-1	0	-1	2	**1**
Upgrade of Birdwood Drive	0	1	0	0	-1	1	**1**
Extension of Turner Close to McKellar Blvd	0	1	0	0	-1	1	**1**
Miscellaneous							
Flood warning system	0	2	-2	0	-2	2	**0**
Refuge in place strategy	0	1	0	0	1	1	**3**

Note: # refer to **Table 21** for a detailed description of each option

In **Table 22** each measure was evaluated against six criteria. The expected performance of each measure against each criterion was scored between -2 (significant negative impact) and +2 (significant positive impact).

The scores were 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. Those options where the assessment yielded an overall score of greater than 0 are highlighted in green and were carried forward into the detailed assessment.

6.3 Flood Risk Management Options Assessed in Detail

Based upon the qualitative assessment presented in Section 6.2.2, the options listed in **Table 26** were selected for detailed assessment.

Table 26 Options Adopted for Detailed Investigations

Flood Modification Options		Property Modification Options		Response Modification Options	
FM1	Doyalson Link Road Basin	PM1	Updates to LEP and DCP	RM1	Community education activities
FM2	Modify Pinehurst Way detention/water quality basin	PM2	Voluntary purchase of select properties	RM2	Preparation of residential flood plans
FM3	Pinehurst Way stormwater upgrades			RM3	Preparation of business flood plans
FM4	Brava Avenue floodwall and drainage modifications			RM4	Local flood plan updates
FM5	Creek maintenance/removal of dense vegetation			RM5	Upgrade of Pacific Highway
FM6	Spring Creek high flow bypass			RM6	Upgrade of Birdwood Drive
FM7	Allambee Crescent channel modifications			RM7	Extension of Turner Close to McKellar Blvd
FM8	Enlarge unnamed watercourse between Brava and Costa Avenues			RM8	Refuge in place strategy
FM9	Dredge Wallarah Creek downstream of Spring Creek confluence				
FM10	Pinehurst Way flow path reshaping				
FM11	Pinehurst Way modified detention basin, stormwater upgrades and flow path reshaping.				

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/populated areas. Flood modification measures will generally benefit multiple properties and are primarily aimed at reducing the existing flood risk. However, they can also assist in reducing the potential future flood risk.

Flood modification options considered in detail as part of the study included:

- FM1 – Doyalson Link Road Basin
- FM2 – Modify Pinehurst Way detention/water quality basin
- FM3 – Pinehurst Way stormwater upgrades
- FM4 – Brava Avenue floodwall and drainage modifications
- FM5 – Creek maintenance/removal of dense vegetation
- FM6 – Spring Creek high flow bypass
- FM7 – Allambee Crescent channel modifications
- FM8 – Enlarge unnamed watercourse between Brava and Costa Avenues
- FM9 – Dredge Wallarah Creek downstream of Spring Creek confluence
- FM10 – Pinehurst Way flow path reshaping
- FM11 – Pinehurst Way modified detention basin, stormwater upgrades and flow path reshaping

The hydraulic benefits of each flood modification option were assessed by including the option in the flood 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. The difference mapping shows the impact that implementation of the option is predicted to have on existing flood levels and extents.

Cost estimates for each option were also prepared and are summarised in **Table 27**. **Table 27** also summarises the predicted reduction in flood damage costs if the option was implemented along with the associated benefit-cost ratio (BCR). The BCR provides the following economic insights:

- BCR > 1: The economic benefits are predicted to be greater than the cost to implement the option.
- 0 < BCR < 1: There is still an economic benefit (i.e., reduction in flood damage costs). However, the cost of implementing the option is greater than the economic benefit.
- BCR = 0: There is no economic benefit (i.e., no reduction in flood damage costs) associated with implementing the option.

- BCR < 0 (i.e., negative): Implementing the option is predicted to generate a negative economic impact (i.e., increase flood damage costs).

Table 27 Summary of Economic Assessment for Flood Modification Options

Option		$ Millions				
		Cost	Existing Flood Damage	Total Damage with Option in Place	Reduction in Damage with Option in Place	Benefit-Cost Ratio (BCR)
FM1	Doyalson Link Road basin	1.97	4.36	4.14	0.22	0.1
FM2	Modify Pinehurst Way detention/water quality basin	0.08		4.33	0.03	0.3
FM3	Pinehurst Way stormwater upgrades	0.27		4.14	0.22	0.8
FM4	Brava Avenue floodwall and drainage modifications	0.30		4.29	0.07	0.2
FM5	Creek maintenance/removal of dense vegetation	2.24		4.27	0.09	0.0
FM6	Spring Creek high flow bypass	0.82		4.33	0.03	0.0
FM7	Allambee Crescent channel modifications	0.36		4.35	0.01	0.0
FM8	Enlarge unnamed watercourse between Brava and Costa Avenues	0.30		4.24	0.12	0.4
FM9	Dredge Wallarah Creek downstream of Spring Creek confluence	30.4		4.16	0.20	<0.01
FM10	Pinehurst Way flow path reshaping	0.10		4.15	0.21	2.2
FM11	Pinehurst Way modified detention basin, stormwater upgrades and flow path reshaping	0.31		4.09	0.27	0.9

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

7.2 Detention Basins

7.2.1 FM1 – Doyalson Link Road Basin

Recommendation: Not recommended for implementation to manage the existing flood risk. However, can be considered for further investigation to manage the future flood risk

A concept plan for the Doyalson Link Road basin is included in **Figure 23**. As shown in **Figure 23**, this option would involve constructing an earthen embankment north of Doyalson Link Road to temporarily "hold back" floodwaters during significant rainfall events. A culvert would be provided to allow for a controlled release of water into Spring Creek. A spillway would also need to be provided to allow flows in excess of the capacity of the basin to discharge back into Spring Creek in a safe manner.

The concept design for the basin was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 14** and **Plate 15**.

Plate 15 shows that some notable flood level reductions are predicted downstream of the basin during the 1% AEP flood. This includes reductions of over 0.2 metres in the vicinity of Turner Close, 0.15 metres near Birdwood Drive and 0.05 metres near Allambee Crescent. Flood level reductions are also predicted to extend along a number of other tributaries that drain into Spring Creek, including Wallarah Creek. However, these reductions typically extend across uninhabited areas.

There is predicted to be a significant increase in 1% AEP water level upstream of the basin wall (i.e., ~1.5 metre increase) with a commensurate increase in inundation extent. The increased inundation area largely extends across open space, although it does encroach close to one property. Although above floor inundation is not predicted at this property, it does highlight there would be limited opportunity to increase the height of the basin wall further in an attempt to provide additional storage volume.

Plate 14 shows that more modest flood level reductions are predicted during the 20% AEP flood. Peak 20% AEP flood levels in the vicinity of Turner Close and Birdwood Drive are predicted to reduce by about 0.03 metres. Flood levels upstream of the basin wall are predicted to increase by about 0.5 metres.

A preliminary cost estimate for the basin was prepared and is included in **Appendix E**. This determined that the basin would likely cost just under $2 million to implement, making it one of the more expensive options that was explored.

The potential financial benefit associated with implementation of the 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 around $220,000 was predicted over the next 50-years. This yielded a preliminary benefit-cost-ration (BCR) of about 0.1. Accordingly, the financial cost of implementing this option outweighs the financial benefits.

The relatively small reduction in damages is considered to be associated with the fact that only small reductions in flood levels are predicted during more frequent floods. It is likely that the basin outlet could be further optimised to provide improved performance during the more frequent events (e.g., through a multi-level outlet). However, these changes are unlikely to improve the economic outcome significantly.

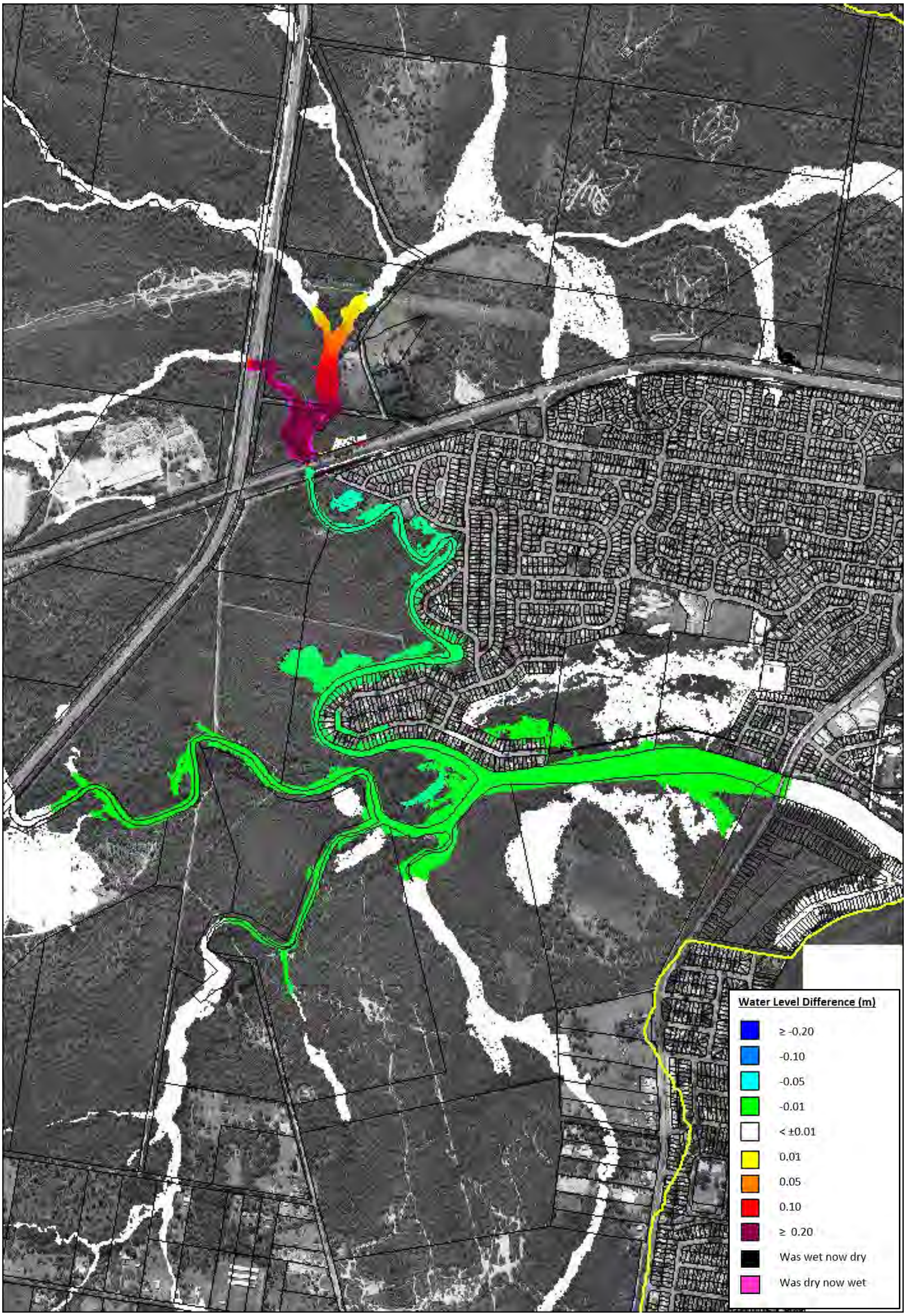


Plate 14 20% AEP Flood Level Difference Map for FM1

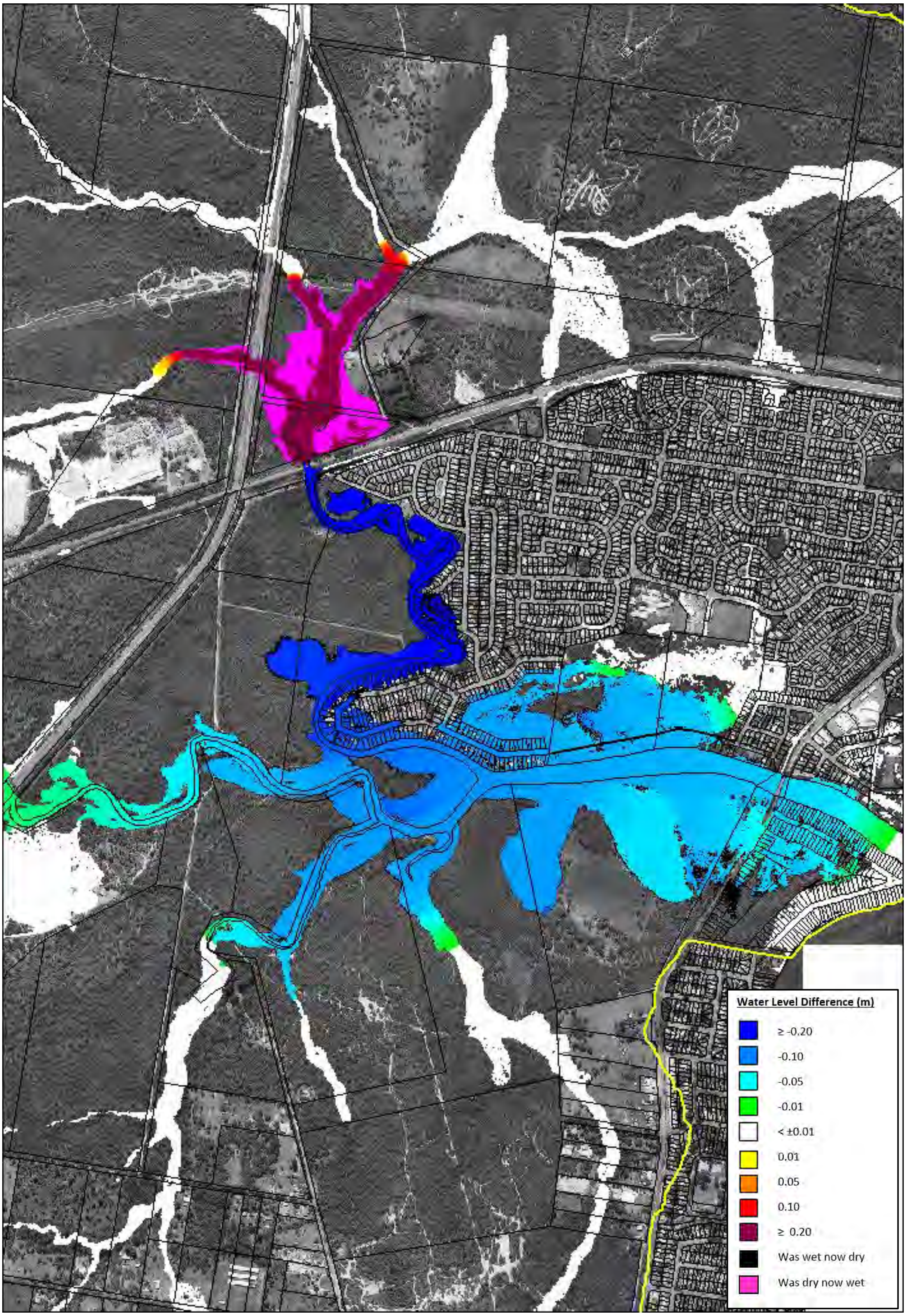


Plate 15 1% AEP Flood Level Difference Map for FM1

This option would likely improve emergency response along some of more problematic flooding areas (i.e., Turner Close). More specifically, 20 minutes of additional evacuation time would be provided along Turner Close during the 1% AEP flood. However, negligible improvements are predicted along Birdwood Drive.

The construction works would be located in close proximity to an Aboriginal land claims area. Therefore, if this option proceeds to more detailed design stages, it may be necessary to consult with the local land owner and/or the NSW Aboriginal Land Council. As it currently stands, the works are contained within the roadway reserve. Therefore, as a minimum, consultation with RMS would be required.

It is also noted that the basin embankment would partly extend into the edge of an Endangered Ecological Community (ECC) (Swamp Sclerophyll Forest on Coastal Floodplain). The ECC status indicates that the area has special protection due to the rare status of the community. Although this does not necessarily mean the works cannot be completed, it may limit the extent of works that are possible and, as a minimum, would require a referral to the Australian Government Minister for the Environment for assessment and approval.

As discussed in Section 3.2.6, areas adjoining Birdwood Drive and Turner Close are predicted to be exposed to a significant hazard (i.e., H5 or H6) during the PMF. Therefore, the PMF results with FM1 in place were also reviewed to determine if this option would reduce the hazard during the PMF to more tolerable levels. This review determined that FM1 would reduce peak flood levels across these areas during the PMF. However, the reductions were typically less than 0.1 metres and were, therefore, insufficient to reduce the flood hazard across this area to more tolerable levels. That is, areas adjoining Birdwood Drive and Turner Close would still be exposed to a significant flood hazard during the PMF even if option FM1 was implemented.

In addition, the results of the PMF simulation within FM1 in place showed that floodwaters are predicted to be redirected across Doyalson Link Road and into properties adjoining Popran Way, Waterhen Close and Olney Drive (refer **Plate 16**). This indicates that the full length of the basin embankment is predicted to be overtopped during the PMF and further refinement of the spillway design would be required to ensure it can safely convey the PMF and ensure downstream properties are not adversely impacted.

As noted in Section 3.4, future catchment development does have the potential to increase the severity of flooding across the catchment, most notably along Spring Creek. Accordingly, the potential for this option to offset future catchment development impacts was also investigated. This was completed by undertaking an additional 1% AEP simulation using the "future catchment conditions" hydrology and with FM1 in place.

Peak floodwater level difference maps for the 1% AEP flood is provided in **Plate 17**. The difference map was prepared by subtracting peak flood levels for <u>existing</u> catchment conditions from peak future catchment flood levels with the basin in place (to verify if the basin could suitably mitigate the adverse impacts that are predicted under future catchment conditions).

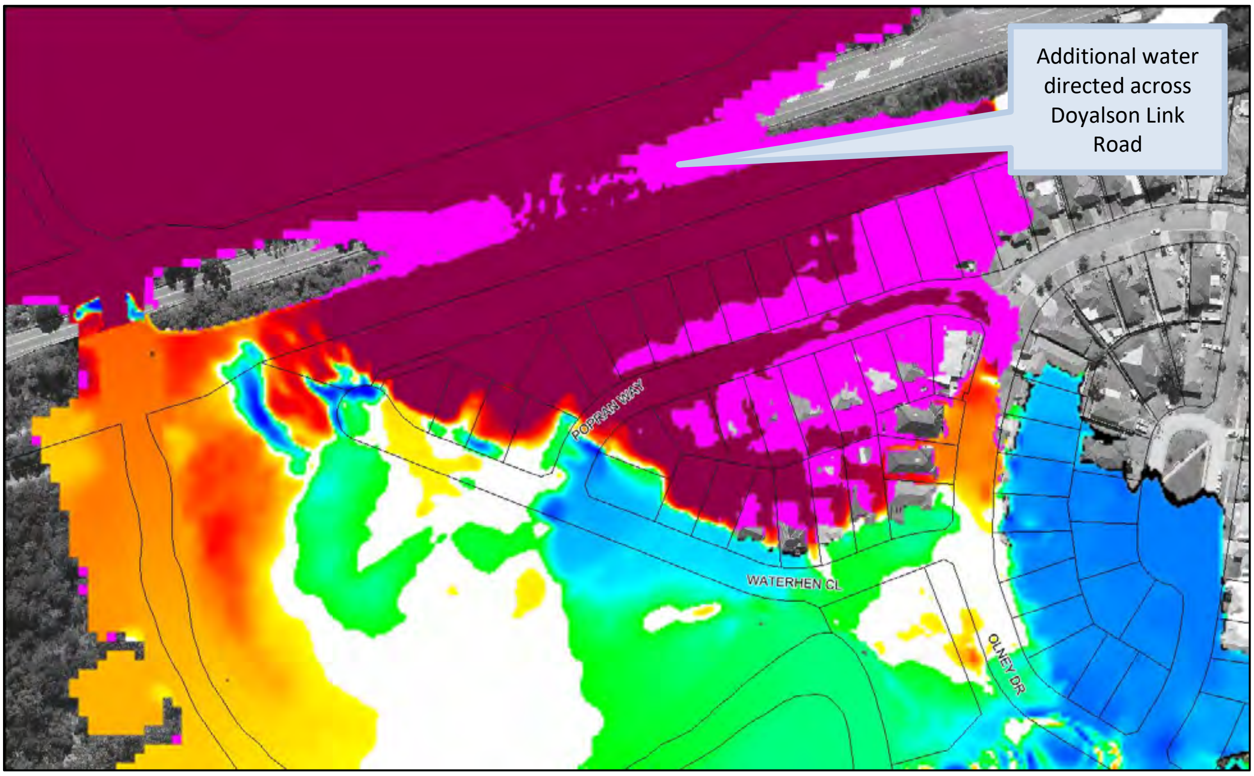


Plate 16 PMF Flood Level Difference Map for FM1

The differences shown in in **Plate 17** indicate that inclusion of the basin is predicted to reduce peak future 1% AEP flood levels to less than existing levels along Spring Creek downstream of Doyalson Link Road. This includes flood level reductions of 0.18 metres near Turner Close and 0.09 metres in the vicinity of Birdwood Drive. Accordingly, implementation of FM1 appears to have potential as a means of ensuring the existing flood risk along Spring Creek does not increase (and actually reduces) as a result of future catchment development.

If the basin is targeted towards managing the flood risk associated with future catchment development (rather than the existing flood risk), a developer contribution plan could be established for the catchment to help fund the construction of the basin (i.e., the basin could be funded under Section 7.11/7.12 contributions). This would significantly improve the financial feasibility of the option as a significant proportion of the implementation cost would be borne by developers.

Although this option does not appear to be a financially viable option for managing the existing flood risk, it does have the potential to be a viable option for managing the future flood risk. Notwithstanding, there are several areas that warrant further detailed assessment before the viability of this option can be confirmed. This includes an EEC assessment, discussions with RMS and refinement of the basin design to better cater for the PMF as well as more frequent floods. If these assessments yield a positive outcome, then this option should be strongly considered for managing the future flood risk.

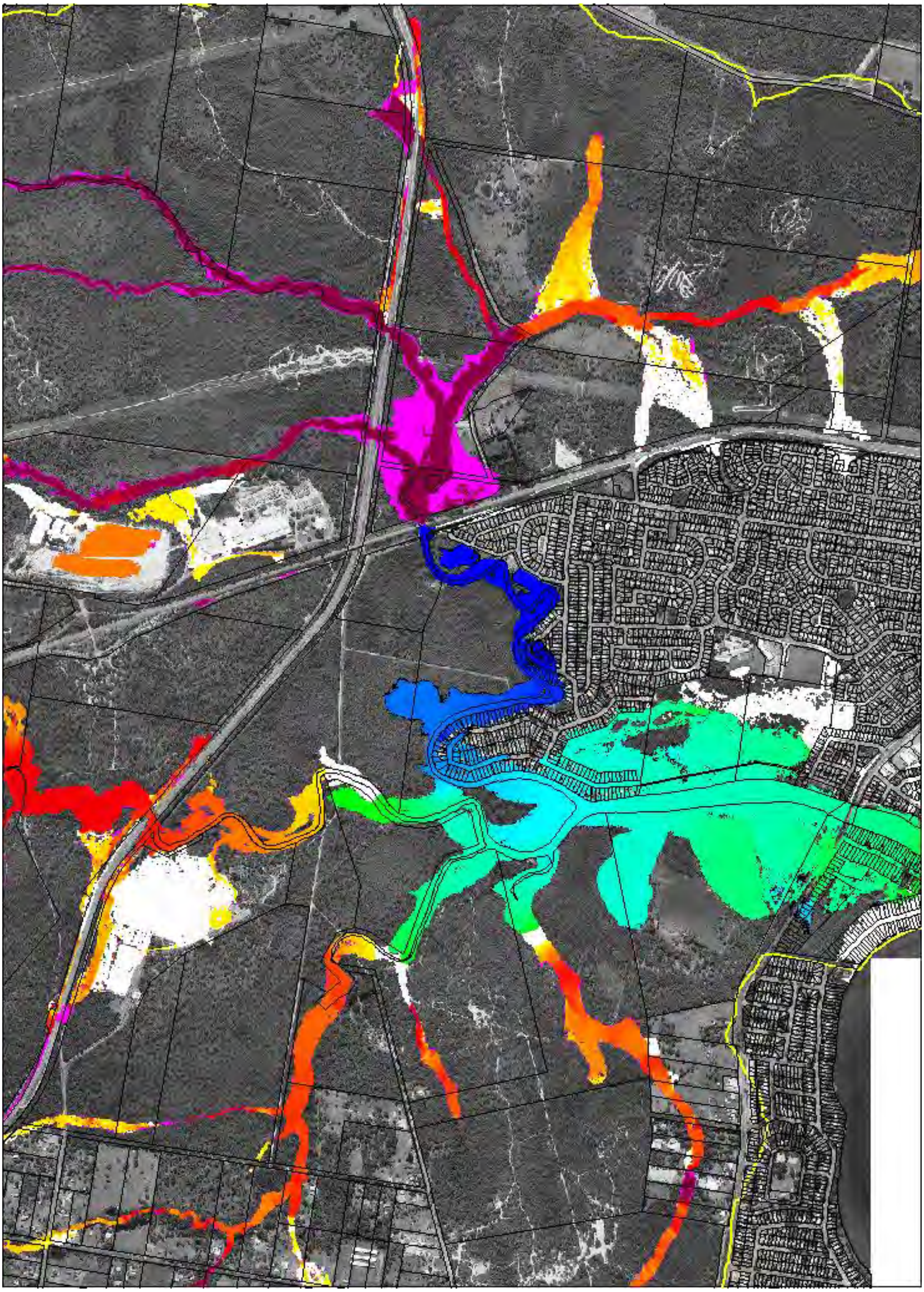


Plate 17 1% AEP Flood Level Difference Map for FM1 with future catchment conditions

7.2.2 FM2 – Modify Pinehurst Way Detention/Water Quality Basin

Recommendation: Not recommended for implementation in isolation. Could be considered for implementation in conjunction with other Pinehurst Way options

This option involves modifications to the existing spillway of a detention/water quality basin located behind 26-28 Pinehurst Way, Blue Haven. This would aim to reduce the maximum water level in the basin, thereby allowing the existing stormwater system in Pinehurst Way to drain more "freely".

The extent of the potential works is shown in **Figure 24** and will involve lowering the existing basin spillway from 2.8 mAHD to 2.5 mAHD. The spillway will also be widened to allow for a greater outflow capacity once the capacity of the basin is exceeded.

The concept design for the modified basin was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 18** and **Plate 19**.

Plate 18 and **Plate 19** show that the modified basin is predicted to generate flood level reductions within the basin of around 0.3 metres. However, the flood level reductions across Pinehurst Way are not nearly as significant. More specifically, flood level reductions during the 20% AEP are predicted to be less than 0.01 metres along Pinehurst Way and just over 0.01 metres along the reserve between 28 and 30 Pinehurst Way. During the 1% AEP flood, flood level reductions of just over 0.01 metres are predicted in Pinehurst Way. Some localised flood level increases are predicted to the south of the basin, which is associated with the additional water being released from the basin. However, the increases are very localised and extend across non-habitable areas.

A preliminary cost estimate for the basin modifications was prepared and is included in **Appendix E**. This determined that the basin modifications would cost approximately $80,000 to implement.

Revised flood damage calculations were prepared based upon the hydraulic modelling results with the basin modifications in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $26,000 was predicted over the next 50-years. This yielded a preliminary BCR of 0.3. Accordingly, the financial cost of implementing this option outweighs the financial benefits.

The proposed works would occur in close proximity to an ecologically endangered community (EEC) (i.e., swamp oak floodplain forest). Although all of the proposed works would likely occur outside of the ECC, the extent of the ECC would need to be confirmed onsite and care would need to be exercised during construction to ensure this area is not adversely impacted.

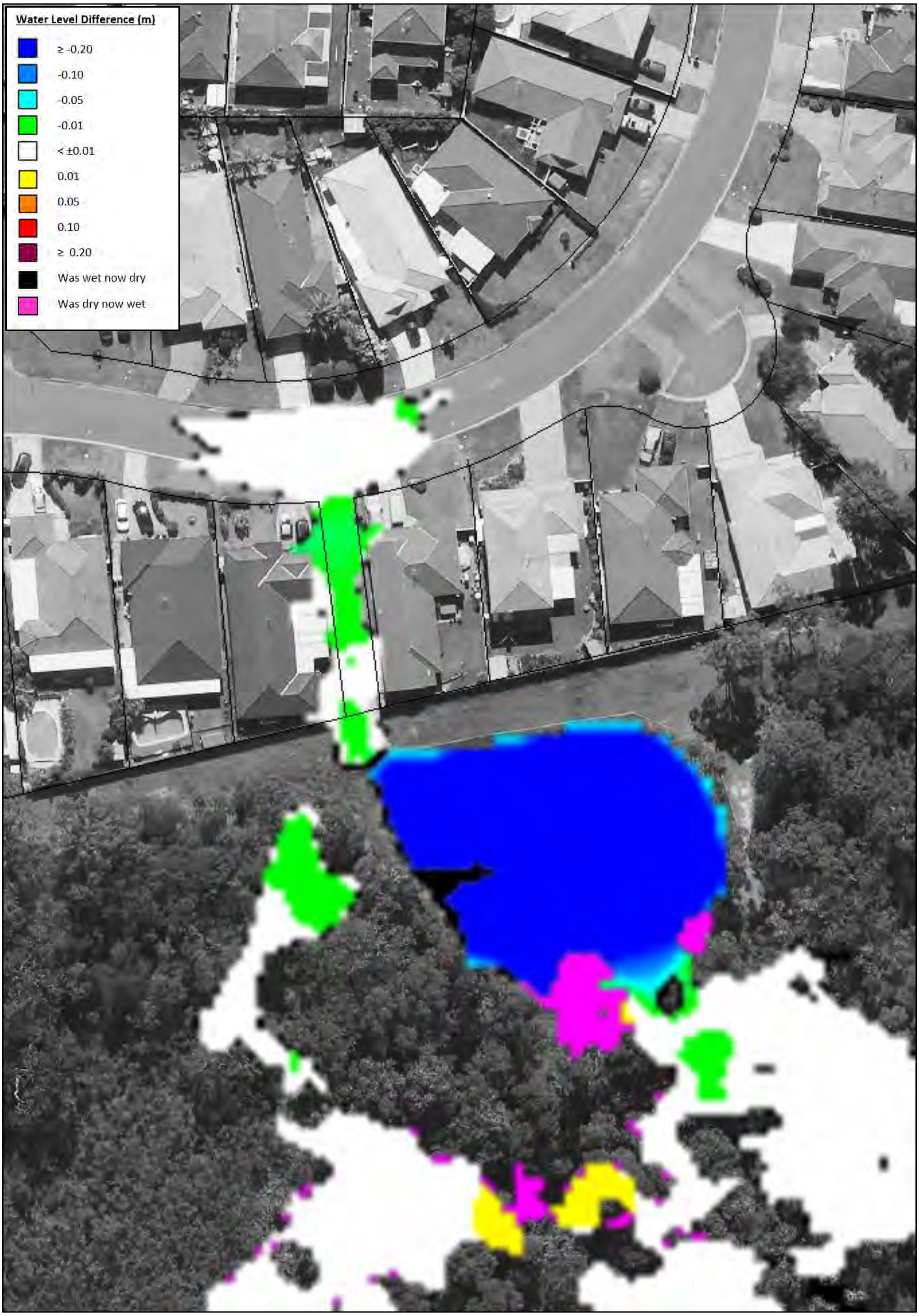


Plate 18 20% AEP Flood Level Difference Map for FM2

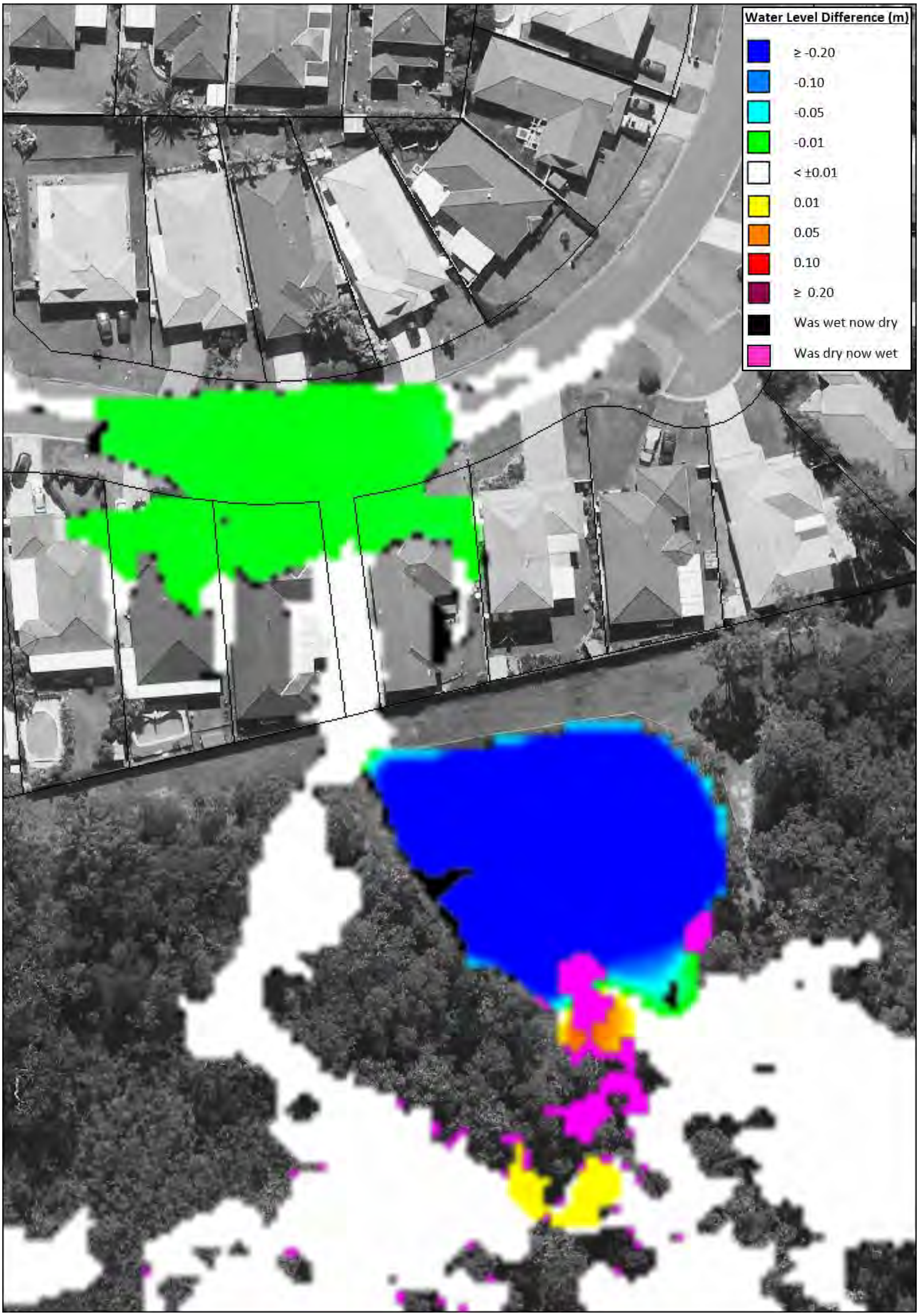


Plate 19 1% AEP Flood Level Difference Map for FM2

The low BCR makes this option difficult to support in isolation. However, it could be considered for implementation in conjunction with some of the other Pinehurst Way options. The individual options are discussed in subsequent sections and the combination of the individual options is discussed further in Section 7.6.1.

7.3 Drainage Modifications

7.3.1 FM3 – Pinehurst Way Stormwater Upgrades

Recommendation: Can be considered for implementation in isolation. However, greater benefits would be afforded if combined with other Pinehurst Way mitigation options

As shown on **Figure 12.1**, the existing stormwater pipe that drains stormwater from the low point in Pinehurst Way into the basin located behind 26-28 Pinehurst Way is predicted to have a capacity of less than a 20% AEP event. As a result, properties adjoining this low point are predicted to be exposed to relatively frequent flooding.

As shown in **Figure 25**, this option would look to increase the capacity of this section of the stormwater system by replacing the existing 1.05 metre diameter pipe with a 0.9m high by 2.4 metre wide box culvert.

The concept design for the stormwater upgrade was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 20** and **Plate 21**.

Plate 20 and **Plate 21** show that the stormwater upgrades are predicted to produce some notable reductions in existing flood levels across Pinehurst Way and adjoining properties. Reductions of around 0.07 metres are predicted during the 20% AEP flood and reductions of just over 0.1 metres are predicted during the 1% AEP flood.

The additional water that is directed through the culvert is predicted to increase flood levels within the receiving basin as well as downstream of the basin. However, the increases are predicted to be no greater than 0.03 metres and do not extend across any habitable areas.

A preliminary cost estimate for the stormwater upgrades was prepared and is included in **Appendix E**. This determined that the stormwater upgrades would cost approximately $270,000 to implement.

Revised flood damage calculations were prepared based upon the hydraulic modelling results with the stormwater upgrades in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $220,000 was predicted over the next 50-years. This yielded a preliminary BCR of 0.8. Accordingly, the financial cost of implementing this option slightly outweighs the financial benefits (although not substantially so).

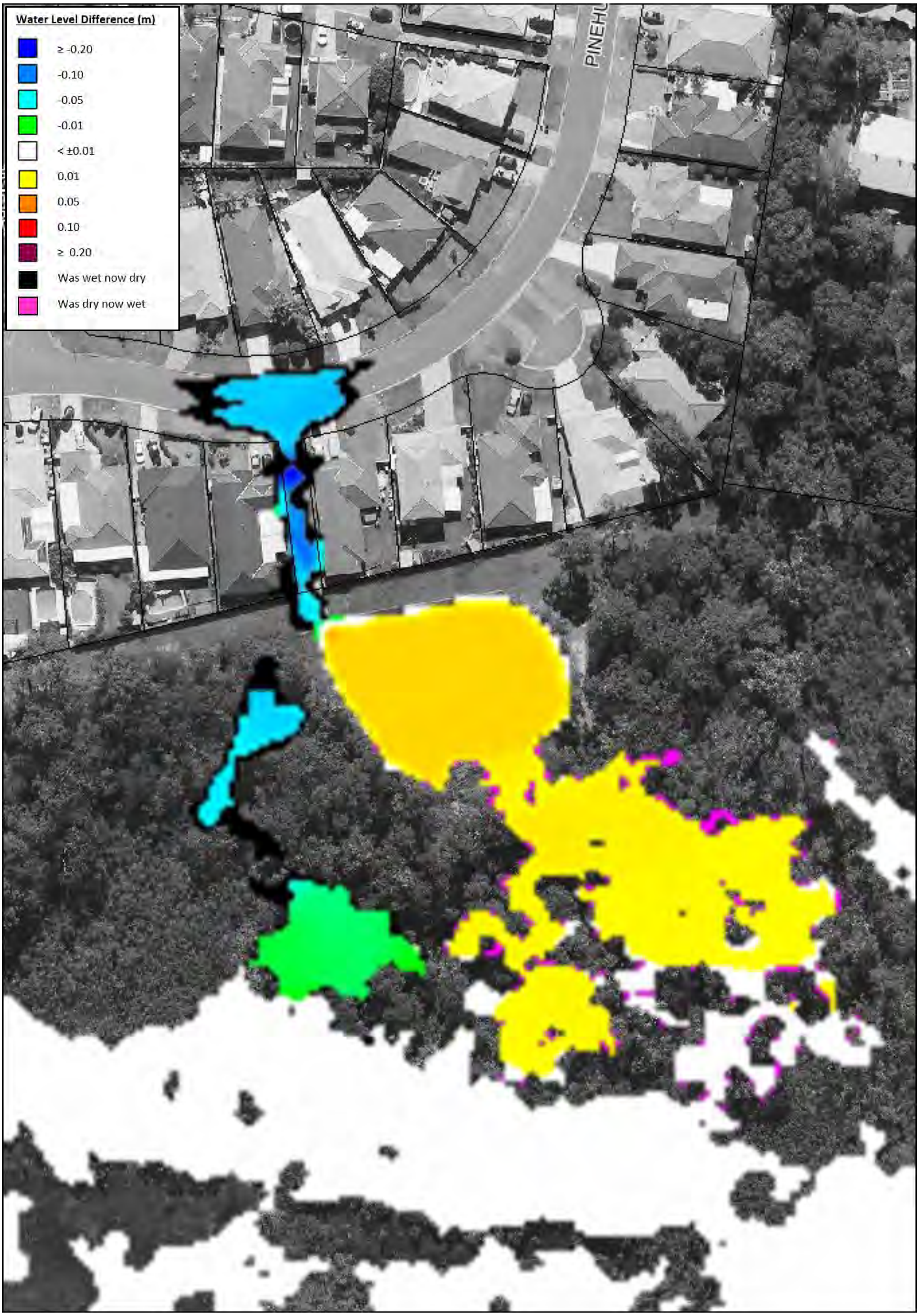


Plate 20 20% AEP Flood Level Difference Map for FM3

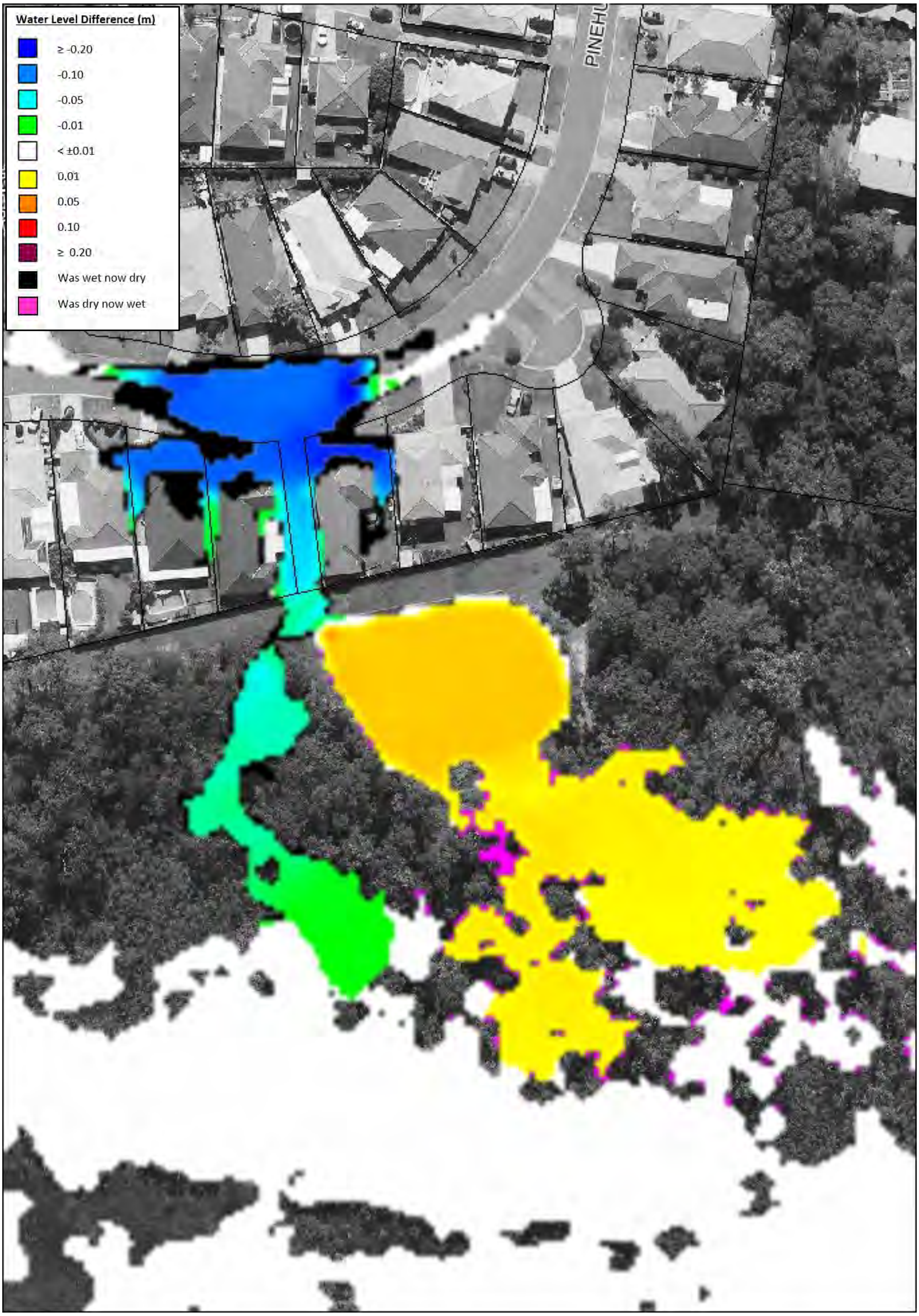


Plate 21 1% AEP Flood Level Difference Map for FM3

A review of existing services in the vicinity of Pinehurst Way indicate a number of services in the area, including (refer **Plate 22**):

- A sewer lines running along the boundary of 28 Pinehurst Way in close proximity to the works. Sewer lines also along the southern boundaries of the Pinehurst Way properties;
- Water mains on the southern side of Pinehurst Way);
- Telstra cables on the southern side of Pinehurst Way;
- Jemena gas main on the southern side of Pinehurst Way;
- AusGrid electrical mains located on the southern side of Pinehurst Way.

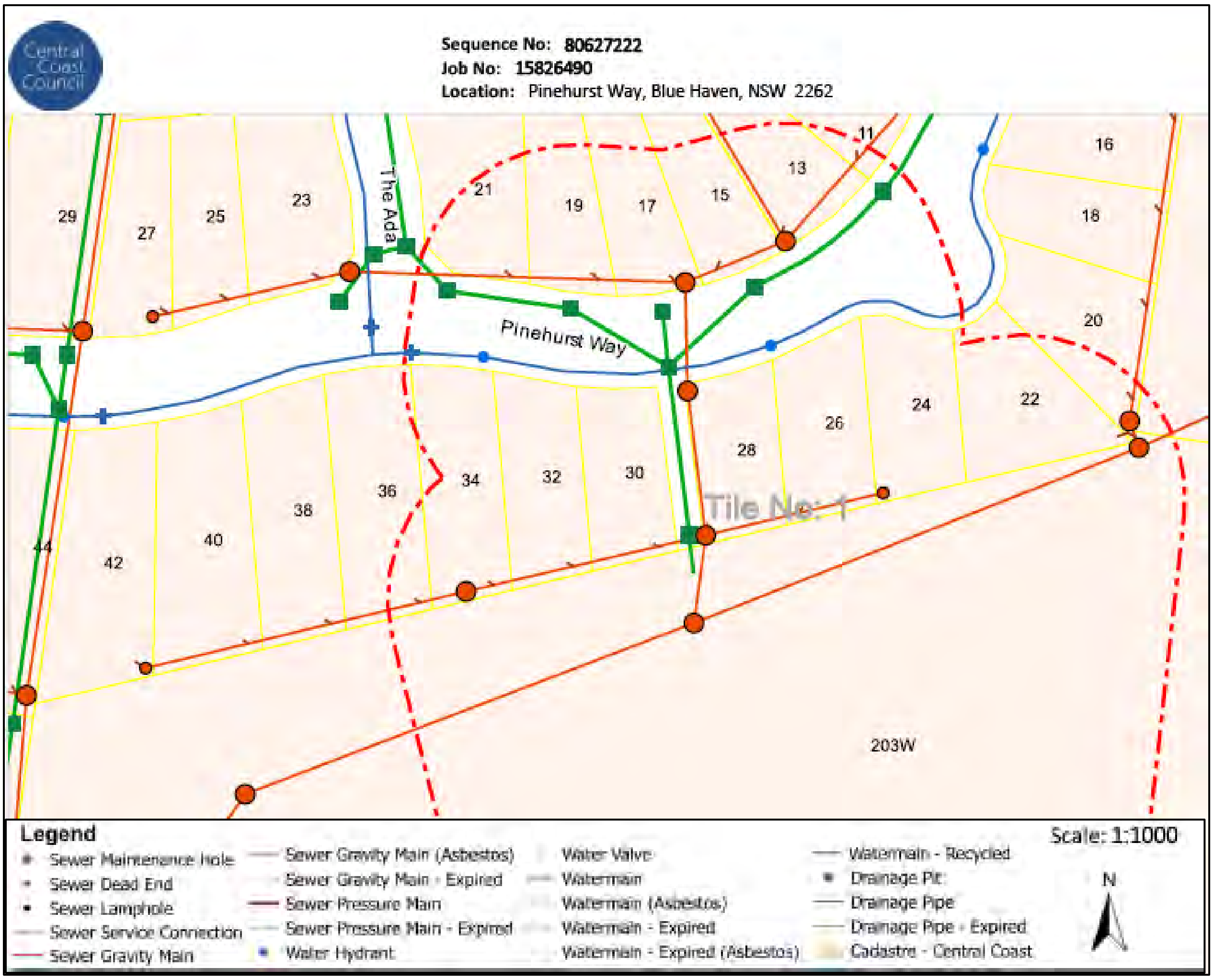


Plate 22 Existing services in the vicinity of Pinehurst Way, Blue Haven (Source: Central Coast Council)

Due to the proximity of some services to the proposed stormwater upgrades, additional subsurface investigations would need to be completed to confirm the exact location of these services and, therefore, confirm the potential extent of the stormwater upgrades. As the proposed stormwater upgrades would not extend any "higher" or "deeper" than the current stormwater pipe, the services in Pinehurst Way as well as along the southern boundary of the Pinehurst Way properties are unlikely to conflict with the proposed stormwater upgrades. However, the sewer running along 28 Pinehurst Way may impact on the lateral extent of the upgrades (i.e., the culvert width may need to be reduced).

The questionnaire responses (refer Section 2.6.3) also indicate that stormwater upgrades are one of the most preferred strategies for reducing the existing flood risk. That is, the stormwater upgrades are likely to be supported by the community.

The stormwater upgrades would likely afford improved emergency response along Pinehurst Way as it will reduce the frequency of inundation of the roadway and, therefore, the frequency that motorists may be tempted to drive through floodwaters. However, the emergency response benefits will be very localised.

Although the BCR of this option is less than 1, it does afford some significant hydraulic and financial benefits. It is suggested that the financial viability of this option could be improved by combining it with the other Pinehurst Way options. The combined Pinehurst Way option is discussed further in Section 7.6.1.

7.3.2 FM4 – Brava Avenue Floodwall and Drainage Modifications

Recommendation: Not recommended for implementation

This option would look to reduce the predicted extent of inundation across properties adjoining Brava Avenue by diverting flood flows into the watercourse located near the eastern end of Brava Avenue. As shown in **Figure 26**, this is to be achieved by constructing a small wall at the rear of the Brava Avenue properties to capture flow from the adjoining shopping centre and implementation of a swale and pipe system to direct the captured flows into the watercourse. As shown in **Figure 26**, the wall would need to be between 0.6 and 0.9 metres high (top of wall = 2.35 mAHD) to fully capture the 1% AEP flood.

The concept design for FM4 was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 23** and **Plate 24**.

Plate 23 shows inundation of properties on the northern side of Brava Avenue is eliminated during the 20% AEP flood. Along Brava Avenue itself, flood levels are predicted to reduce by around 0.05 metres. Minor inundation is still predicted across some properties on the southern side of Brava Avenue, however the peak flood levels are generally reduced by 0.03 metres.

Plate 24 shows that more extensive flood level reductions are predicted during the 1% AEP flood, with properties on the northern and southern side of Brava Avenue predicted to experience reductions of between 0.01 and 0.07 metres. Although the extent of inundation is reduced, it is not eliminated during the 1% AEP flood.

Plate 23 and **Plate 24**, also show flood level increases of between 0.1 and 0.2 metres are predicted on the northern side of wall. Along the receiving watercourse (located at the eastern end of Brava Avenue) flood level increases of 0.01 to 0.02 metres are anticipated. In general, the flood level increases do not extend across habitable areas.

Plate 23 20% AEP Flood Level Difference Map for FM4

Plate 24 1% AEP Flood Level Difference Map for FM4

A preliminary cost estimate for FM4 was prepared and is included in **Appendix E**. This determined that the implementation cost would be approximately $300,000.

Revised flood damage calculations were prepared based upon the hydraulic modelling results with the option in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $70,000 was predicted over the next 50-years. This yielded a preliminary BCR of 0.2. Accordingly, the financial cost of implementing this option outweighs the financial benefits.

Overall, the flood wall and drainage modifications are not predicted to afford particularly significant reductions in flood levels and extents. This is reflected in the low BCR of 0.2. As a result, this option is not recommended for implementation.

7.4 Channel Modifications

7.4.1 FM5 – Creek Maintenance/Removal of Dense Vegetation

Recommendation: Not recommended for implementation

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

As shown in **Figure 27**, most of the vegetated areas adjoining Wallarah and Spring Creeks fall within a Coastal Environment Area under the Coastal Management Act. Parts also extend across a coastal wetland area or include ecologically endangered communities. Accordingly, there are many sensitive ecological communities in the area that will significantly limit the removal of vegetation across these areas. However, a reduced clearing option involving just the removal of non-native plant species could be investigated. This may assist in reducing the resistance to flow afforded by the vegetation and provide improvements to local flora and fauna, thereby, meeting the requirements of the Coastal Management Act. However, it would require expert involvement to ensure that endangered species are not removed or damaged.

The extent of the area where vegetation removal was investigated as part of the study is shown in **Figure 27**. As shown in **Figure 27**, the vegetation removal includes sections of the floodplain contained within ~10 metres of Spring Creek, Wallarah Creek and the unnamed watercourse adjoining Brava Avenue. No vegetation removal was assumed to be undertaken across private properties.

The option was included in the TUFLOW model by applying a reduced Manning's "n" roughness coefficient to the areas where the vegetation removal is proposed, and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 25** and **Plate 26**.

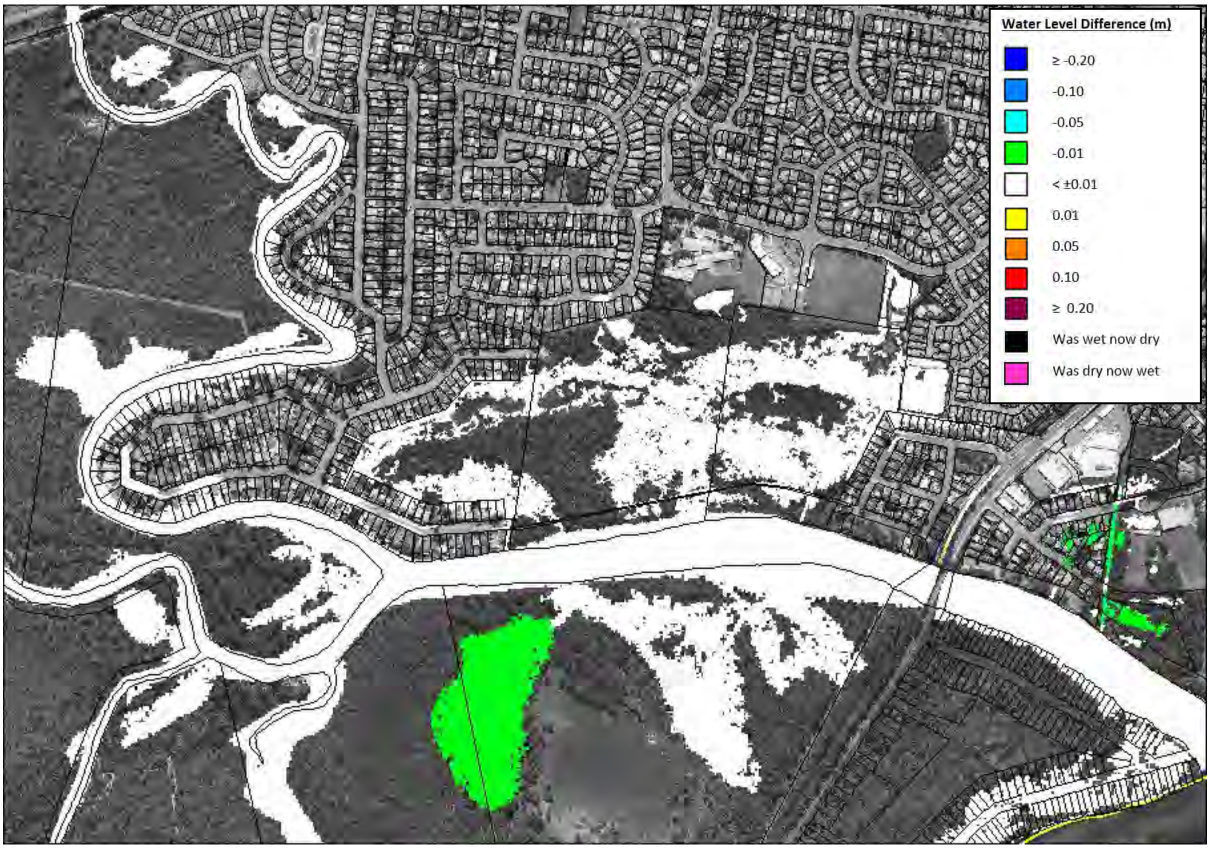


Plate 25 20% AEP Flood Level Difference Map for FM5

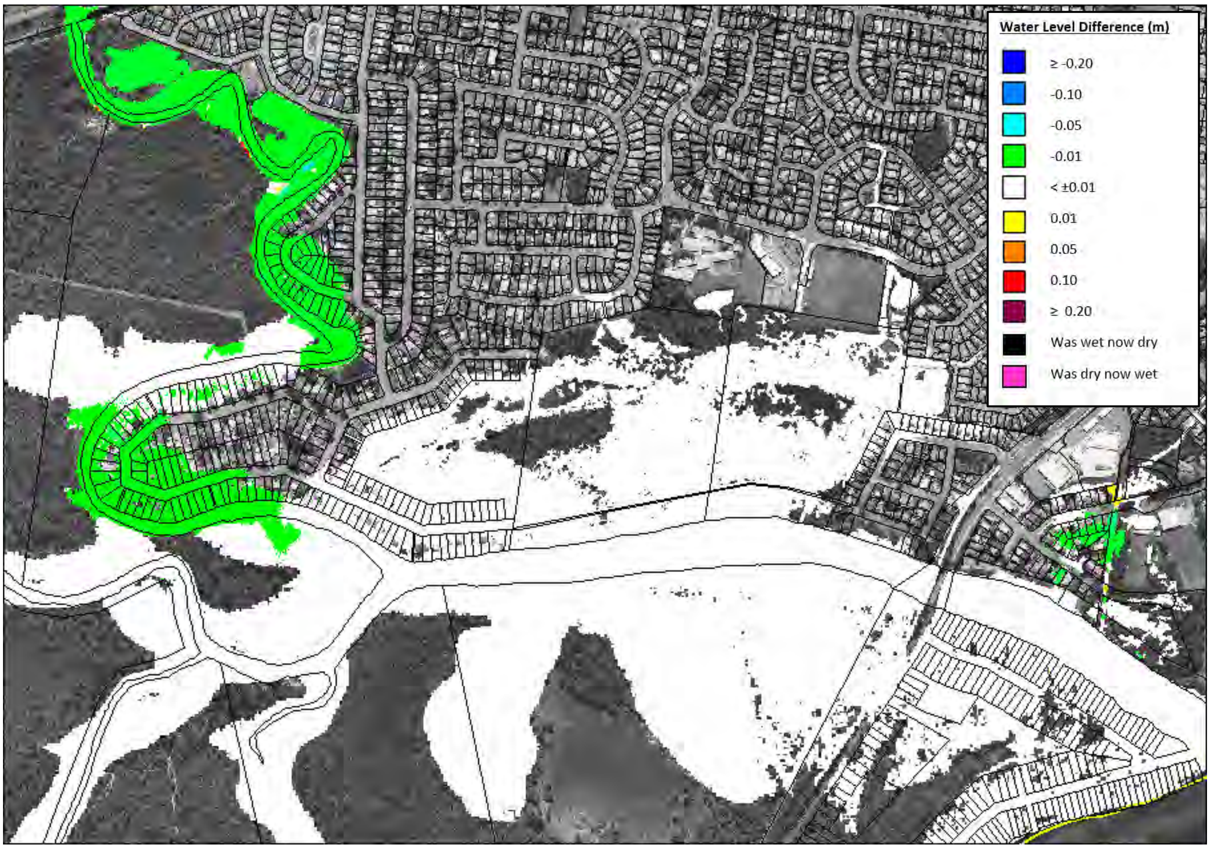


Plate 26 1% AEP Flood Level Difference Map for FM5

Plate 25 and **Plate 26** show that the vegetation removal is predicted to generate small, localised reductions in existing flood levels. The flood level reductions along Wallarah Creek are typically less than 0.02 metres and flood level reductions in the vicinity of Brava Avenue are generally less than 0.03 metres. Accordingly, the hydraulic benefits of this option are minor.

A preliminary cost estimate for the vegetation removal was prepared and is included in **Appendix E**. This determined that vegetation removal would cost over $2 million to implement over 50 years. The relatively high costs are associated with the considerable ongoing maintenance costs that would be required to maintain the selective vegetation clearing.

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the vegetation clearing. This determined that vegetation clearing would not reduce flood damage costs. This provides a BCR of zero indicating that there are minimal economic incentives to implement this option.

There may be opportunities for local land care groups to be involved in clearing of non-native species which may assist in reducing the up front and ongoing costs of implementation of this option. But, as discussed, this would need to be guided by experts and it is unlikely to improve the hydraulic and flood damage outcomes (i.e., the BCR would likely remain zero).

As discussed, the primary disadvantage associated with this option is the potential for adverse environmental impacts. This is considered to be a significant impediment to the implementation of this option given the large range of ecologically sensitive assets in the area.

Overall, the high capital and ongoing costs and negligible financial benefits mean that vegetation clearing is not supported for implementation.

7.4.2 FM6 – Spring Creek High Flow Bypass

Recommendation: Not recommended for implementation

The Spring Creek High Flow Bypass would aim to lower existing ground surface elevations to allow water to spill from Spring Creek into Wallarah Creek during large floods (thereby reducing water levels in Spring Creek). As shown in **Figure 28**, this will involve lowering the existing terrain between Spring Creek and Wallarah Creek from >2 mAHD to around 1 mAHD. Therefore, the bypass would only be "activated" during floods where the water level in Spring Creek exceeds 1 mAHD.

The TUFLOW model was updated to include a representation of the bypass. As the area is located within a Coastal Environment Area under the Coastal Management Act, it was assumed that the existing vegetation would be reinstated to its current form (i.e., only the terrain was modified). The updated model was subsequently used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 27** and **Plate 28**.

Plate 27 20% AEP Flood Level Difference Map for FM6

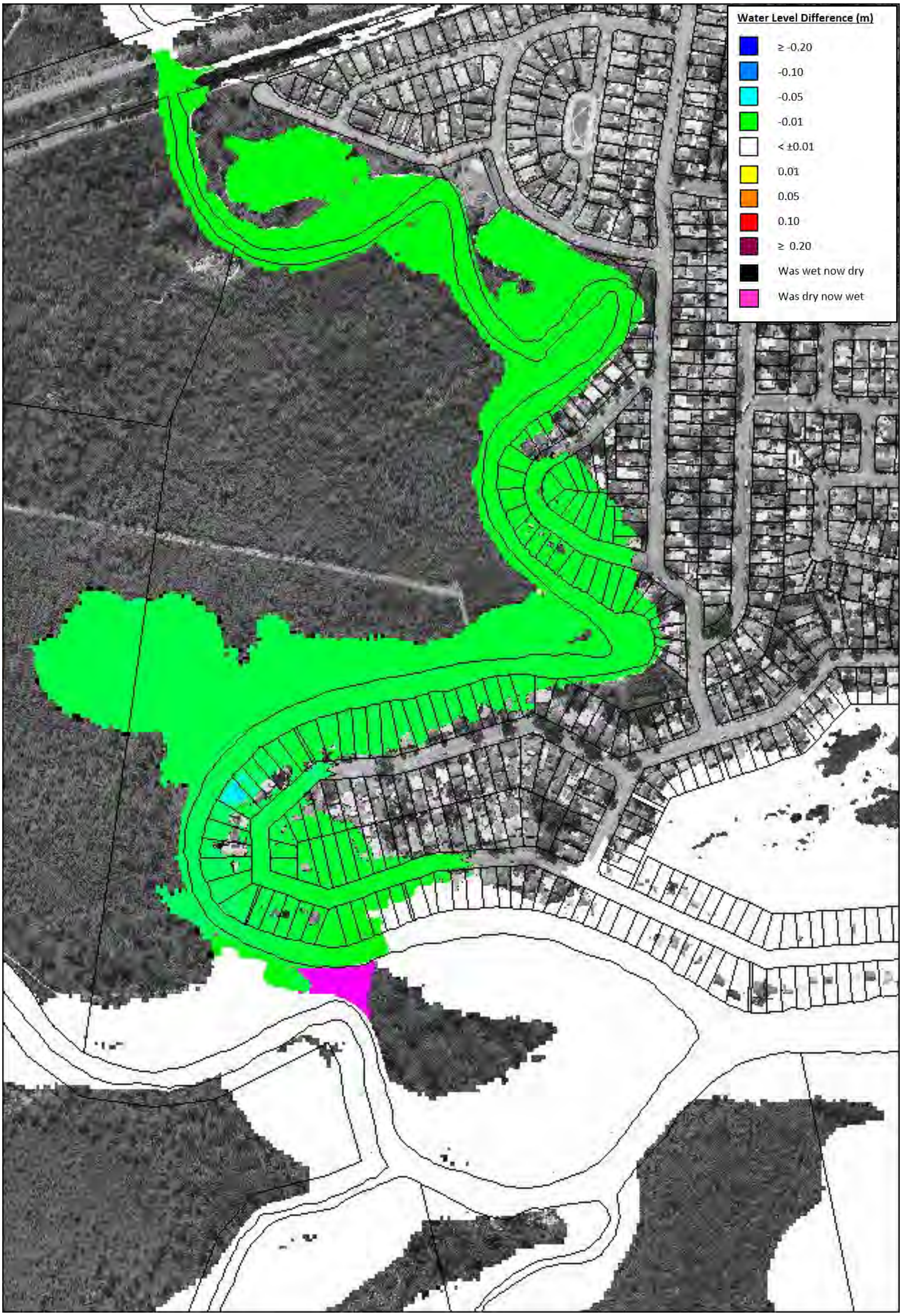


Plate 28 1% AEP Flood Level Difference Map for FM6

Plate 27 and **Plate 28** show that the high flow bypass is predicted to generate small reductions in flood levels along Spring Creek during the 20% and 1% AEP floods. Flood level reductions of up to 0.05 metres are predicted during the 20% AEP flood and reductions of up to 0.03 metres are predicted during the 1% AEP flood. In the vicinity of Turner Close and Birdwood Drive, flood level reductions are generally less than 0.03 metres. Small increases in flood level are also predicted along Wallarah Creek during the 20% AEP flood (although these increases do not extend across habitable areas).

A preliminary cost estimate was prepared and is included in **Appendix E**. This determined that the bypass would cost approximately $820,000 to implement. A significant contributor to this overall cost is associated with replanting/revegetation of the area.

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the bypass. This determined that flood damages would not change significantly if this option was implemented. This provided a BCR of zero.

Furthermore, part of the bypass extends into an Endangered Ecological Community (ECC). The ECC will make implementation of this option difficult to support from an environmental impact perspective.

The option would afford small emergency response improvements. More specifically, implementation of the option would provide a lightly more evacuation time for Turner Close and Birdwood Drive properties, however, the additional evacuation time is likely to be less than 10 minutes.

Overall, this option is not predicted to afford any significant hydraulic or financial benefits. As a result, it is not recommended for implementation.

7.4.3 FM7 – Allambee Crescent Channel Modifications

Recommendation: Not recommended for implementation

The rear yards of properties located on the northern side of Allambee Crescent are subject to relatively frequent inundation. During major floods (e.g., 1% AEP event), the majority of each of these lots is predicted to be submerged. Inundation occurs as a result of a small drainage channel that runs along the northern boundary of these properties (refer **Plate 29**). The most significant inundation occurs due to water “backing up” from the downstream wetland and overtopping the banks of the channel.

Originally, this option investigated the potential to enlarge the drainage channel. However, this yielded negligible benefits as the additional capacity afforded by the enlarged channel was insignificant relative to the volume of floodwater across the balance of floodplain.

Accordingly, this option was subsequently modified to include an elevated perimeter “bund” with a culvert structure that contains a flood gate. This option aims to prevent floodwaters from “backing up” along the drainage channel during Wallarah Creek floods but still allow floodwaters from the local catchment to drain in a westerly direction into the wetland adjoining Wallarah Creek.

Plate 29 Allambee Crescent Drainage Channel

Although it was considered desirable to provide a "bund" that afforded protection during all events up to and including the 1% AEP event, this would require significant topographic modifications that extend well beyond the drainage channel. Inspection of the available topographic information determined that a bund with a crest height of about 1.8 mAHD is likely to be the maximum achievable crest elevation and would afford protection during events up to and including the 20% AEP event. As shown in **Figure 29**, this will require elevating the pathway leading from Allambee Crescent as well as the embankment of the adjoining wetland (located on the northern side of the channel) by up to 0.9 metres (with fill depths less than 0.4 metres being most common). A 0.6 metre diameter pipe with a flood gate will also be required (the culvert will replace the existing footbridge).

The TUFLOW model was updated to include a representation of FM7. The updated model was subsequently used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 30** and **Plate 31**.

Plate 30 shows small reductions are predicted across the backyards of multiple Allambee Crescent properties. However, the magnitude of the reductions is quite small (i.e., <0.02 metres). **Plate 30** also shows flood level increases of up to 0.08 metres are predicted across the wetland. However, these increases are not predicted to extend across any adjoining properties.

Plate 30 20% AEP Flood Level Difference Map for FM7

Plate 31 1% AEP Flood Level Difference Map for FM7

Plate 31 shows negligible reductions in flood levels are predicted across Allambee Crescent properties at the peak of the 1% AEP flood. In fact, a small increase of 0.02 metres is predicted across one property. This indicates that the 0.6 metre diameter outlet pipe may be insufficient to fully convey the local catchment 1% AEP flows. Regardless, even if the size of the pipe size was increased, it is unlikely to yield any significant hydraulic benefits as the bund would be overtopped at the peak of the 1% AEP event. Similar to the 20% AEP flood, increases in flood levels are predicted across the wetland on the northern side of the channel, but the increases are contained to the wetland and do not extend across any habitable properties.

A preliminary cost estimate was prepared and is included in **Appendix E**. This determined that the bund and culvert system would cost approximately $360,000 to implement.

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the bund and culvert. This determined that flood damages would reduce by $7,000 over 50 years if this option was implemented. This provides a BCR of less than 0.1. Therefore, the financial benefits associated with the proposed modifications are much lower than the implementation costs to implement and maintain this option.

Emergency response benefits are considered to be negligible with no notable changes in flood levels across Allambee Crescent itself.

Overall, the low hydraulic and financial benefits indicate that this option is not worth pursuing.

7.4.4 FM8 – Enlarge Unnamed Watercourse Between Brava and Costa Avenues

Recommendation: Not recommended for implementation

As shown in **Figure 30**, FM8 will involve enlarging an existing, unnamed watercourse located at the eastern end of Brava and Costa Avenues, between Brava Avenue and Wallarah Creek. The channel enlargement aims to increase the conveyance capacity of the existing watercourse, thereby reducing the frequency of water overtopping the banks of the channel. It may also assist in improving the efficiency of the local stormwater system by lowering water levels in the receiving watercourse.

The TUFLOW model was updated to include a representation of the enlarged channel. It was assumed that the vegetation along the watercourse would be reinstated to current levels (i.e., only the channel geometry was modified). The updated model was subsequently used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 32** and **Plate 33**.

Plate 32 shows that the channel enlargement is predicted to provide significant reductions in 20% AEP flood levels along the watercourse itself (i.e., reductions >0.4 metres). More modest flood level reductions are predicted across some properties located south of Brava Ave (i.e., 0.04 metre reductions).

Plate 32 20% AEP Flood Level Difference Map for FM8

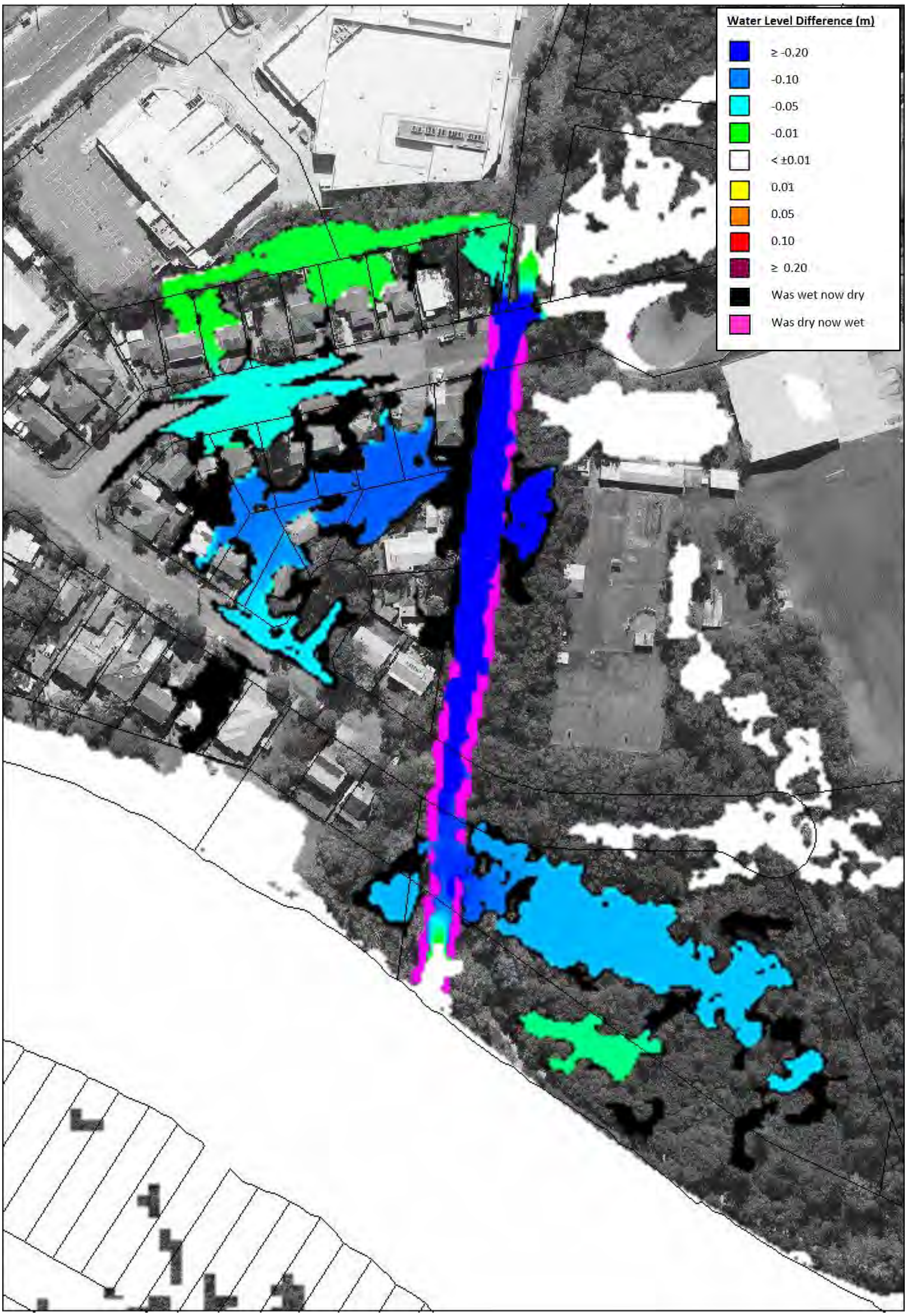


Plate 33 1% AEP Flood Level Difference Map for FM8

Plate 33 shows that some more extensive flood level reductions are predicted during the 1% AEP flood. This includes:

- > 0.3 metre reductions along the watercourse. This is sufficient to ensure floodwaters are fully contained to the channel during the 1% AEP flood;
- 0.13 metre reductions across properties located on the southern side of Brava Avenue; and,
- 0.02 metres reductions across properties located on the northern side of Brava Avenue.

Accordingly, the hydraulic benefits of this option tend to be most significant during larger floods.

A preliminary cost estimate was prepared for this option and is included in **Appendix E**. As shown in **Appendix E**, the channel enlargement is expected to cost approximately $300,000 to implement.

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the channel modification. This determined that flood damages would reduce by $120,000 over 50 years if this option was implemented. This provides a BCR of 0.4. Therefore, the financial benefits associated with enlarging the channel are lower than the costs to implement and maintain this option.

It is also noted that the channel works fall within a Coastal Environment Area under the Coastal Management Act. In addition, the creek is home to endangered ecological communities (e.g., swamp oak floodplain forest), which would likely restrict the potential to undertake significant works in the area.

In addition, the works would occur within a Class 3 Acid Sulfate Soils area (acid sulfate soils likely to be encountered >1m below the ground surface). Although, the works are not expected to involve excavation to depths of more than 1 metre, the presence of acid sulfate soils will need to be confirmed before any works can be completed. This may necessitate the preparation of an Acid Sulfate Soil Management Plan demonstrating how the excavated material will be managed.

The questionnaire responses (refer Section 2.6.3) indicate that the community generally supported channel enlargement as a flood risk reduction measure.

Overall, this option is predicted to afford some notable reductions in flood levels in the vicinity of Brava and Costa Avenue. Unfortunately, the most significant flood level reductions are contained to the watercourse and do not extend across habitable areas. In addition, the potential for adverse environmental impacts significantly reduces the viability of this option. As a result, this option is not recommended for implementation.

7.4.5 FM9 – Dredge Wallarah Creek Downstream of Spring Creek Confluence

Recommendation: Not recommended for implementation

This option investigates the potential benefits of dredging of the Wallarah Creek channel between Spring Creek and Budgewoi Lake. The dredging would aim to increase the flow carrying capacity of the main creek channel, thereby, reducing flood levels in the channel and, potentially, across the adjoining floodplain.

The extent of the dredging considered as part of the current study is shown in **Figure 31**. The dredged creek profile was determined by attempting to minimise the amount of works required in the vicinity of the bridge (to ensure the bridge foundations are not comprised). As shown in **Figure 31,** the bed of the creek would be lowered by up to 0.7 metres under this scenario.

Council does have access to a "cutter suction" dredge that is suitable for dredging fine silt and clay. This dredge may be suitable for dredging the downstream sections of the creek (i.e., near Budgewoi Lake), however, the sediment types would need to be confirmed to determine compatibility.

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

The potential environmental impacts are reflected in the large range of statutory requirements that would need to be satisfied before proceeding with any dredging activities. This may include:

- Commonwealth Environment Protection and Biodiversity Act 1999;
- Environmental Planning & Assessment Act 1979;
- Crown Lands Act 1989;
- Protection of the Environmental and Operations Act 1997;
- Threatened Species Conservations Act 1995;
- Fisheries Management Act 1994; and,
- Water Management Act 2000.

Figure 3 also shows that the dredging area falls within a Class 1 Acid Sulfate Soils area (i.e., acid sulfate soils are likely to be found on and immediately below the natural ground surface. If these soils are exposed to oxygen as part of the dredging process (which is likely), they would likely convert to Actual Acid Sulfate Soils and would potentially release acid and heavy metals into the surrounding environmental. Therefore, an Acid Sulfate Soil Management Plan would need to be prepared to demonstrate how the dredged material will be managed.

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

The up front and ongoing costs of dredging are also likely to be significant. The exact cost of ongoing dredging is difficult to estimate without detailed sediment transportation modelling to gain an understanding of the volume of sediment that is likely to be regularly deposited in the channel. It is estimated that 22,500 m^3 of sediment would need to be initially removed and, for the purposes of providing an indicative cost estimate, that an additional 20% of this volume would need to be removed by the dredge on an annual basis to maintain the dredged channel. These assumptions yielded a total implementation cost over 50 years of over $30 million (refer to **Appendix E** for a detailed cost breakdown). Accordingly, the life cycle cost of this option is significant.

The hydraulic impacts associated with dredging of the creek was quantified by updating the channel geometry in the hydraulic model to reflect the channel dredging. The updated TUFLOW model was then used to re-simulate each design flood. The flood level difference maps for the 20% and 1% AEP floods are also provided in **Plate 34** and **Plate 35**.

Plate 34 and **Plate 35** show that the dredging is predicted to reduce existing flood levels during the 20% AEP and 1% AEP floods. During the 20% AEP flood, flood level reductions are typically contained in close proximity to the creek channel, although flood level reductions of up to 0.1 metres are predicted across Birdwood Drive and reductions of up to 0.05 metres are predicted across some Turner Close properties. The flood level reductions are not sufficient to prevent inundation of Birdwood Drive during the 20% AEP flood.

Plate 35 shows that the flood level reductions are more expansive during the 1% AEP flood. Reductions of up to 0.1 metres across most of the eastern end of Birdwood Drive and reductions of around 0.03 metres are predicted across many Turner Close properties.

The flood level reductions would afford slightly improved emergency response with approximately 15 minutes of additional evacuation time being provided along Birdwood Drive and Turner Close.

Revised damage estimates were prepared based on the revised simulation results and determined that the dredging would potentially reduce flood damage costs by around $200,000. This yields a BCR of less than 0.01. Therefore, the high capital and ongoing costs are likely to significantly outweigh the financial benefits.

The financial viability of this option could be potentially improved if the dredging was completed by a commercial entity. For example, there may be opportunities for private operators to undertake the dredging and use the dredged material for aggregate in concrete, for example. However, this is highly dependent on the dredged material being suitable for commercial application (e.g. appropriate particle size distribution, grading, particle shape etc). Overall, the potential for the dredging to be being undertaken by a commercial entity cannot be guaranteed at this point in time. However, it could be explored if this option is investigated in more detail in the future.

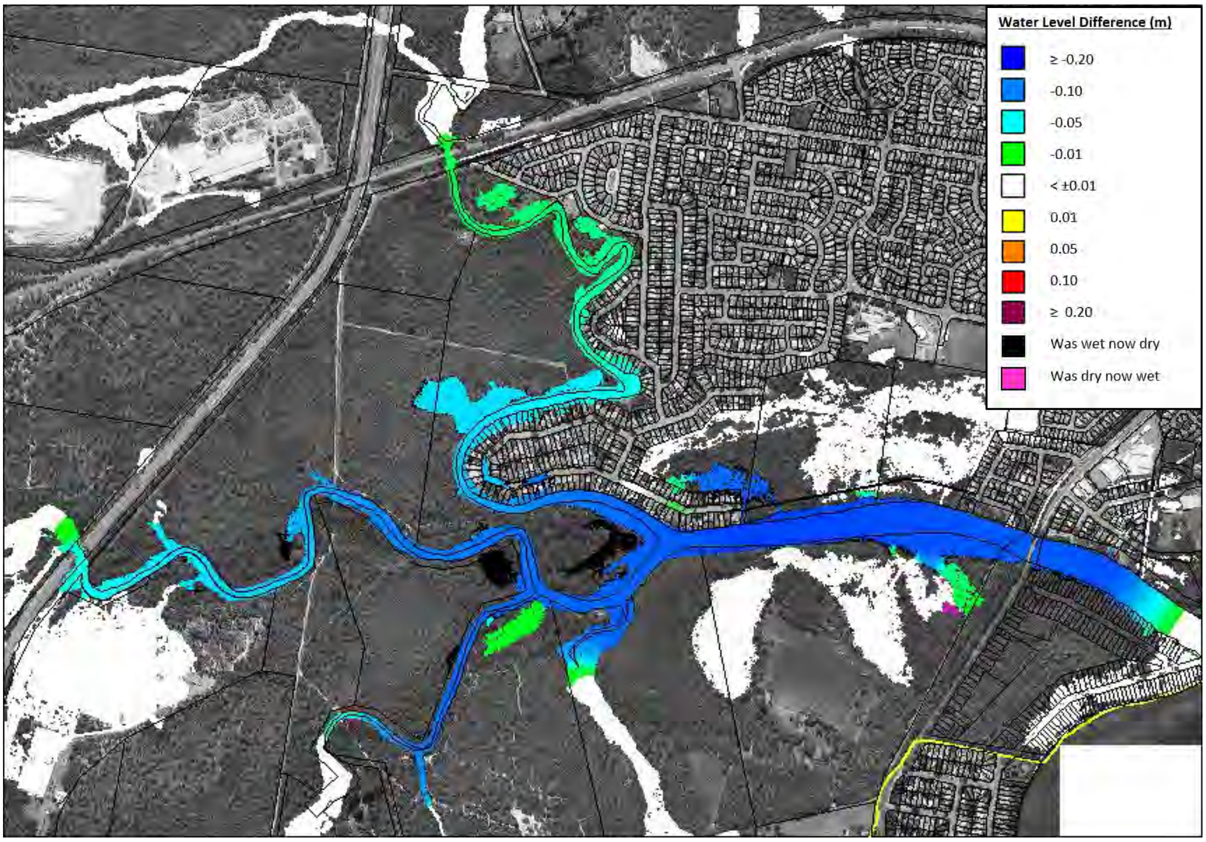


Plate 34 20% AEP Flood Level Difference Map for FM9

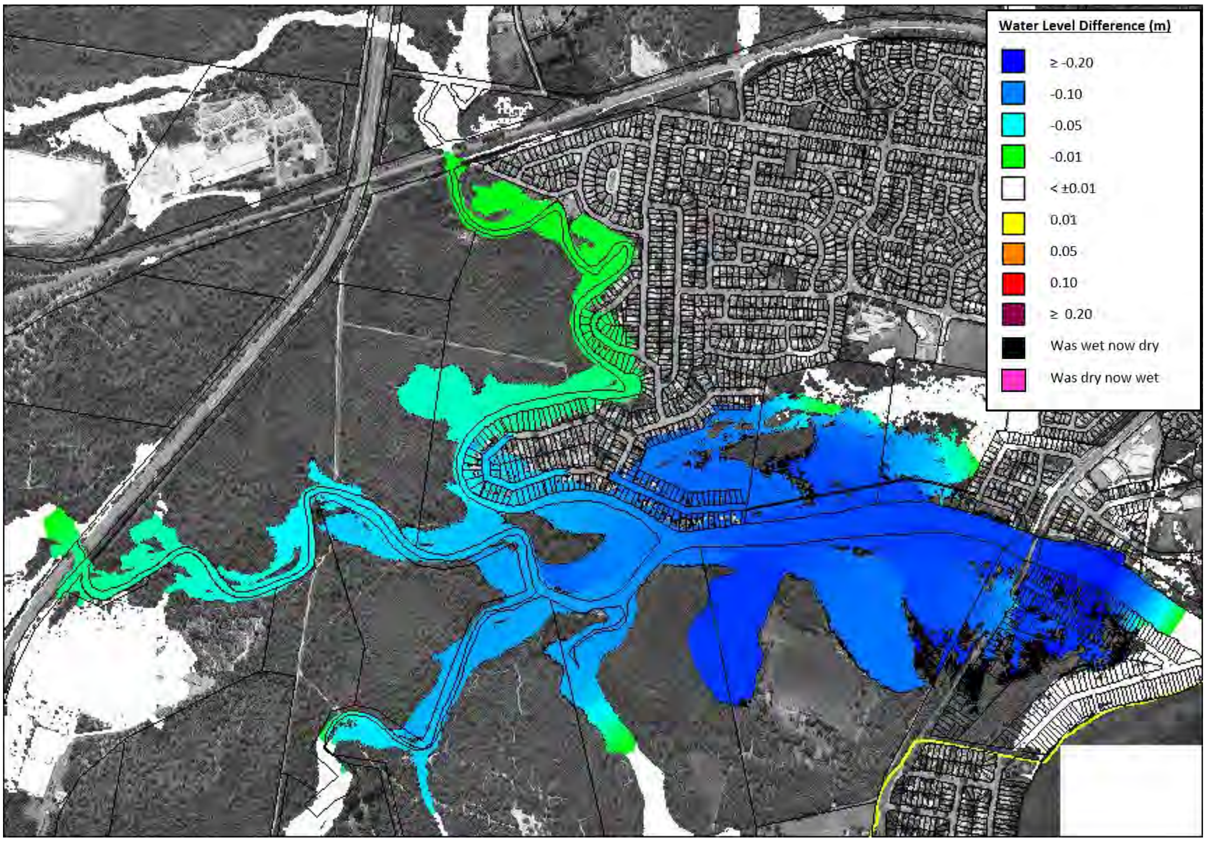


Plate 35 1% AEP Flood Level Difference Map for FM9

As it currently stands, the significant capital and ongoing costs coupled with the potential for significant environmental impacts make this option difficult to support.

7.5 Earthworks

7.5.1 FM10 – Pinehurst Way Flow Path Reshaping

Recommendation: Recommended for implementation in isolation or in conjunction with other Pinehurst Way mitigation options

This option would look to reshape the area located between 28 and 30 Pinehurst Way to more efficiently direct overland flows from the low point in Pinehurst Way to the rear of these properties. This will involve lowering the existing concrete "path" by around 0.1 metres to create a trapezoidal cross-section. Reshaping of the grassed area behind 30 Pinehurst Way would also occur to allow flows in excess of the capacity of the pipe system to bypass the basin located behind 28 Pinehurst Way. The design concept for this option is provided in **Figure 32**.

The concept design for the reshaping was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 36** and **Plate 37**.

The difference mapping included in **Plate 36** and **Plate 37** shows that the reshaping is predicted to reduce existing flood levels within Pinehurst Way and the northern sections of the reserve/flow path. Flood level reductions in this area are predicted to be about 0.09 metres during the 20% AEP flood and 0.12 metres during the 1% AEP flood.

Plate 36 and **Plate 37** also show that this option is predicted to generate flood level increases along the southern sections of the flow path as well as behind 30 Pinehurst Way. In general, the flood level increases are small (i.e., <0.05 metres) and extend across areas that are not habitable. Nevertheless, the flood level increases do extend in close proximity to the rear sections of 28 and 30 Pinehurst Way. Therefore, this option has the potential to reduce flood damages at the front of each property but arguably increase the potential for damage at the rear of properties. However, on average, the flood level reductions are far more extensive. Nevertheless, it does highlight the concept design for the reshaping may need to be refined to reduce the potential for flood level increases (e.g., potentially "deepen" the flow path near the southern property boundaries).

A preliminary cost estimate for the reshaping was prepared and is included in **Appendix E**. This determined that the reshaping would cost approximately $100,000 to implement.

Revised flood damage calculations were also prepared based upon the hydraulic modelling results with the reshaping in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $210,000 was predicted over the next 50-years. This yielded a preliminary BCR of 2.2. Accordingly, the benefits of implementing this option far outweighs the implementation costs.

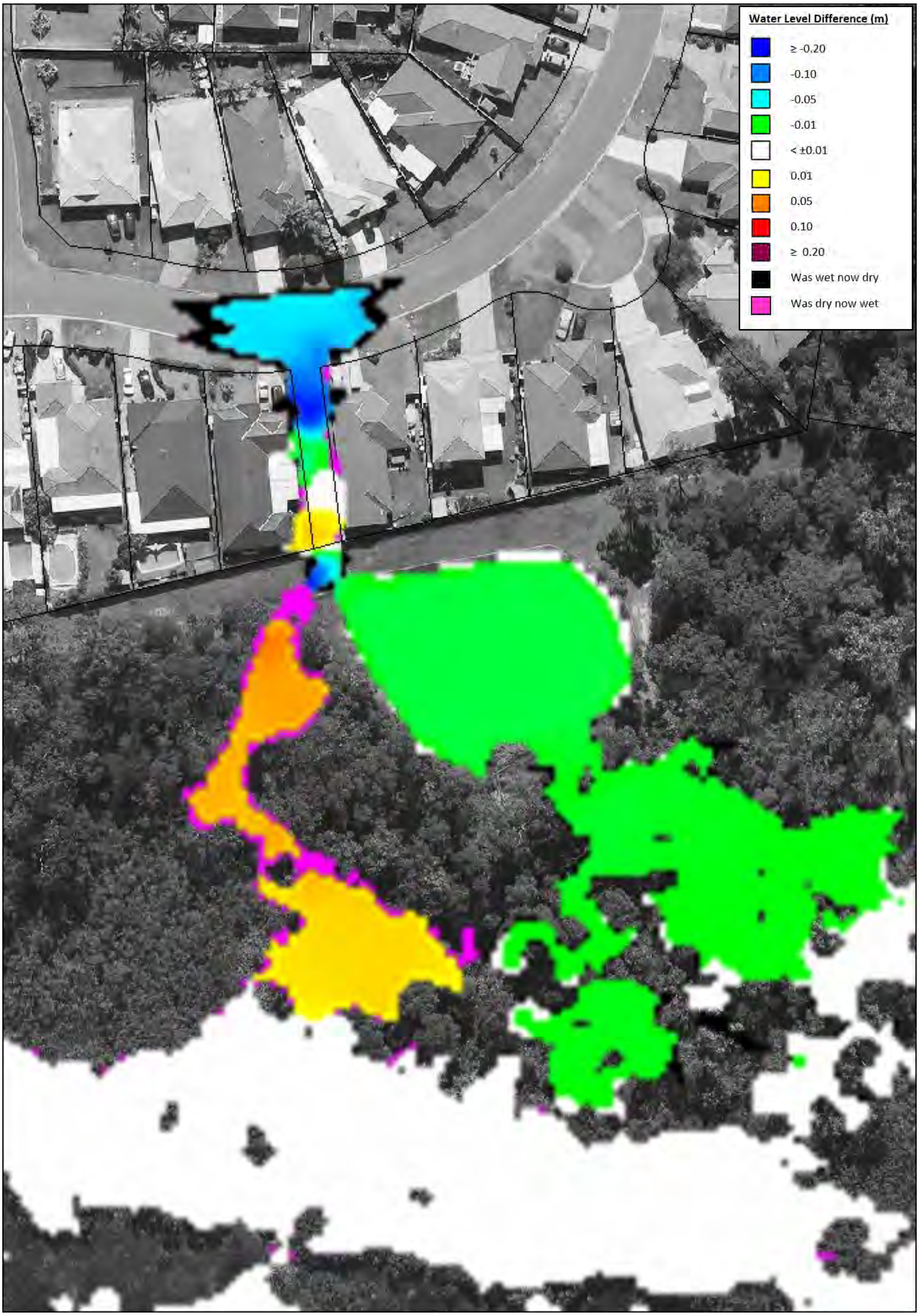


Plate 36 20% AEP Flood Level Difference Map for FM10

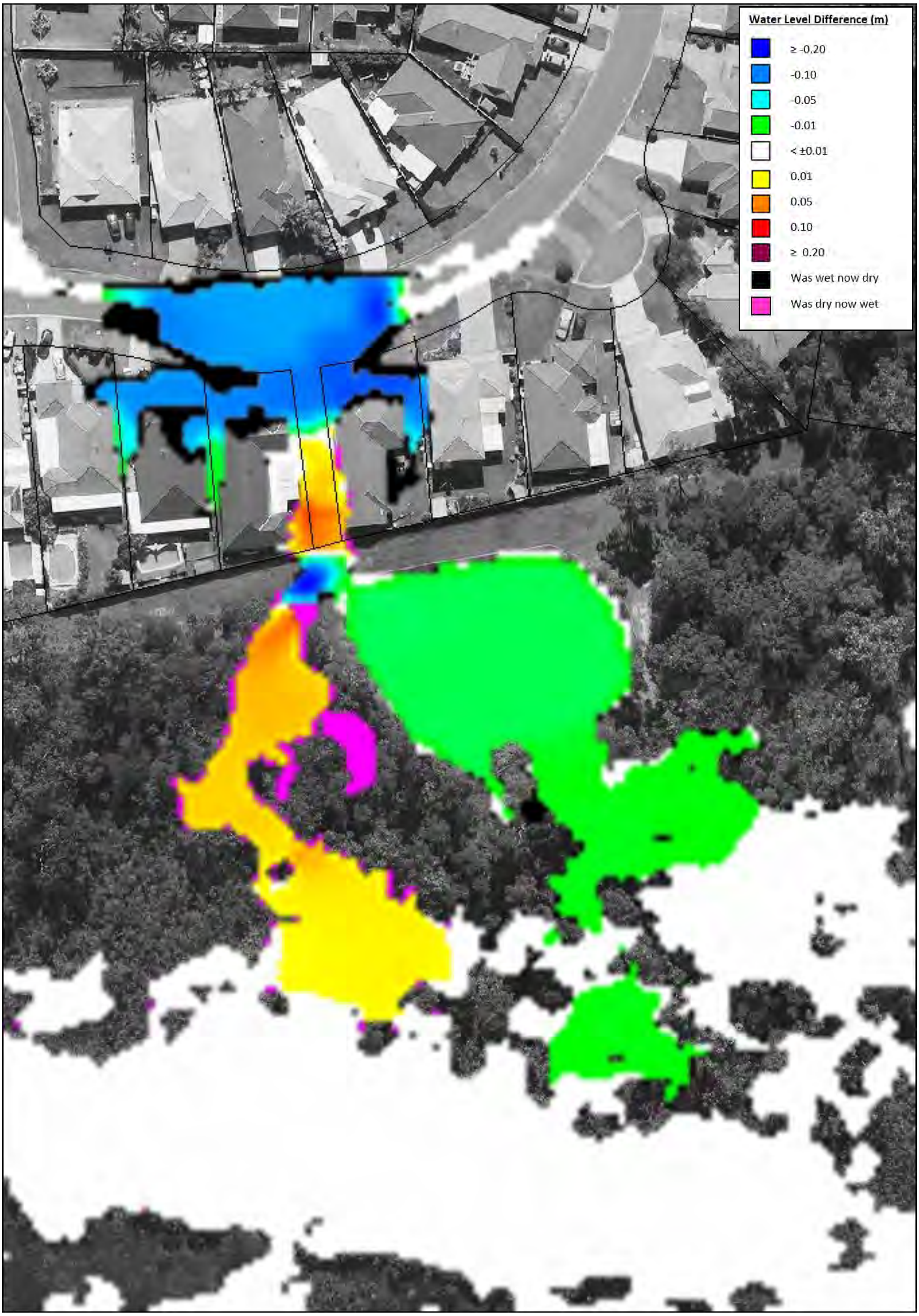


Plate 37 1% AEP Flood Level Difference Map for FM10

The reshaping would likely afford some localised emergency response improvements by reducing the frequency of roadway inundation and, therefore, the frequency that motorists may be tempted to drive through floodwaters. Some small improvements in evacuation time would also be provided, but the additional evacuation time is likely to be less than 10 minutes during most floods.

The high BCR indicates that this option would likely yield a positive financial outcome for properties in Pinehurst Way. The only major concerns are the anticipated flood level increases at the rear of the Pinehurst Way properties. However, refinement of the concept design presented in this report may be able to offset these increases. There may also be opportunities to implement this option in conjunction with the other Pinehurst Way options to further reduce the predicted flood level increases, which is discussed in more detail below.

Overall, this option is recommended for implementation either in isolation or in combination with one or more of the other Pinehurst Way mitigation options.

7.6 Combined Options

7.6.1 FM11 – Pinehurst Way Modified Detention Basin, Stormwater Upgrades and Flow Path Reshaping

Recommendation: Recommended for implementation

This option would combine all of the individual Pinehurst Way mitigation options (i.e., FM2, FM3 and FM10). This would include upgrading the local stormwater system, reshaping of the overland flow path and modification of the receiving basin.

The concept design for the combined option was included in the TUFLOW model and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 38** and **Plate 39**.

Plate 38 and **Plate 39** show that the combined option is predicted to generate significant flood level reductions across Pinehurst Way and adjoining properties during the 20% AEP and 1% AEP floods. Flood level reductions of over 0.2 metres are predicted across Pinehurst Way properties and along the overland flow path between 28 and 30 Pinehurst Way. The flood level reductions are sufficient to effectively eliminate inundation of Pinehurst Way properties during all floods up to and including the 1% AEP flood.

Plate 38 and **Plate 39** also show the flood level increases that were evident with some of the individual options are also fully offset under the combined option. This includes the flood level increases that were anticipated for Option FM10. The only locations of flood level increases occur across non-habitable areas downstream of the basin.

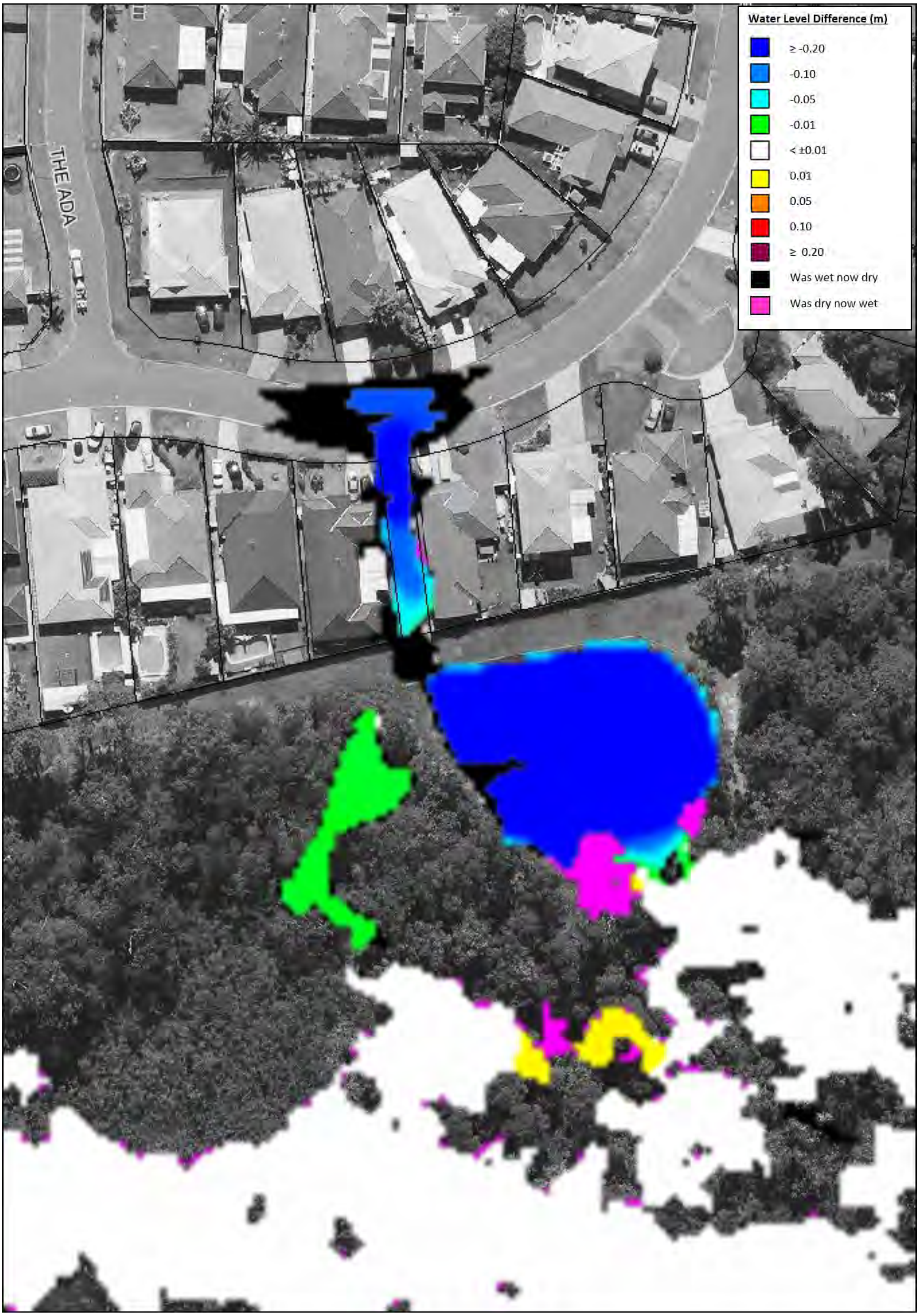


Plate 38 20% AEP Flood Level Difference Map for FM11

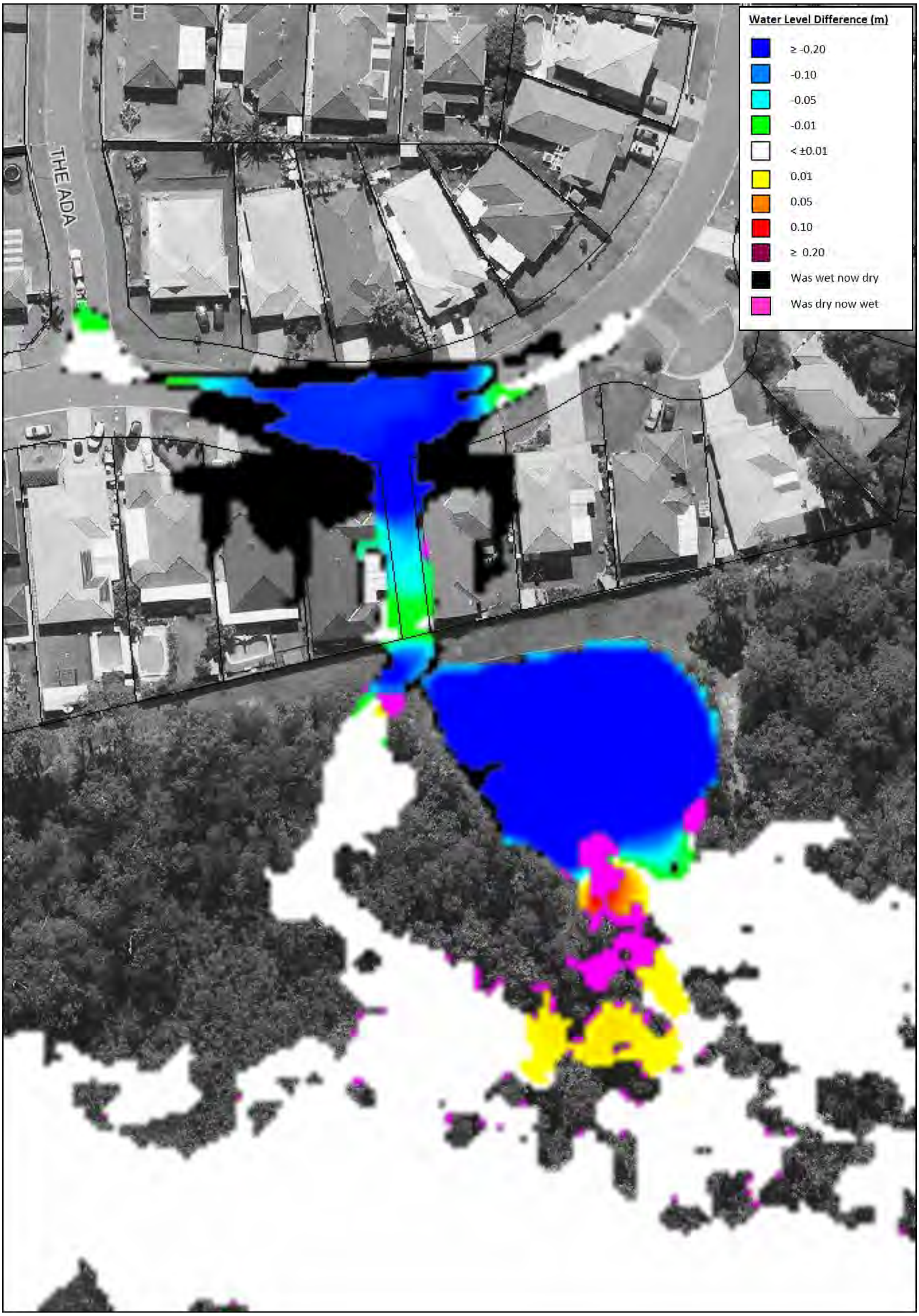


Plate 39 1% AEP Flood Level Difference Map for FM11

A preliminary cost estimate for the combined option was prepared and is included in **Appendix E**. This determined that the combined option would cost approximately $310,000 to implement. Accordingly, the combined option is predicted to cost much less than the total cost of implementing each option individually (an estimated total cost about $450,000).

Revised flood damage calculations were prepared based upon the hydraulic modelling results with the reshaping in place. The outcomes of the revised damage assessment determined that a reduction in total flood damage costs of around $270,000 was predicted over the next 50-years. This yielded a preliminary BCR of 0.9. Accordingly, the implementation cost is predicted to slightly outweigh the reduction in flood damage (albeit, not by much).

Overall, the combined option is predicted to afford some significant hydraulic and financial benefits during a range of floods across the Pinehurst Way area. Although FM10 is predicted to afford a better financial outcome (in terms of BCR), the combined option is predicted to provide a higher overall reduction in damages and no adverse flood impacts across any habitable properties. Therefore, if sufficient funding is available, it is recommended that the combined option is implemented.

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 existing flood risk while planning measures are employed to manage future flood risk.

The following property modifications were investigated as part of the study:

- PM1 – Updates to LEP and DCP
- PM2 – Voluntary purchase of select properties

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

8.2 PM1 - Updates to LEP and DCP

Recommendations:

Central Coast LEP:

- Consider applying for 'adequate justification' as per Ministerial Direction No. 4.3 Flood Prone Land
- Amend the definition of flood planning level (FPL) provided in the LEP dictionary so as to apply a variable freeboard across the Wallarah Creek catchment
- Apply to amend Clause 7.3(3) to provide Council with discretion to be assured of either safe evacuation or safe on-site refuge above the PMF

Central Coast DCP:

- Consider incorporating flood function and hydraulic categories, in addition to flood hazard, for the definition of flood precincts
- Recognise the risk associated with events rarer than the 1% AEP flood and strive to mitigate this risk, especially through evacuation requirements
- Include different freeboards into FPLs for setting minimum habitable floor levels, appropriate to the type of flooding
- Include controls to facilitate safer on-site refuges (for a PMF event), where appropriate

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

- Consider applying for 'adequate justification' as per 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.

This could better ensure risk to life is managed satisfactorily in those parts of the floodplain located between the flood planning area (FPA) and the PMF extent, where PMF hazard is greater than H3. If successful, this would have the effect of adding residential uses to Clause 7.3(3) of the LEP. It would also remove any ambiguity about Council's ability to impose flood-related development controls referring to the PMF (particularly, to facilitate safer on-site refuges) on land within the FPA.

- If not already addressed, amend the definition of flood planning level (FPL) provided in the LEP dictionary so as to apply a variable freeboard across the Wallarah Creek catchment, since a 0.5m freeboard may be appropriate for properties subject to mainstream flooding, while a lesser freeboard may be more fitting for properties subject only to overland flow. It is noted that a definition of FPL does not appear in the dictionary of the draft consolidated Central Coast LEP 2018. Instead, FPL is defined in the draft consolidated Central Coast DCP 2018, offering considerable flexibility:

  > *'the combinations of flood levels and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans'*

- Apply to amend Clause 7.3(3) of the LEP to provide Council with discretion to be assured of either safe evacuation or safe on-site refuge above the PMF.

A review of the relevant chapter of Wyong DCP 2013 is provided in Section 4.3.2. Following that review, Council exhibited a draft consolidated Central Coast DCP 2018, as an interim measure to bring together the two recently merged councils' DCPs into one plan. It is understood that in due course, Council will be looking to review and update the floodplain management chapter of its DCP to confirm it is consistent with industry best practice and fit-for-purpose for the different kinds of flood behaviour and flood risks across the LGA.

As a new Central Coast DCP is prepared, it is recommended than Council consider the following points:

- Consider incorporating flood function and hydraulic categories, in addition to flood hazard, for the definition of flood precincts;
- Recognise the often significant risk associated with events rarer than the 1% AEP flood, and strive to mitigate this risk, especially through evacuation requirements;
- Include different freeboards into FPLs for setting minimum habitable floor levels, appropriate to the type of flooding; and
- Include controls to facilitate safer on-site refuges (for a PMF event) to provide a 'Plan B' where early evacuation fails.

8.3 PM2 – Voluntary Purchase of Select Properties

Recommendation: Voluntary house purchase not considered feasible

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

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

It should also be noted that VHP is voluntary. That is, the implementation of this option is reliant on the cooperation of the individual home owners.

The computer flood modelling outputs were interrogated with existing building footprints to identify houses that may be eligible for VHP. More specifically, buildings that fell within the following areas at the peak of the 1% AEP flood were considered potentially eligible for VHP (Office of Environment & Heritage, 2013a):

- High flood hazard areas; and
- Floodway areas.

It is noted that the 'high hazard' definition in the Office of Environment & Heritage guideline refers to the NSW Government's "Floodplain Development Manual" (2005) hazard categories. The more recent national hazard categories have been adopted as part of the current study (refer Section 3.2.6). In this regard, it was assumed that the national H1, H2 and H3 categories would fall under the 'low' hazard category in the "Floodplain Development Manual" and the national H4, H5 and H6 categories would fall under the 'high' hazard category in the Manual.

A total of 8 houses were identified as being potentially eligible for voluntary purchase, which are shown in **Figure 33.** As shown in **Figure 33**, all of the identified properties adjoin Spring Creek and are located on either Birdwood Drive or Turner Close. All identified properties are located within high hazard floodway areas at the peak of the 1% AEP event. However, only 4 of the 8 properties are predicted to be subject to above floor flooding during the 1% AEP flood.

The current median house price in Blue Haven is $507,000 (REA Group Ltd, 2019). Therefore, the purchase of all eight properties will likely cost over $4 million. Revised flood damage estimates were also prepared by removing the damage contribution provided by these houses. That is, it was assumed that the purchased properties would be demolished, and the current occupants relocated to an area outside of the PMF extent. The revised damage calculations yielded a reduction in the net present value of damages of $0.1 million, providing a preliminary BCR of 0.03.

The questionnaire responses (refer Section 2.6.3) also indicate that voluntary purchase of properties was typically not favoured by the community as a flood risk management option.

The high capital cost and low BCR associated with voluntary purchase indicates that this measure is unlikely to be financially viable and is not recommended for implementation.

9 RESPONSE MODIFICATION OPTIONS

9.1 Introduction

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

Response modification options considered as part of the study include:

- RM1 – Community education activities
- RM2 – Preparation of residential flood plans
- RM3 – Preparation of business flood plans
- RM4 – Local flood plan updates
- RM5 – Upgrade of Pacific Highway
- RM6 – Upgrade of Birdwood Drive
- RM7 – Extension of Turner Close to McKellar Boulevard
- RM8 – Refuge in place strategy

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

9.2 RM1 - Community education activities

Recommendations:

Make flood information available:

- Update and extend type of flood information on Council's online mapping portal
- Prepare a Wallarah Creek flood fact sheet
- Undertake modelling of an intermediate event between the 1% AEP and PMF
- Consider including information about all floods up to the PMF on Section 10.7(5) planning certificates, and/or issue customised flood information certificates regularly

Provide guidance to help people plan for flooding:

- Organise a 'meet-the-street' style event for residents in the vicinity of Birdwood Drive and Turner Close, and repeat at intervals

The *National Strategy for Disaster Resilience* (COAG, 2011) recognises that disaster resilience is the collective responsibility of all sectors of society including government, business and individuals. The resilience of people and households is significantly increased by active planning and preparation for protecting life and property, based on an awareness of the threats relevant to their locality. It is also increased by knowing and being involved in local community emergency management arrangements and being involved as a volunteer.

As well as raising awareness of floods through provision of information, disaster research increasingly highlights the need to build community resilience through learning. Disseminating information alone does not necessarily trigger changed attitudes and behaviours (Dufty, 2011). Flood education programs are most effective when they:

- are participatory, i.e. not consisting only of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;
- are tailored to an individual and local community's learning needs. This requires social research to first understand the community of interest (Dufty, 2018);
- enable learning from social interaction within communities;
- involve a range of learning styles including experiential learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, videos, the media), collaborative group learning (e.g., scenario role plays with community groups) and community discourse (e.g., forums, post-event de-briefs); and,
- are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits for public safety far outweigh the costs. However, it needs to be recognised that ongoing funding is required to sustain gains that have been made, which historically, has been a challenge.

It is beyond the scope of the current study to develop a full flood education program for the Wallarah Creek catchment. This might be more effectively and efficiently accomplished as part of an LGA-wide approach to disaster risk education. Nonetheless, the discussion below considers activities that are considered of benefit for community flood education in the Wallarah Creek catchment.

First, residents and businesses living and working on the floodplain do require easy access to flood information so that they may better understand their flood risks. Flood depth, velocity and hazard mapping has been prepared for a range of design events for this study. Flood hazard mapping is anticipated to be particularly useful for the community as the hazard categories are directly relatable to the vulnerabilities of vehicles, people and buildings (see **Plate 6**). The draft consolidated Central Coast DCP 2018 also uses these hazard categories for the 1% AEP and PMF events as flood precincts for the purpose of development control. It is therefore recommended that:

- Council update the mapping on its flood mapping portal to display flood depths and flood hazard for all available design floods (for Wallarah Creek, flood hazard is available for the 1% AEP and PMF events).
- Council prepare a one-page 'Wallarah Creek catchment flood fact sheet' to help readers interpret the flood hazard categories and also convey other aspects of flooding not easily conveyed by mapping (e.g. rapid rate-of-rise).
- Council prepare modelling and mapping of an intermediate event between the 1% AEP flood and the PMF, such as a 0.2% (1 in 500) AEP event. This is important for a more complete risk profile for the Wallarah Creek catchment. It would enable residents to better understand the kind of flooding that, although rare, has occurred in the recent past in NSW. It would also facilitate more accurate pricing of insurance premiums.
- Council consider including information about all floods up to the PMF on Section 10.7(5) planning certificates. Whilst these certificates may not have a broad reach, they do represent one means of recording a property's flood risk. In addition, Council could consider proactive issuance of flood information (e.g. a customised certificate) to all occupiers of the floodplain, on a regular basis (e.g. annually with a rates' notice).

Second, residents and businesses in the floodplain need to plan for what to do before, during and after flooding. That is, better information about flooding potential needs to be accompanied by guidance about preparing for, responding to and recovering from flooding. However, as discussed earlier in this report, what constitutes an appropriate response at one property may be different from another property. This reflects the varying depth and velocities of floodwaters at buildings and on access roads, the varying height and resilience of building structures, and the varying vulnerability of building occupants. Also, what may be the best approach early in an event (evacuation) may be too dangerous if delayed. It will therefore not be possible to provide prescriptive guidance, but tools (even a decision support tool) could be developed to enable people to develop their own plans (see Sections 9.3 and 9.4). Generic messages would still have value in the catchment to target common misconceptions and poor behaviours, such as:

- Floods much bigger than what you've experienced are possible in the Wallarah Creek catchment.
- Avoid driving, riding, walking or playing in floodwaters – most flood deaths in Australia are associated with these activities.
- *Early* evacuation, before roadways are flooded, to an area above the extent of the worst possible flood, is generally the safest response to flood emergencies - However, a person may find it difficult to decide what constitutes 'early' evacuation and to safely identify whether roadways are flooded, once a storm has commenced.

For the Wallarah Creek catchment, the concentration of the highest areas of flood risk in a few streets lends itself to 'meet-the-street' style events. These involve Council and NSW SES personnel setting up a 'stall' at an appropriate and visible location at a time that people will be at home. The 'meet-the-street' would be advertised through a specific doorknocking or letter box drop to the targeted neighbourhood. The stall could consist of flood maps on boards, historic flood photos and NSW SES collateral.

Meet-the-street events would be aimed at increasing understanding of flood risks, encouraging preparedness behaviours (e.g. developing emergency plans) and helping people decide what to do before, during and after a flood. One other advantage of local street meetings is the opportunity to promote 'social capital' by encouraging community networking. Longer-term residents with flood experience could provide newer residents with an understanding of previous floods, though this would need to be balanced by the scientific information on extreme floods that no one has yet experienced. Residents could also potentially collaborate on response strategies. In addition, the NSW SES could use the opportunity to recruit volunteers to its ranks, including people who could be enlisted and trained for active reconnaissance of the area during floods.

For the Wallarah Creek catchment, one location with a compelling case for direct engagement is around Birdwood Drive and Turner Close. Possible venues are in Bamayi (Spring Creek) Reserve or Blue Haven Public School.

Council may also like to consider installing a flood marker with major peak flood heights (e.g., 2007 flood) at a highly trafficked location such as on the southern Pacific Highway approach to the Wallarah Creek bridge. It may also be beneficial to include "design" flood levels on the marker (e.g., 0.2% AEP and PMF) to serve as a reminder that larger floods can and will occur in the future.

9.3 RM2 - Preparation of residential flood plans

Recommendations: Promote 'Get Ready' messaging and resources available for developing household flood plans (NSW SES, Council)

The NSW Government has developed a five-step 'Get Ready' approach to assist people to prepare for emergencies (**Plate 40**). The NSW SES has also developed an online template to help residents develop flood plans (http://www.seshomeemergencyplan.com.au/index.php). Dufty (2015) has queried the wisdom of encouraging the writing of flood plans as the main preparedness activity for individuals and households. For rapid response catchments without a formal flood warning system, like the Wallarah Creek catchment, preparing written plans may offer limited benefit. Dufty argues for alternative learning approaches including the use of social and experiential learning (e.g. community/agency exercises, scenario problem solving, oral histories, simulation) along with clear warning messaging, as a potentially more effective means of enabling safe responses and resilience.

Despite these reservations, helping people to at least recognise the possibility of extreme flooding, and to consider how they would safeguard their families, is considered a worthy endeavour provided it is not the sum total of community engagement and education activities. One straightforward activity would be for Council's relevant website (https://www.centralcoast.nsw.gov.au/environment/bushfires-and-flooding/preparing-flood-emergencies) to include a link to NSW SES resources.

Plate 40 Get Ready disaster preparedness (NSW SES)

9.4 RM3 - Preparation of business flood plans

Recommendations: Engage with flood prone businesses to help them understand flood hazard and prepare emergency business continuity plan (NSW SES)

Relatively few businesses in the Wallarah Creek catchment are exposed to flooding (**Appendix C**). These include a number of home-operated businesses and the Caltex Service Station on the Pacific Highway. Given the small number of affected businesses, it may be practical for personnel to contact each and make them aware of Council's flood information and the NSW SES's online template for an emergency business continuity plan (http://www.sesemergencyplan.com.au/business/).

9.5 RM4 - Local flood plan updates

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

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

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

9.6 Options to Improve Emergency Response During a Flood

9.6.1 RM5 – Upgrade of Pacific Highway

Recommendation: Not recommended for implementation

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

As outlined in Section 3.3.3, a number of roadways are predicted to be inundated during flooding in the catchment. This includes the Pacific Highway which serves as one of the major north-south transportation links in the area. This roadway is predicted to be cut by floodwaters during floods as frequent as the 5% AEP event (refer to photo on the front cover of this report which shows the overtopping occurring approximately 100 metres south of the Pacific Highway bridge crossing of Wallarah Creek). Accordingly, this option investigated the potential to elevate the Pacific Highway in an effort to reduce the frequency of roadway inundation and, therefore, the frequency that motorists may be tempted to drive through floodwaters.

The concept design of this option is provided in **Figure 34** and would involve elevating the roadway by up to 0.45 metres, which would be sufficient to prevent roadway inundation during floods up to and including the 1% AEP event. A culvert would also be provided to reduce the potential for the elevated embankment to adversely impact on existing flood behaviour (i.e., provide a way for water to move under the highway rather than over it).

The TUFLOW model was updated to include a representation of the elevated highway and the updated model was used to re-simulate each design flood. Peak flood level difference mapping for the 20% and 1% AEP events with this option in place were prepared and are presented in **Plate 41** and **Plate 42**.

Plate 41 shows that negligible changes in flood level and extent are predicted during the 20% AEP flood. **Plate 42** shows that more notable changes in flood level and extent are predicted during the 1% AEP flood. This includes increases in flood level of up to 0.03 metres on the western side of the highway. However, the increases are contained to non-habitable areas of the floodplain. The difference mapping also shows that the highway would remain "flood free" during the 1% AEP flood. Reduction in 1% AEP flood levels of up to 0.07 metres are predicted on the eastern side of the roadway.

A review of the PMF results shows that overtopping of the highway would still occur during the PMF. However, approximately 20 minutes of additional evacuation time would likely be provided.

Plate 41 20% AEP Flood Level Difference Map for RM5

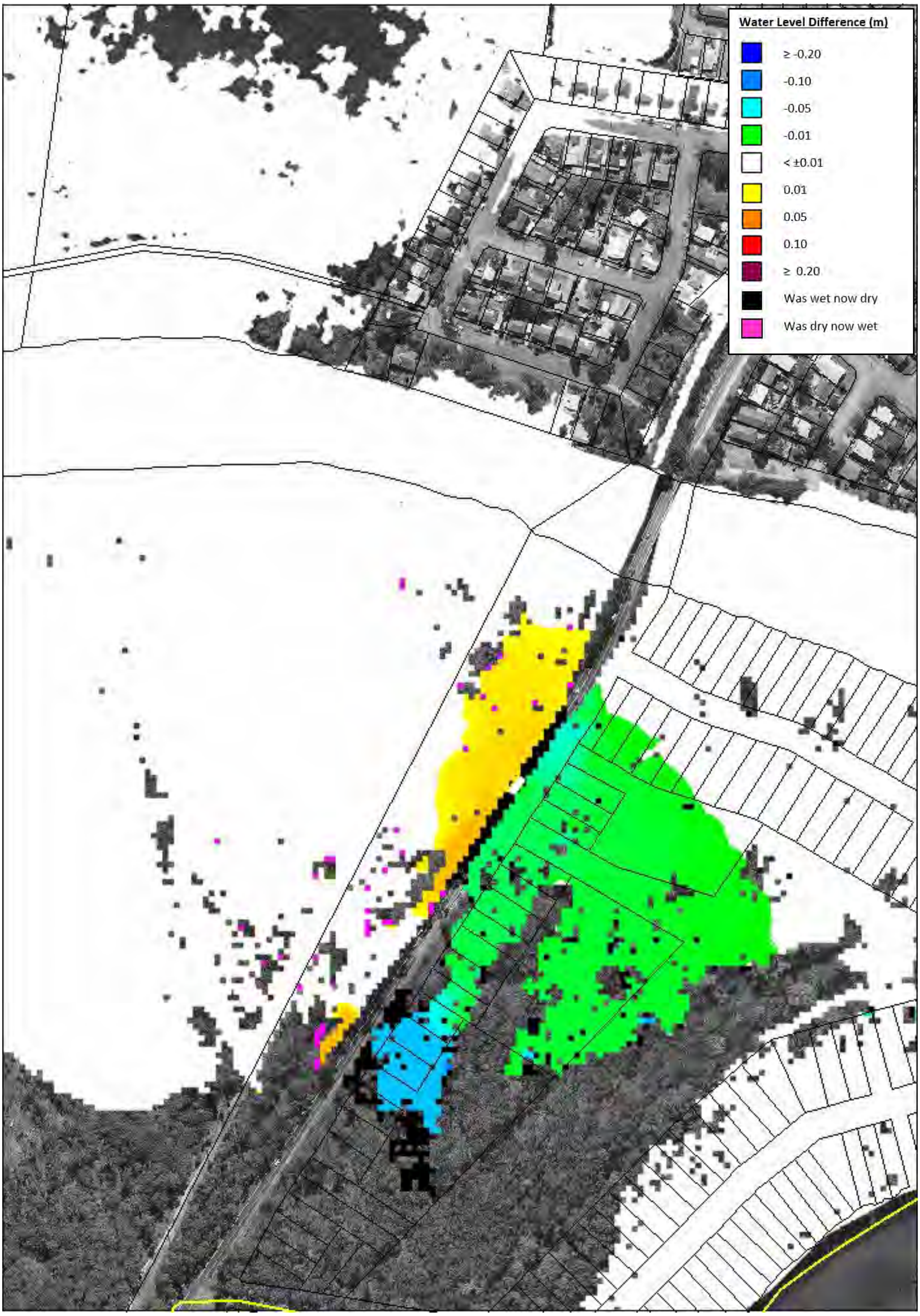


Plate 42 1% AEP Flood Level Difference Map for RM5

The cost to implement the Pacific Highway upgrade is expected to cost about $2 million (refer cost estimate enclosed in **Appendix E**). Therefore, the cost associated with implementation of this option is significant. No reduction in flood damage costs are expected with this option in place yielding a preliminary BCR of zero.

The Pacific Highway is a major transportation route. Therefore, any roadworks does have the potential to cause an inconvenience to traffic during construction.

The construction works are proposed within a class 2 acid sulfate soils zone. However, it is unlikely that the proposed works would disturb this zone. Therefore, the potential for acid sulfate soil exposure is considered to be limited. No Aboriginal or other heritage sites are located within the works zone.

Although the Pacific Highway forms an important transportation link, flooding of the highway would typically not lead to isolation of the different sections of the community. For example, those sections of the catchment located north of Wallarah Creek could likely travel north and join the Doyalson Link Road while areas to the south of Wallarah Creek could travel south and join Sparks Road. Accordingly, although upgrading of the Pacific Highway will result in less frequent overtopping of the roadway and improved convenience for the local community, it is not considered essential from an emergency response perspective (i.e., alternate access could be provided along other roads). When coupled with the high implementation cost, it is difficult to lend support to this option. Nevertheless, if RMS does plan to upgrade the highway in the future, then the potential to elevate the existing roadway embankment as part of this upgrade work is considered to be a worthwhile pursuit if it does not add significantly to the overall implementation cost.

9.6.2 RM6 – Upgrade of Birdwood Drive

Recommendation: Recommended for implementation as a long term strategy

During a PMF, many areas adjoining Birdwood Drive would be exposed to H5 or H6 hazard. This hazard categorisation indicates that, not only would it be unsafe for people, there is also potential for structural damage to buildings in this area. As a result, it is not considered safe to refuge in place during large floods (i.e., evacuation is the preferred response strategy for this area). However, inundation of Birdwood Drive can occur in events as frequent as a 20% AEP flood and as quickly as 15 minutes after the initial onset of rainfall. This limits the potential for evacuation (i.e., by the time water reaches individual properties it is likely that access along Birdwood Drive would already be cut). Therefore, this option would look to upgrade Birdwood Drive to improve the potential for evacuation during both frequent and rare floods.

A review of available topographic information indicates that there is limited potential to significantly elevate Birdwood Drive. However, it is noted that existing low points in the road profile could be elevated to ensure that all properties adjoining Birdwood Drive would have access to a "rising road" evacuation route. That is, an evacuation route that grades constantly up and out of the floodplain. This is beneficial from an evacuation perspective as it ensures that vehicles will not be required to travel through deeper water to reach higher ground (assuming vehicles travel in the appropriate direction).

The suggested roadway profile modifications are shown in **Figure 35**. As shown in **Figure 35**, the suggested modifications will require elevating existing roadway "low points" by up to 0.45 metres. This will provide rising road access from the western and eastern ends of Birdwood Drive to Penguin Road.

The proposed roadway modifications were included in an updated version of the TUFLOW hydraulic model and the updated model was used to re-simulate each design flood. Flood level difference mapping was prepared but the difference mapping showed the roadway upgrade would produce negligible changes in existing flood levels. However, with the exception of the western end of Birdwood Close, the roadway profile changes will be sufficient to prevent inundation along the balance of the roadway during the 20% AEP and will reduce inundation depths sufficiently to remain trafficable at the peak of the 5% AEP flood. Evacuation is unlikely to be safe at the peak of the 1% AEP flood or the PMF. However, depths will be reduced and rising road evacuation will be provided. Accordingly, it still affords a significant emergency response improvement relative to the current conditions.

The profile adjustments would also provide additional time for evacuation. The additional evacuation times that would be provided are shown in **Plate 43**, **Plate 44** and **Plate 45** for the 5% AEP, 1% AEP and PMF events, respectively. As shown in **Plate 44**, at least 1 hour of additional time would typically be available during the 1% AEP flood and at least 20 minutes of additional time would be available during the PMF (refer **Plate 45**).

During the 5% AEP flood, large sections of Birdwood Drive are predicted to remain "dry", while the lowest point of Birdwood Drive (i.e., the very western end) would afford more than an hour and a half of additional time to evacuate (refer **Plate 43**).

It is expected that the roadway modifications would involve an investment of over $600,000 (refer cost estimate enclosed in **Appendix E**). As discussed, negligible changes in flood levels are anticipated with this option. As a result, no changes in flood damages are predicted, which provides a BCR of zero. Accordingly, there is little financial incentive to implementing this option.

Nevertheless, the significant risk to life across this area during the PMF cannot be overlooked. The outcomes of the flood modification and property modification options assessment indicates that none of the options considered as part of the current study would reduce the flood risk to more tolerable levels across this area during the PMF. Therefore, regardless of which flood risk reductions measures are ultimately adopted, it is highly probable that the flood risk across this area will remain largely unchanged during the PMF. Moreover, given the high potential for loss of life during the PMF and the potential for this option to reduce the risk, it must be given strong consideration for implementation.

Plate 43 Additional evacuation time provided by RM6 during the 5% AEP flood

Plate 44 Additional evacuation time provided by RM6 during the 1% AEP flood

Plate 45 Additional evacuation time provided by RM6 during the PMF

It is questionable as to whether this option will be eligible for state government funding under the Floodplain Management Program due to the low BCR. In the event that state government funding cannot be secured, opportunities to implement the roadway modifications may be considered as part of any future roadworks/stormwater modifications for the area (e.g., funded under Council's capital works program). However, due to the significant capital investment, it is likely that this can only be implemented as a long-term strategy.

As noted in Section 3.4, future development across the catchment does have the potential to increase existing flood levels along Spring Creek. Therefore, the existing flood risk has the potential to increase further as a result of future development. At the same time, future development may provide an opportunity to reduce the future flood risk. For example, Section 7.11 contributions from future development could be invested in one or more regional flood risk management options that may assist in reducing the flood risk across Birdwood Drive properties to more tolerable levels (e.g., FM1).

As Section 7.11 contributions can be used to fund the upgrade of amenities and services that are required as a result of development, an argument could be put forward that the Section 7.11 contribution could also be used to fund the upgrade of Birdwood Drive (as the level of service afforded by the road would potentially reduce as a result of the future development). Although this may improve the financial viability of this option, it is unlikely to be a successful short-term strategy (i.e., development across the upper catchment and the associated contributions are unlikely to occur in the near future). Council may also like to consider implementing this option (or a variation of this option) should roadway upgrades in this area be earmarked in the future as part of Council's capital works program.

Therefore, in the short term, it is recommended that Council and/or SES staff meet with home owners in Birdwood Drive to outline the extent of the flood risk during particularly large floods and encourage people to prepare flood plans which will outline evacuation protocols for residents. Further discussion on community education and flood plans are provided in Section 9.2 and Section 9.3. However, upgrades to Birdwood Drive are still recommended as a long-term risk mitigation strategy.

During the public exhibition of the draft report, residents adjoining Birdwood Drive noted that the lack of kerb and guttering contributed to more frequent inundation of front yards. They also mentioned that the local stormwater drainage system can struggle to cope with the quantity of runoff during even frequent rainfall events. Upgrading of Birdwood Drive would serve as an excellent opportunity to upgrade the local stormwater system and install kerb and guttering. Therefore, it is recommended that these components also be explored as part of the road upgrade to ensure better management of the more frequent rainfall events.

9.6.3 RM7 – Extension of Turner Close to McKellar Boulevard

Recommendation: Recommended for further consideration/consultation with the local community (Council)

As shown in **Figure 14.8**, a significant number of properties adjoining Turner Close are also predicted to be exposed to a H5 or H6 hazard during the PMF. As discussed earlier, this hazard categorisation indicates that there is potential for structural damage to buildings. As a result, evacuation from this area is the preferred flood response strategy.

Turner Close is a cul-de-sac with the south-eastern end of the roadway being closed to McKellar Boulevard. As a result, properties adjoining the southern end of Turner Close must travel in the westerly direction before looping back around to the north-eastern exit onto McKellar Boulevard. This requires prospective evacuees at the south-eastern end of the roadway to travel from higher terrain down into lower terrain and, therefore, deeper water. Accordingly, RM7 investigates the potential to improve evacuation for properties located at the south-eastern end of Turner Close by providing a direct "linkage" between the south-eastern end of the roadway and McKellar Boulevard.

Council's engineers were initially consulted to obtain feedback on the option. These discussions indicated that the construction of a permanent two-way connection with McKellar Boulevard is unlikely to be supported by residents of the street as it will likely increase through traffic and may be perceived as devaluing properties.

As an alternative, Council suggested that a one-way linkage could be provided that would allow cars to exit from the south-eastern end of Turner Close only (i.e., cars would not be able to "enter" Turner Close at the south-eastern connection). However, it would still allow some "through traffic" and the changed traffic conditions may not be supported by residents near the current cul-de-sac.

The potential to include the one-way link with a locked gate was also raised as a potential way to eliminate the "through traffic" problem. That is the gate would be unlocked only during floods. However, issues associated with who would open the gate during floods were raised. If an agency or organisation (e.g., Council or SES) is vested with the responsibility of opening the gate, there could be issues with the agency/organisation representatives being unable to access the area given that many of the local roadways may be cut by floodwaters. In addition, due to the relatively short amount of warning time available, the agency representative would need to be located in relatively close proximity to Turner Close which may not be possible. There is potential to provide one or more homeowners with the keys, but this will be reliant on the home owner(s) being home at the time of flood, which may not always be possible (e.g., if flooding occurs during business hours or while the home owners are on holidays).

One final option that was considered was replacing the existing bollards at the end Turner Close and constructing a "green" road (i.e., plant this area with low vegetation) between Turner Close and McKellar Boulevard. The vegetation would aim to discourage this evacuation point from being utilised during non-flood times but still provide an alternate evacuation route that could be utilised during large Spring Creek floods.

Overall, it is considered difficult to balance the emergency response benefits of providing an alternate evacuation route without losing the amenity that is currently provided by the cul-de-sac. However, it is considered worthwhile discussing potential options with local residents to confirm if any of the options outlined above would be acceptable to the community and, based on the outcomes of these discussions, potential implementation.

It is noted that there is pedestrian access currently available between the south-eastern end of Turner Close and McKellar Boulevard. Therefore, in the event that Turner Close becomes cut by floodwaters, it should still be possible for residents to evacuate on foot to McKellar Boulevard. However, the success of this strategy will be reliant on local residents fully understanding the nature of the flood risk during extreme floods and reinforcing the mantra to never drive through floodwaters. Accordingly, it is recommended that dedicated community education is completed for this (and other high risk) areas and existing homeowners are encouraged to prepare flood plans to ensure the most appropriate actions are taken during future floods. Further discussion on community education and flood plans are provided in Section 9.2 and Section 9.3.

9.7 RM8 – Refuge in Place Strategy

Recommendations: Conduct further research to inform appropriate response strategies for the Wallarah Creek catchment, and implement a community-led planning process to confirm response strategies (NSW SES, Council)

Emergency responses to flooding in the Wallarah Creek catchment are canvassed in Section 5.3.2. For much of the catchment, taking refuge within existing buildings may generally be safer than trying to escape via flooded roadways. However, for some areas, the potential depths and velocities of floodwater means that on-site refuge is not safe.

From a purely risk management perspective, only in dwellings where a place of refuge above the PMF level is provided and where the dwelling is known to be capable of surviving the PMF should people in areas subject to high hazard flooding contemplate not evacuating before flooding. However, studies of behaviours during recent Australian floods (e.g. Lismore, 2017; Townsville, 2019) demonstrate again people's reluctance to evacuate, including due to concern about the security of their property (see Section 2.6.3). Providing safer on-site refuge as a 'Plan B' for people who fail to evacuate in timely fashion is a desirable back up, especially for communities where there is no formal flood warning system.

In the long-term, unless houses subject to high hazard (H4-H6) conditions in the PMF can be voluntarily purchased to entirely remove the risk exposure, facilitating safer on-site refuges requires the *redevelopment* of those houses:

- with a portion of habitable floor area above the PMF (and not in an enclosed roof space but with opportunity for boat rescue from the refuge); and
- with the assurance of the building structure's ability to withstand the forces of floodwater, buoyancy and debris in a PMF.

This would require amendments to the Central Coast DCP (and, possibly, a successful application for 'adequate justification' so as to be able to apply controls to dwellings related to the PMF) (see Section 8.2).

In the short-term, there is a need to help people understand their flood risks and prepare flood plans, and to promote community networks that look out for each other during flood emergencies. This might mean that those with a lesser flood risk are able to offer temporary refuge to those with greater flood risk during floods.

To better understand the scale of the issue during extreme flooding, the GIS buildings layer used for the purpose of assessing flood damages was compared to the GIS PMF flood hazard layer. This shows that in the Wallarah Creek catchment:

- 126 dwellings are located within H5-H6 flood hazard categories, where buildings are vulnerable to failure. Whether these dwellings are currently viable to function as on-site refuges during extreme flooding requires individual assessments by a structural engineer and comparison of highest habitable floor levels to the PMF level. In the absence of this granular information, it is assumed that none of these dwellings would be suitable for refuge during an extreme flood.
- Another 84 dwellings are located within the H4 flood hazard category, where conditions are unsafe for people including:
    - Twenty of these dwellings are two storeys, where flooding is unlikely to reach the upper level;
    - Four of these dwellings are high-set single storey, with flooding either below floor or less than 0.8 metres deep; and
    - Nine of these dwellings are low-set single storey, with flooding less than 0.8 metres deep.

This suggests that based on existing housing stock and flood behaviour, an on-site refuge strategy may be viable in up to 33 dwellings out of the 210 subject to high hazard (H4-H6) conditions in the PMF event.

One way forward is for the NSW SES to commence a community-led planning process for the Wallarah Creek catchment, so that residents have a good appreciation of the flood hazard and are co-opted as partners in confirming strategies for their households and community (see Webber & Rae, 2015).

In advance of community engagement to confirm response strategies, there would be benefit in modelling and mapping at least one intermediate event between the 1% AEP flood and the PMF (e.g. 0.2% AEP), to assist understanding of hazard distribution across the range of rare to very rare floods.

10 Floodplain Risk Management Plan

10.1 Introduction

The Floodplain Risk Management Plan sets out a preferred set of options that can be implemented to better manage the flood risk across the Wallarah Creek catchment. It also outlines responsibilities for the implementation of each option along with cost estimates and funding opportunities. This Floodplain Risk Management Plan is based on the outcomes of the Floodplain Risk Management Study which is documented in the previous sections of this report.

10.2 Recommended Options

The options that are recommended for implementation as part of the Wallarah Creek catchment Floodplain Risk Management Plan are summarised in **Table 28** and are also shown in **Figure 36**. 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, reduction in flood damages, implementation costs, community feedback as well as any potential social and environmental impacts. The outcomes of the detailed options assessment are discussed in more detail in Chapters 7, 8 and 9 of this report.

10.3 Plan Implementation

10.3.1 Prioritisation / Timing

Each of the recommended options has been assigned a preliminary implementation priority based upon an initial consideration of the above factors. The implementation priorities are summarised in **Table 25** and are also included below:

High Priority Options:

- PM1: LEP & DCP Amendments
- RM1: Community Education Activities
- RM2: Preparation of household Flood Plans
- RM3: Preparation of business Flood Plans
- RM4: Local Flood Plan updates

Medium Priority Options:

- FM10: Pinehurst Way Flow Path Reshaping
- FM11: Pinehurst Way Modified Detention Basin, Stormwater Upgrades and Flow Path Reshaping
- RM6: Upgrade of Birdwood Drive
- RM7: Extension of Turner Close to McKellar Boulevard
- RM8: Refuge in Place Strategy

Low Priority Options:

- FM1: Doyalson Link Road Basin (not recommended for managing the existing flood risk but could be considered for managing the potential future flood risk)

A timeframe has also been estimated that reflects the likely time to implement each option. However, the implementation time estimates will most likely need to be refined moving forward based upon available resources (i.e., financial and human resources) as well as the need to undertake additional investigations and/or community consultation.

Table 28 also summarises the agency that will be responsible for implementation of each option.

10.3.2 Costs and Funding

The total capital cost to implement the structural components of the Plan is expected to be about $2.9 million. The most significant contributors to this cost are the Doyalson Link Road detention basin ($2 million) and the Birdwood Drive upgrades ($600,000).

In addition to the capital costs, some options will require an investment in time from various agencies including Central Coast Council and the State Emergency Service in addition to monetary contributions.

It should be noted that the costs are estimates only. The cost for each option will need to be refined through further detailed investigations and preparation of detailed design plans which is beyond the scope of the current study.

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

- NSW State Government's Floodplain Management Grants (through OEH)
- Wingecarribee Shire Council's capital and operating budgets
- Developer (i.e., Section 7.11) contributions
- Australian Rail Track Corporation (ARTC)
- Roads and Maritime Services (RMS)
- Volunteer labour from community groups
- Volunteer labour from property owners / interested parties

It is expected that most options targeted at addressing the existing flood risk 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.

Although the cost of the Doyalson Link Road detention basin is significant there may be opportunities to partly fund this option through a developer contributions plan as it targets the management of the future flood risk. Opportunities to part fund the Birdwood Drive upgrades could also be explored through developer contributions and/or Council's capital works program.

It should also be noted that ongoing costs will generally be the responsibility of Council.

10.3.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually monitored, reviewed and updated over time to ensure that it evolves with the catchment and new flood knowledge. Some events that may prompt a review of the Plan could include:

- If significant impediments are identified for any of the recommended options;
- A significant historic flood occurs which provides updated data of flood behaviour;
- A new flood study is prepared;
- New knowledge becomes available (e.g., climate change); or,
- New issues come to light that were not considered or not know at the time the Plan was prepared.

As noted in **Table 28**, most options are scheduled for implementation within a 5-year time frame. Therefore, as a minimum, it is recommended that a thorough review of the Plan be completed after 5 years.

Table 28 Wallarah Creek Floodplain Risk Management Plan

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

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
Flood Modification Options								
FM10	Pinehurst Way Flow Path Reshaping	7.5.1	Council	$100,000	2.2	Medium	5 years	Can be considered for implementation in isolation. However, greater benefits would be afforded if combined with other Pinehurst Way mitigation options (refer FM11).
FM11	Pinehurst Way Modified Detention Basin, Stormwater Upgrades and Flow Path Reshaping	7.6.1	Council	$310,000	0.9	Medium	5 years	May be potential to reduce capital cost by removing detention basin modifications from this option without significantly impacting on hydraulic performance.
Property Modification Options								
PM1	LEP Amendments	8.2	Council	Council Time	-	High	3 years	Amend Central Coast Council LEP considering the detailed review presented in Section 4.3.1. Suggested amendments include: • Consider applying for 'adequate justification' as per Ministerial Direction No. 4.3 Flood Prone Land • Amend the definition of flood planning level (FPL) provided in the LEP dictionary so as to apply a variable freeboard across the Wallarah Creek catchment • Apply to amend Clause 7.3(3) to provide Council with discretion to be assured of either safe evacuation or safe on-site refuge above the PMF

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
	DCP Amendments		Council	Council Time	-	High	2 years	Amend Central Coast Council DCP considering the detailed review presented in Section 4.3.2. Suggested amendments include: • Consider incorporating flood function and hydraulic categories, in addition to flood hazard, for the definition of flood precincts • Include different freeboards into FPLs for setting minimum habitable floor levels, appropriate to the type of flooding • Include controls to facilitate safer on-site refuges (for a PMF event), where appropriate
Response Modification Options								
RM1	Community Education Activities	9.2	SES & Council	Council & SES Time	-	High	1 year	Make flood information available: • Update and extend type of flood information on Council's online mapping portal • Prepare a Wallarah Creek flood fact sheet • Undertake modelling of an intermediate event between the 1% AEP and PMF • Consider including information about all floods up to the PMF on Section 10.7(5) planning certificates, and/or issue customised flood information certificates regularly Provide guidance to help people plan for flooding: • Organise a 'meet-the-street' style event for residents in the vicinity of Birdwood Drive and Turner Close, and repeat at intervals

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
RM2	Preparation of residential flood plans	9.3	Individual residents with assistance from SES & Council	Residents, SES & Council time	-	High	1 year	Potential to promote flood plan preparation as part of the 'meet-the-street' events discussed above.
RM3	Preparation of business flood plans	9.4	Individual business owners with assistance from SES & Council	Business owners, SES & Council time	-	High	1 year	
RM4	Local Flood Plan Updates	9.5	SES	SES time	-	High	1 year	Update Wyong Local Flood Plan to align with new SES LFP template and to incorporate new flood intelligence
RM6	Upgrade of Birdwood Drive	9.6.2	Council	$600,000	0	Medium	5+ years	Recommended for implementation as a long-term strategy. It is recommended that stormwater upgrades and installation of kerb and gutter is also completed at the time of the upgrade to assist with better management of frequent rainfall events.
RM7	Extension of Turner Close to McKellar Boulevard	9.6.3	Council	unknown	0	Medium	5+ years	Recommended for further consultation with the local community and potential implementation pending the outcomes of those discussions. Extent of preferred works not known at this stage so a cost estimate cannot be prepared.

#	Option	Report Section	Implementation Responsibility	Total Cost	BCR	Priority	Timing	Recommendation/Comments
RM8	Refuge in Place Strategy	9.7	Council & SES	Council & SES time	-	Medium	2 years	Conduct further research to inform appropriate response strategies for the Wallarah Creek catchment, and implement a community-led planning process to confirm response strategies
Options for Reducing the Future Flood Risk								
FM1	Doyalson Link Road Basin	7.2.1	Council & RMS	$2 million	-	Low	10 years	Not recommended for implementation to manage the existing flood risk. However, can be considered for further investigation to manage the future flood risk

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APPENDIX A

COMMUNITY CONSULTATION

10. PLEASE RATE EACH OF THE FOLLOWING POTENTIAL FLOOD RISK REDUCTIONS TO FURTHER ASSIST US IN PREPARING A SHORT LIST OF MEASURES.

Flood Modification Option	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure
Flood detention basins						
Levees						
Stormwater upgrades						
Enlarging channels						
Regular maintenance and clearing of the creeks						
Culvert/bridge upgrades						
Voluntary house raising						
Voluntary house flood proofing						
Voluntary house purchase						
Development/planning controls						
Flood forecasting/warning system						
Boom gates/signs at roadway overtopping locations						
Upgrade of flood evacuation routes						
SES local flood plan updates						
Community education						

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

____
____
____
____
____
____
____
____
____

FURTHER INFORMATION

To obtain further information about the study, please contact David Tetley at Catchment Simulation Solutions using the contact details below:

Suite 2.01,
210 George Street
Sydney NSW 2000

(02) 8355 5501
dtetley@csse.com.au

Wallarah Creek Floodplain Risk Management Study

Community Questionnaire

The following questionnaire should take less than 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. Please complete the questionnaire and return by **21 September 2018** using the enclosed reply-paid envelope or by email (dtetley@csse.com.au). Alternatively, if you have internet access, an online version of the questionnaire can be completed at: www.yourvoiceourcoast.com/floodplain-risk-management-study-plan-wallarah-creek-catchment

CONTACT DETAILS

Please provide your address to help us identify where floods have (or haven't) been problematic. It would also be helpful to have a means of contacting you if required.

Name: ________________________________

Address: ________________________________

____

Phone No. ________________________________

Email: ________________________________

Do you wish to stay informed for the duration of the study?

☐ Yes (please ensure your email address is provided) ☐ No

Do you give permission for us to publish your flooding photos and/or experiences as part of the report (your contact details will remain confidential at all times)?

☐ 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 WOULD YOU OBTAIN INFORMATION DURING FUTURE FLOODS (TICK ALL THAT YOU WOULD USE)?

- ☐ radio
- ☐ television
- ☐ online/internet
- ☐ emergency services (e.g., SES, police)
- ☐ other – please describe ________________________________
- ☐ don't know/not sure

6. 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

7. IF YOU ARE LIKELY TO EVACUATE, WHAT FACTORS ARE MOST IMPORTANT TO YOU (PLEASE SELECT ALL THAT APPLY)?

- ☐ discomfort/inconvenience/cost of being isolated by floodwater
- ☐ need for uninterrupted access to medical facilities
- ☐ safety of our family
- ☐ other – please describe ________________________________

8. IF YOU ARE LIKELY TO REMAIN AT YOUR HOUSE, WHAT FACTORS ARE MOST IMPORTANT TO YOU (PLEASE SELECT ALL THAT APPLY)?

- ☐ discomfort/inconvenience/cost of evacuating
- ☐ need to care for animals/pets
- ☐ my house cannot be flooded and we can cope with isolation
- ☐ concern for security of my property if I evacuate
- ☐ other – please describe ________________________________

9. 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
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					
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)					
Improves the recreational amenity of area					

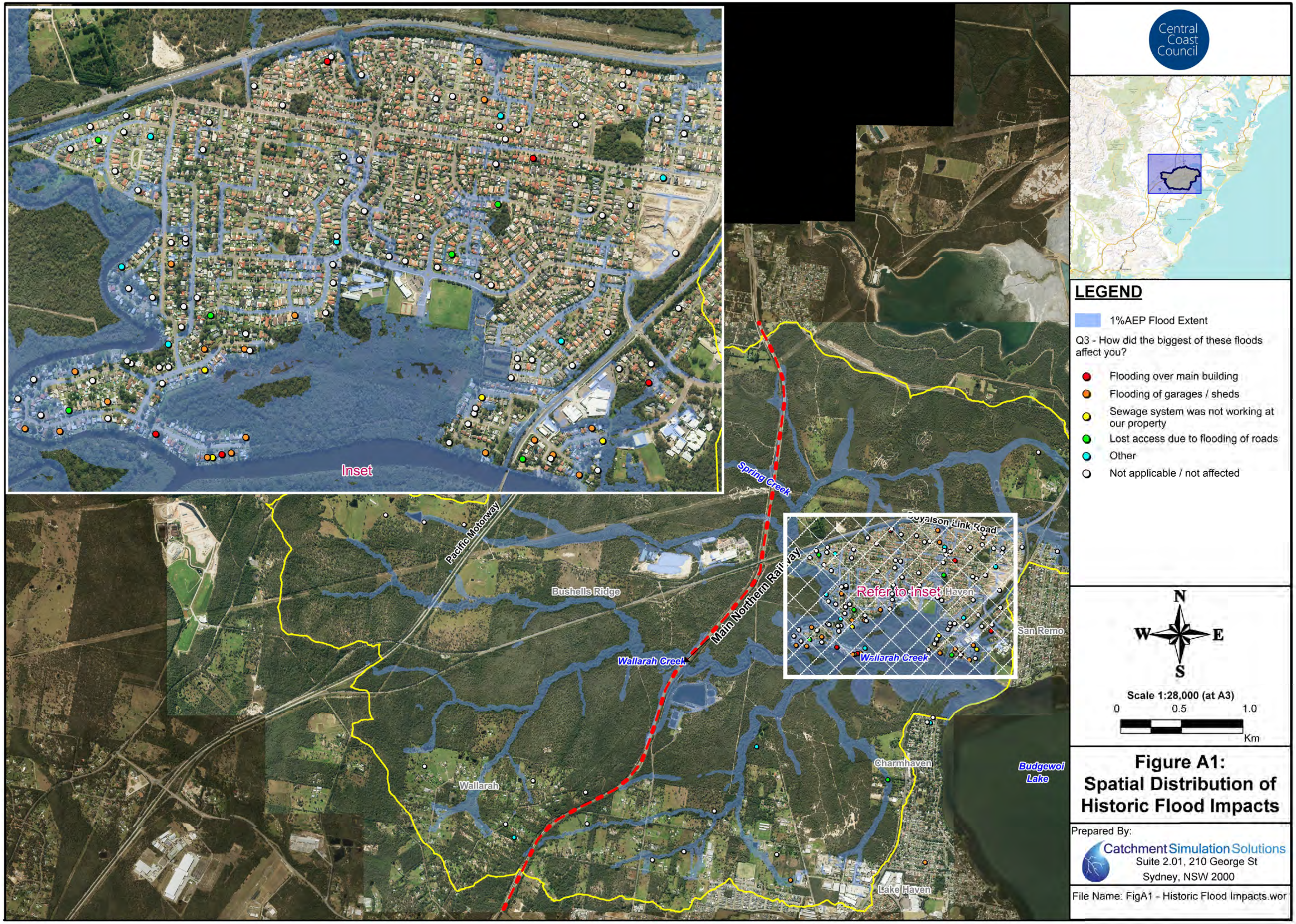

Figure A1: Spatial Distribution of Historic Flood Impacts

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
1	X				37	X							X		X	
2	X			Leased Out			X									X
3				Rural	5		X								X	
4	X						X						X		X	
5	X				23		X									X
6	X				15		X								X	
7				Rental Property			X					Unkown Rental				X
8	X						X						X		X	
9	X				0.6		X									X
10	X				0.6		X									X
11	X					X				X						X
12	X				30	X							X		X	
13	X				12	X						High Water Level Lower Part of backyard			X	
14	X				2		X									X
15	X				12		X								X	
16	X				37	X							X	X		
17	X				10		X									X
18	X				15		X								X	
19	X						X								X	
20	X						X								X	
21				Semi Rural	20		X								X	
22	X						X									X
23	X				9		X									X
24	X				5	X			X							X
25	X				23	X						Flooded low half of property			X	
26	X				11		X								X	
27	X				6		X							X		

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
28	X						X							X		
29	X				16	X										X
30	X				53	X			X	X				X		
31	X						X								X	
32	X				1		X									X
33	X						X						X			X
34	X						X									X
35	X				18		X		X							X
36	-						X	X								X
37	X						X		X							X
38				Rural Property & Residence	40		X								X	
39	X				20		X									X
40	X				8	X			X			Minor Yard Flooding,due to bad drainage in the road (no guttering etc)				X
41	X				8		X						X			X
42	X						X								X	
43	X				21		X								X	
44	X			Residential /Rural	30	X				X		Road Washed Away				X
45	X				25	X						It onlt Came up on Our Lawn			X	
46	X				16	X							X			X
47	X				14		X								X	
48	X				50		X								X	
49	X				25		X						X			X
50	X				35				X		X			X		
51	X				2		X					Water inundation of back & side yard				X
52	X				36	X					X	Inconvenienc-no Power Plane		X		

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
53	X				12	X			X					X		
54	X					X							X			X
55	X			Residential /Rural	22		X								X	
56	X				20		X						X		X	
57	X						X							X		
58	X				21		X								X	
59	X				50		X								X	
60	X				34											
61	X				20		X						X			X
62	X				4		X									X
63	X				14	X			X	X						X
64	X				12	X				X					X	
65	X				17		X									X
66	X				10		X								X	
67	X				35	X						only came up the yard to nearly the clothes line			X	
68	X				13		X									X
69	X				5	X							X			X
70	X				8		X								X	
71	X				36	X			X	X		Au yard under 1 mtr water- house ok		X		
72	X					X						Came into Backyard			X	X
73	X				16		X						X		X	
74	X						X								X	
75	X				17		X									X
76	X				8	X						Water in back yard,no big deal				X
77	X				14		X									X
78	X						X									X
79	X				0.5		X									X

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
80	X						X						X			X
81	X						X									X
82	X				1		X								X	
83	X				12		X					yard				X
84	X				3		X						X		X	
85	X						X						X		X	
86	X						X						X		X	
87	X				4		X									X
88	X				19	X		X	X					X		
89	X				0.6		X									X
90	X				0.6		X									X
91	X				19		X						X		X	
92	X				17		X								X	
93	X				32	X						Flooping in Nearby Lake Budgew				X
94	X			rental property			X						X		X	
95	X				21	X			X			Sun-Room Flooded Three Times		X		
96	X				36.5	X			X			Stormwater Backlogs Causing rear awning gutters to overflow due to front stormwater off load to street having nowhere to go in heavy rain				X
97	X						X									X

Catchment Simulation Solutions

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
98	X				20		X					The properties behind our in white lwan av has 2 jump next to our back fence during the pasha bulita storm some years ago they flooded due to				
99	X					X							X		X	
100	X						X									X
101	X				36		X								X	
102	X				33	X							X			X
103	X				35	X				X						X
104	X				20		X									X
105	X						X								X	
106	X				11		X								X	
107	X				25	X			X	X	X					X
108	X				12		X									X
109	X				14	X										X
110	X						X									X
111	X				29	X					X					X
112	X						X									X
113	X				3		X								X	
114	X				8	X							X			X
115	X						X									X
116	X				27	X			X	X				X		
117	X						X								X	
118	X	X	X				X								X	
119	X				31	X						Moderate Flooding on Roads				X
120	X				23		X								X	
121	X				4.5		X					Fences to hard to be Replaced				X

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
122	X				11	X				X						X
123	X						X									X
124	X				18		X									X
125	X				32	X		X	X	X	X			X		
126	X				19		X								X	
127	X				39	X				X	X	x		X		
128	X						X									X
129	X				40	X			X						X	
130	X					X		X	X	X	X					X
131	X				23		X						X			
132	X				18		X									X
133	X						X							X		
134	X				40	X							X			X
135	X				35		X						X		X	
136	X				32	X			X					X		
137	X				22		X								X	
138	X						X									X
139	X				38		X									X
140				acreage	30		X								X	
141	X				11		X									X
142	X				27	X			X							X
143	X				13	X							X		X	
144	X				34		X								X	
145	X						X									X
146	X				8	X				X				X		
147	X				24		X	X								X
148	X						X									X
149	X				20		X							X		
150	X				14		X						X		X	

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
151					24	X			X		X	Drain Behinds has Blocks of land floods behind comes and N Taver N Never Gets Cleaned,				
152	X						X						X			X
153	X			Small acreage	19	X			X					X		
154	X						X									X
155	X					X			X							X
156	X				6	X								X		
157	X				40	X							X			X
158	X						X								X	
159	X				1		X							X		
160	X				20	X						The bridge on Pacific Highway				X
161	X				38	X			X	X		Further inundation due to wake				X
162	X				14	X							X			X
163	X				16	X			X							X
164	X				0.25		X									X
165	X				15		X									X
166	X				25		X									X
167	X						X							X		
168	X						X								X	
169				Rural	60		X								X	
170	X				3.5	X			X	X				X		
171	X				30	X				X				X		
172	X				1.5	X			X			Back garden		X		
173	X				16	X		X	X	X				X		
174	X				3	X				X						X
175	X				45	X			X		X			X		

Table A1 - Property Types and Historic Flood Impacts

#	What type of property do you have?					Have you experienced previous floods in this area?		How did the biggest of these floods affect you?						Do you know if your house / business has a risk of being flooded?		
	Residential	Commerical	Industrial	Other (please specify)	How long have you lived/worked at this property? (years)	Yes	No	Flooding over main building floor	Flooding of garages / sheds	Lost access due to flooding of roads	Sewage 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
176	X				5		X						X			X
177				Small acreage	15		X						X		X	
178	X				33	X				X	X					X
179	X				16	X							X			X
180	X					X				X						X
181	X				1.5		X						X	X		
182	X				2		X						X		X	

Central Coast Council

LEGEND

PMF Extent

Q6 - How do you anticipate you would respond in a future major flood in this area?

- Remain at my house
- Don't know/ not sure
- Evacuate elsewhere
- Evacuate early to an offical evacuation centre
- Other

N W E S

Scale 1:28,000 (at A3)

0 0.5 1.0 Km

Figure A2: Spatial Distribution of Preferred Flood Response

Prepared By:

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

File Name: FigA2 - Preferred Flood Response .wor

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
1	X	X							X					X				X		
2	X	X									X	X				X				
3	X	X	X	X					X					X		X	X	X	X	
4	X	X	X	X	neigbours				X					X	Not going to Happen			X		
5			X	X				Friend or Relative						X			X			
6	X	X	X	X			X					X		X						
7		X			Property managers						X				Not Resident At That Address					Not Resident At That Address
8						X		X				X	X	X		X		X	X	
9	X	X	X	X			X					X	X	X		X	X			
10	X	X	X	X			X					X	X	X		X	X			
11						X			X						X		X			
12	X	X	X						X									X		
13					Look out at the backyard?					Do as least as possible, put cans of beer in freezer					Remain at home. Thinking of why the council couldn't help the people downstream effected from flood.					Possible loss of power due to other residents in trouble. May have warm beer.
14	X	X	X				X							X				X	X	
15		X							X							X	X	X		
16						X			X					X				X		
17	X	X	X	X							X	X	X	X					X	
18	X	X	X	X			X					X		X						
19		X		X					X					X			X	X	X	
20		X		X					X					X			X	X	X	
21	X	X	X						X									X		
22	X	X	X	X					X										X	
23	X	X		X			X					X		X					X	
24	X	X							X				X			X			X	

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
25	X	X			monitor amount of rain				X					X				X		
26	X	X		X				Family					X	X						
27	X	X	X	X			X					X		X			X			
28						X			X									X		
29	X		X						X			X						X		
30	X	X	X	X					X					X			X		X	
31			X						X					X	X			X	X	
32	X	X	X					Parents Place						X		X				
33	X	X							X			X						X		
34	X	X	X	X			X					z				X	X		X	
35	X	X	X	X	RSI Culb(Doylo)			Relatives				X	X	X		X	X	X	X	
36	X	X	X	X			X							X			X			
37	X		X	X	neigbours			Friends				X				X				
38	X	X							X							X	X	X		
39	X								X				X						X	
40		X		X							X	X				X	X		X	
41	X	X							X					X					X	
42	X	X	X	X					X					X				X		
43				X							X		X					X	X	
44	X		X	X					X			X	X	X			X			
45	X		X		It does'nt cause problems for us so we don't worry about it				X			X		X	X			X	X	
46	X	X	X	X							X		X	X			X		X	
47	X	X						X				X						X	X	
48	X								X				X	X			X	X	X	
49	X	X		X			X						X	X			X		X	
50	X	X		X					X			X						X		
51		X	X						X								X		X	
52	X	X							X			X						X		

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
53	X	X	X	X					X	Risk has been minimised due to improved drainage works under taken on our property.				X					X	
54		X		X				Friend/family					X			X				
55	X	X	X	X			X	Relative or friends						X				X	X	
56	X	X	X								X			X				X		
57	X	X	X	X			X					X		X		X			X	
58	X	X		X					X					X				X		
59	X								X				X	X			X	X	X	
60																				
61	X	X		X			X							X				X	X	
62	X	X	X	X			X					X		X		X	X	X		
63				X			X					X							X	
64	X	X	X	X					X			X		X		X			X	
65	X	X					X							X					X	
66	X	X		X					X					X				X	X	
67		X							X				X					X		
68		X	X	X			X						X						X	
69	X	X			From Friends				X			X		X			X		X	
70		X	X	X			X							X				X		
71	X	X	X	X					X			X				X		X		
72	X	X	X	X					X			X	X	X		X		X	X	
73	X	X							X									X		
74	X	X	X	X				Relative					X	X		X	X	X	X	
75	X								X				X	X				X	X	
76	X	X	X	X					X			X								
77		X		X				only of mt children's homes						X					X	
78	X	X	X	X			X					X		X		X	X		X	
79	X		X								X	X		X		X	X		X	
80						X					X			X					X	

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
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81		X	X				X		X			X		X		X		X		
82	X	X							X									X		
83		X						X						X					X	
84	X	X	X	X					X			X		X		X	X	X		
85	X	X		X					X			X	X	X	X			X		
86	X	X		X					X			X	X	X	X			X		
87	X	X	X	X					X				X					X		
88	X	X	X						X			X		X		X	X		X	
89	X	X	X	X			X					X		X	X	X				
90	X	X	X	X			X					X		X	X	X				
91	X					X			X					X				X		
92	X	X	X						X									X		
93	X								X			X				X				
94		X							X					X				X		
95	X	X	X				X					X	X	X		X	X		X	
96	X	X		X				Would go to family elsewhere				X		X	X		X		X	
97	X						X							X						
98	X	X	X	X			X					X		X			X			
99	X	X	X	X			X							X				X	X	
100				X							X	X		X						
101	X	X	X	X					X				X	X				X		
102	X	X	X	X	family				X									X		
103	X	X		X					X							X	X	X	X	
104	X	X					X													
105	X		X	X			X							X						
106	X	X									X		X	X			X	X		
107	X			X	Viz other ppl in our area.				X			X	X	X		X	X		X	
108			X	X			X					X		X		X	X		X	
109		X		X																
110	X										X			X				X		
111	X	X	X				X					X		X		X	X			
112	X	X	X	X							X	X		X		X			X	
113	X	X	X	X					X									X		

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
114	X	X	X	X							X	X							X	
115	X	X	X	X			X					X		X		X	X		X	
116	X	X	X						X							X			X	
117						X					X	X	X	X		X	X		X	
118	X	X	X	X																
119	X		X	X					X								X	X		
120	X	X		X					X			X		X		X		X		
121	X	X	X				X					X						X	X	
122	X	X	X						X					X	X		X			
123	X	X		X			X					X	X			X			X	
124						X					X	X							X	
125	X				Family Telephone				X							X	X		X	x
126	X	X	X	X				X					X	X						x
127	X				Telephone	X			X		X					X			X	x
128	X	X	X	X			X					X				X		X		
129	X			X					X			X						X		
130	X	X	X	X					X	Unable to go anywhere else.2 Aged Residents aged 100 Yrs 7 67 Yrs Handicapper Physically	X	X					X			
131	X	X		X				Daughters House(Jilliby)				X		X						
132	X	X					X						X	X			X	X		
133	X	X	X	X			X					X	X	X		X			X	
134	X	X					X					X		X			X		X	
135		X	X						X									X		
136	X	X	X		we see it Buildings				X			X	X	X		X	X		X	
137		X						Springfield(daughter)				X						X		
138	X								X					X			X	X	X	
139	X	X	X	X					X					X				X	X	
140									X					X				X		

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
141						X					X			X					X	
142		X	X	X					X	being pensioners if the time eventvates		X				X			X	
143		X				X					X			X				X		
144	X	X		X					X			X						X		
145	X	X	X				X							X					X	
146						X					X	X		X		X			X	
147	X	X	X	X					X					X		X			X	
148	X	X	X						X			X	X	X				X	X	
149	X	X		X					X		X	X	X			X			X	
150	X	X	X	X			X							X			X			
151											X									
152	X	X									X		X	X				X		
153	X	X			look outside				X								X	X		
154			X		online SES Website				X					X						x
155	X	X							X			X		X			X		X	
156					I would know when to leave from past experince					Watch - Wait									X	
157	X			X					X						X			X		
158			X				X							X				X		
159	X	X	X					Son's House	X		Depnds on the Height of the flood			X			X	X	X	
160	X	X		X							X	X	X	X				X		
161	X	X							X					X					X	
162						X			X										X	
163	X	X	X	X			X					X						X		
164	X	X	X				X					X		X	X	X	X		X	
165				X					X				X	X				X		
166		X		X				X				X		X			X			
167	X	X	X					X						X		X				
168	X	X	X								X			X				X		

Table A2 - Preferred Flood Response

#	How would you obtain information during future floods (tick all that you would use)?						How do you anticipate you would respond in a future major flood in this area?					If you are likely to evacuate, what factors are most important to you (please select all that apply)?				If you are likely to remain at your house, what factors are most important to you (please select all that apply)?				
	Radio	Television	Online / internet	Emergency services (e.g., SES, police)	Other – please describe	Don't know / not sure	Evacuate early to an official evacuation centre	Evacuate elsewhere – please describe:	Remain at my house	Other – please describe	Don't know/not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Need for uninterrupted access to medical facilities	Safety of our family	Other – please describe:	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:
169				x				x						x				x		
170	x	x	x	x				x				x		x			x		x	
171	x		x						x							x	x			
172				x					x			x	x	x	x	x			x	
173	x			Emergency services (e.g., SES, police)				x					x	x		x	x		x	
174		x	x						x					x			x		x	
175	x		x	x				x				x				x	x		x	
176	x	x	x	x				x					x				x			
177			x	x					x						x			x		
178		x	x				x					x	Need for uninterrupted access to medical facilities	x		x	x		x	
179	x	x	x	x					x			x	Need for uninterrupted access to medical facilities	x		x	x	x	x	
180			x		x						x	x		x		x	x		x	
181				x		x	x					x	Need for uninterrupted access to medical facilities	x		x	x		x	
182	x	x	x	x					x					x				x		

Table A3 - Feedback on Potential Flood Risk Reduction Measures

#	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?:								
	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	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)	Improves the recreational amenity of area
1	Moderately Important	Very Important	Slightly Important	Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Slightly Important
2	Very Important	Very Important	Very Important	Moderately Important	Extremely Important	Very Important	Very Important	Moderately Important	Very Important
3	Moderately Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Moderately Important	Not Important
4	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Not Important
5	Moderately Important	Very Important	Moderately Important	Extremely Important	Slightly Important	Slightly Important	Very Important	Extremely Important	Very Important
6	Very Important	Very Important	Moderately Important	Slightly Important	Not Important	Not Important	Moderately Important	Moderately Important	Slightly Important
7	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Moderately Important
8	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
9	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important
10	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important
11	Not Important	Not Important	Not Important	Not Important	Not Important	Not Important	Not Important	Not Important	Not Important
12	Moderately Important	Very Important	Moderately Important	Not Important	Very Important	Very Important	Very Important	Very Important	Moderately Important
13									
14	Moderately Important	Very Important	Very Important	Slightly Important	Moderately Important	Moderately Important	Very Important	Extremely Important	Slightly Important
15									
16	Slightly Important	Very Important	Very Important	Slightly Important	Very Important	Very Important	Very Important	Very Important	Very Important
17	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important
18	Very Important	Extremely Important	Very Important	Slightly Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Slightly Important
19	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important
20	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important
21	Moderately Important	Very Important	Very Important	Moderately Important	Slightly Important	Very Important	Very Important	Very Important	Moderately Important
22	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
23	Moderately Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Very Important	Extremely Important	Extremely Important	Very Important
24	Very Important	Very Important	Very Important	Moderately Important	Not Important	Moderately Important	Very Important	Very Important	Very Important
25		Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important
26	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important
27	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
28	Extremely Important	Moderately Important	Not Important	Not Important	Not Important	Very Important	Very Important	Not Important	Not Important
29	Moderately Important	Moderately Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important
30	Very Important	Extremely Important	Very Important	Very Important	Very Important	Very Important		Extremely Important	Very Important

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31	Extremely Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Very Important	Slightly Important
32	Very Important	Extremely Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Very Important
33	Moderately Important	Very Important	Very Important	Slightly Important	Moderately Important	Very Important	Extremely Important	Moderately Important	Slightly Important
34	Extremely Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Very Important
35	Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important
36	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Extremely Important	Moderately Important	Slightly Important
37	Very Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
38	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
39	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Very Important
40	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important
41	Moderately Important	Very Important	Extremely Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Very Important
42	Moderately Important	Extremely Important	Very Important	Very Important	Very Important	Moderately Important	Extremely Important	Very Important	Very Important
43	Extremely Important	Extremely Important	Extremely Important			Extremely Important			
44	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important
45	Very Important	Very Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important
46	Moderately Important	Very Important	Moderately Important	Moderately Important	Very Important	Extremely Important	Very Important	Very Important	Moderately Important
47	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
48	Extremely Important	Extremely Important	Extremely Important	Not Important	Very Important	Very Important	Extremely Important	Extremely Important	Slightly Important
49	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
50	Very Important	Moderately Important	Slightly Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Slightly Important
51	Very Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
52	Very Important	Very Important	Very Important	Slightly Important	Very Important	Very Important	Very Important	Very Important	Slightly Important
53	Very Important	Very Important	Very Important		Slightly Important	Slightly Important	Very Important	Very Important	Slightly Important
54									
55	Very Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Moderately Important	Slightly Important
56	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Extremely Important	Moderately Important	Moderately Important	Moderately Important
57	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Very Important
58	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Moderately Important
59	Extremely Important	Extremely Important	Extremely Important	Not Important	Very Important	Very Important	Extremely Important	Extremely Important	Slightly Important
60									

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	How important is it that the flood risk reduction measure?:								
	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	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)	Improves the recreational amenity of area
61		Not Important	Not Important						
62	Very Important	Very Important	Very Important	Very Important	Moderately Important	Slightly Important	Very Important	Very Important	Very Important
63	Moderately Important	Very Important	Moderately Important	Moderately Important	Slightly Important	Very Important	Very Important	Moderately Important	Moderately Important
64	Extremely Important	Extremely Important	Very Important	Moderately Important	Not Important	Not Important	Extremely Important	Extremely Important	Moderately Important
65	Very Important	Extremely Important	Very Important	Very Important	Not Important	Not Important	Extremely Important	Very Important	Extremely Important
66	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important	Very Important
67	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
68	Very Important	Extremely Important	Very Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important
69	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Very Important	Very Important	Extremely Important	Not Important
70	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
71	Moderately Important	Moderately Important	Very Important	Moderately Important	Slightly Important	Moderately Important	Moderately Important	Very Important	Moderately Important
72	Very Important	Very Important	Extremely Important	Slightly Important	Slightly Important	Slightly Important	Very Important	Very Important	Not Important
73									
74	Not Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Moderately Important
75	Moderately Important	Very Important	Very Important	Not Important	Not Important	Not Important	Very Important	Very Important	Not Important
76	Moderately Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important
77	Slightly Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Slightly Important	Slightly Important
78	Very Important	Very Important	Moderately Important	Slightly Important	Not Important	Not Important	Very Important	Very Important	Moderately Important
79	Moderately Important	Very Important	Moderately Important	Very Important	Slightly Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
80	Not Important	Very Important	Extremely Important	Not Important	Moderately Important	Not Important	Not Important	Not Important	Moderately Important
81									
82	Very Important	Extremely Important	Very Important	Slightly Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important
83	Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important	Moderately Important
84	Very Important	Extremely Important	Very Important	Very Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
85	Very Important	Extremely Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Extremely Important
86	Very Important	Extremely Important	Very Important	Very Important	Very Important	Moderately Important	Very Important	Slightly Important	Extremely Important
87	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Not Important	Extremely Important	Extremely Important	Extremely Important	
88	Very Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important
89	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Not Important	Not Important	Extremely Important	Moderately Important	Extremely Important
90	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Not Important	Not Important	Extremely Important	Moderately Important	Extremely Important

Table A3 - Feedback on Potential Flood Risk Reduction Measures

#	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?:								
	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	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)	Improves the recreational amenity of area
91	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Moderately Important	Moderately Important	Moderately Important
92	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important
93	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
94	Slightly Important	Very Important	Extremely Important	Moderately Important	Very Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
95	Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Moderately Important
96	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important
97	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
98	Not Important	Very Important	Very Important	Moderately Important	Moderately Important		Moderately Important	Moderately Important	Not Important
99		Extremely Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
100	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important
101	Very Important	Extremely Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
102	Moderately Important	Extremely Important	Very Important	Extremely Important	Not Important	Not Important	Extremely Important	Extremely Important	Very Important
103	Moderately Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important
104	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Very Important
105	Very Important	Extremely Important	Very Important	Very Important	Very Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
106	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
107	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
108	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important
109									
110	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
111	Moderately Important	Very Important	Very Important	Moderately Important	Slightly Important	Slightly Important	Very Important	Very Important	Slightly Important
112	Extremely Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Slightly Important
113	Very Important	Very Important	Very Important	Moderately Important	Very Important	Moderately Important	Very Important	Moderately Important	Slightly Important
114	Very Important	Extremely Important	Extremely Important	Moderately Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important
115	Very Important	Extremely Important	Very Important	Moderately Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
116	Slightly Important	Moderately Important	Moderately Important	Moderately Important	Not Important	Slightly Important	Moderately Important	Moderately Important	Not Important
117	Very Important	Very Important	Very Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Moderately Important
118	Not Important	Moderately Important	Moderately Important	Not Important	Extremely Important	Extremely Important	Moderately Important	Extremely Important	Slightly Important
119	Moderately Important	Very Important	Moderately Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Slightly Important
120	Extremely Important	Extremely Important	Moderately Important	Very Important	Not Important	Not Important	Very Important	Extremely Important	Not Important

Table A3 - Feedback on Potential Flood Risk Reduction Measures

#	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?:								
	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	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)	Improves the recreational amenity of area
121	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
122	Very Important	Extremely Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Not Important
123	Very Important	Extremely Important	Extremely Important	Moderately Important	Very Important	Very Important	Very Important	Very Important	Slightly Important
124		Very Important							
125	Very Important	Extremely Important	Very Important	Extremely Important	Not Important	Slightly Important	Very Important	Very Important	Not Important
126	Slightly Important	Extremely Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Very Important	Slightly Important
127	Moderately Important	Very Important	Very Important	Extremely Important	Slightly Important	Not Important	Extremely Important	Extremely Important	Not Important
128	Very Important	Very Important	Very Important	Not Important	Not Important	Slightly Important	Extremely Important	Extremely Important	Not Important
129	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
130	Slightly Important	Slightly Important	Moderately Important	Moderately Important	Moderately Important	Slightly Important	Slightly Important	Slightly Important	Not Important
131	Extremely Important	Extremely Important	Very Important	Very Important	Not Important	Very Important	Very Important	Extremely Important	Very Important
132	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
133	Very Important	Very Important	Very Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important
134	Very Important	Extremely Important	Very Important	Extremely Important	Very Important	Very Important	Very Important	Very Important	Very Important
135	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
136		Extremely Important	Extremely Important				Extremely Important	Extremely Important	
137	Very Important	Very Important	Extremely Important	Very Important	Moderately Important	Very Important	Extremely Important	Extremely Important	Extremely Important
138	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Not Important	Very Important	Extremely Important	Extremely Important	Extremely Important
139	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
140	Very Important	Extremely Important	Very Important	Moderately Important	Very Important	Very Important	Moderately Important	Very Important	Moderately Important
141	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Slightly Important	Moderately Important	Very Important	Very Important	Moderately Important
142	Very Important	Extremely Important	Very Important	Extremely Important	Moderately Important	Very Important	Extremely Important	Extremely Important	Extremely Important
143	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important
144	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
145	Very Important	Very Important	Extremely Important	Very Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important	Extremely Important
146	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Extremely Important
147	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
148	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
149	Very Important	Not Important	Not Important	Very Important	Extremely Important	Extremely Important	Not Important	Extremely Important	Not Important
150	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important

Table A3 - Feedback on Potential Flood Risk Reduction Measures

#	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?:								
	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	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)	Improves the recreational amenity of area
151					Extremely Important	Extremely Important		Extremely Important	
152	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Very Important	Very Important	Moderately Important
153	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important	Slightly Important
154	Moderately Important	Extremely Important	Extremely Important	Not Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important	Moderately Important
155	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
156					Extremely Important				
157	Very Important	Very Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Extremely Important	Very Important	Not Important
158	Extremely Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
159		Extremely Important	Very Important	Moderately Important	Moderately Important	Moderately Important	Extremely Important	Very Important	Very Important
160	Very Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Very Important
161	Very Important	Very Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important
162	Very Important	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important
163	Very Important	Extremely Important	Very Important	Very Important	Very Important	Extremely Important	Extremely Important	Extremely Important	Very Important
164	Moderately Important	Very Important	Extremely Important	Slightly Important	Moderately Important	Very Important	Extremely Important	Slightly Important	Moderately Important
165	Very Important	Extremely Important	Moderately Important	Slightly Important	Slightly Important	Slightly Important	Very Important	Very Important	Very Important
166	Not Important	Moderately Important	Moderately Important	Moderately Important	Slightly Important	Not Important	Moderately Important	Slightly Important	Not Important
167	Very Important	Extremely Important	Extremely Important	Extremely Important	Slightly Important	Slightly Important	Extremely Important	Extremely Important	Not Important
168	Not Important	Very Important	Very Important	Moderately Important	Moderately Important	Very Important	Very Important	Very Important	Very Important
169									
170	Moderately Important	Extremely Important	Very Important	Moderately Important	Slightly Important	Slightly Important	Extremely Important	Very Important	Extremely Important
171	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
172	Extremely Important	Extremely Important	Extremely Important		Extremely Important	Extremely Important		Extremely Important	
173	Very Important	Extremely Important	Moderately Important	Slightly Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important
174	Moderately Important	Extremely Important	Very Important	Moderately Important	Extremely Important	Not Important	Slightly Important	Extremely Important	Extremely Important
175	Slightly Important	Extremely Important	Very Important	Very Important	Extremely Important	Moderately Important	Very Important	Very Important	Very Important
176	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important	Very Important
177	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important
178	Slightly Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Very Important	Very Important
179	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Extremely Important	Very Important	Extremely Important	Very Important
180	Very Important	Very Important	Extremely Important	Moderately Important	Extremely Important	Extremely Important	Very Important	Very Important	Very Important

Table A3 - Feedback on Potential Flood Risk Reduction Measures

#	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?:								
	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	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)	Improves the recreational amenity of area
181	Extremely Important	Extremely Important	Very Important	Very Important	Extremely Important	Very Important	Very Important	Very Important	Very Important
182	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Extremely Important	Moderately Important	Moderately Important	Extremely Important	Extremely Important

Table A4 Feedback on Potential Flood Modification Options

#	Please rate each of the following potential flood risk reductions to further assist us in preparing a short list of measures.														
	Flood Modification Option														
	Flood detention basins	Levees	Stormwater upgrades	Enlarging channels	Regular maintenance and clearing of the creeks	Culvert/bridge upgrades	Voluntary house raising	Voluntary house flood proofing	Voluntary house purchase	Development /planning controls	Flood forecasting/ warning system	Boom gates/signs at roadway overtopping locations	Upgrade of flood evacuation routes	SES local flood plan updates	Community education
1	Neutral	Neutral	Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Support	Neutral
2	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Support	Strongly Against		Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Support
3	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
4	Neutral	Neutral	Strongly Support	Support	Support	Support	Neutral	Neutral	Against	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral
5	Strongly Against	Strongly Against	Support	Neutral	Against	Strongly Support	Neutral	Support	Support	Unsure	Unsure	Neutral	Unsure	Unsure	Unsure
6	Neutral	Neutral	Strongly Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Strongly Support	Support	Neutral	Support	Strongly Support	Strongly Support
7	Support	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
8	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support
9	Strongly Support	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support
10	Strongly Support	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support
11	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Unsure	Strongly Support	Unsure	Unsure	Unsure	Unsure	Unsure
12	Against	Against	Support	Support	Support	Support	Against	Against	Against	Neutral	Support	Against	Neutral	Support	Support
13															
14	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
15															
16	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
17	Unsure	Unsure	Strongly Support	Support	Support	Support	Unsure	Unsure	Unsure	Strongly Support	Support	Unsure	Support	Support	Support
18	Neutral	Neutral	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Neutral
19	Support	Support	Support	Support	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support
20	Support	Support	Support	Support	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support
21	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
22	Support	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support
23	Unsure	Unsure	Strongly Support		Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
24	Support	Support	Neutral	Strongly Support	Strongly Support	Support	Unsure	Unsure	Unsure	Support	Support	Neutral	Neutral	Support	Support
25	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Support
26	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
27	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
28	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
29	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
30	Unsure	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Support	Support	Unsure	Unsure	Unsure	Support
31	Neutral	Against	Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Support	Against	Support	Strongly Support	Neutral
32	Support	Support	Support	Support	Strongly Support	Support	Against	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Support	Support
33	Support	Support	Neutral	Support	Neutral	Neutral		Against	Neutral		Support	Support	Support	Support	Strongly Support
34	Unsure	Unsure	Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support

Table A4 Feedback on Potential Flood Modification Options

#	Please rate each of the following potential flood risk reductions to further assist us in preparing a short list of measures.														
	Flood Modification Option														
	Flood detention basins	Levees	Stormwater upgrades	Enlarging channels	Regular maintenance and clearing of the creeks	Culvert/bridge upgrades	Voluntary house raising	Voluntary house flood proofing	Voluntary house purchase	Development /planning controls	Flood forecasting/ warning system	Boom gates/signs at roadway overtopping locations	Upgrade of flood evacuation routes	SES local flood plan updates	Community education
35	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Support	Strongly Support	Unsure	Neutral
36	Neutral	Neutral	Support	Neutral	Strongly Support	Strongly Support	Neutral	Strongly Support	Support	Support	Unsure	Strongly Support	Unsure	Unsure	Unsure
37	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Strongly Support	Strongly Support
38	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
39	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support		Neutral	Neutral	Neutral	Strongly Support	Support	Support	Support	Support
40	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Neutral		Support
41	Unsure	Unsure	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	strongly against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support
42	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
43	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support
44	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
45	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support		Neutral	Neutral	Neutral	Neutral	against	against	Neutral	Neutral	against
46	Support	Support	Strongly Support	Strongly Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Neutral	Neutral	Support	Support
47	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
48			Strongly Support	Support	Neutral	Support	Strongly Against	Neutral	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
49	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Support	Neutral	Support	Support
50	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Support	Support	Support	Strongly Support	Support	Strongly Support	Strongly Support
51	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
52	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Support	Support	Support	Strongly Support	Support	Strongly Support	Strongly Support
53	Unsure	Unsure	Strongly Support	Support	Strongly Support	Strongly Support	Support	Support	Unsure	Neutral	Strongly Support	Neutral	Neutral	Neutral	Support
54	Support	Strongly Against	Strongly Support	Support	Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Support	Support	Support	Support
55	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
56		Strongly Against	Against	Against	Neutral	Strongly Against	Neutral	Neutral	Neutral	Support	Support	Support	Support	Neutral	Support
57	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support	Support	Support	Strongly Support	Strongly Support	Support
58	Unsure	Support	Support	Unsure	Support	Unsure	Neutral	Support	Neutral	Support	Support	Support		Support	Support
59			Strongly Support	Support	Neutral	Support	Strongly Against	Neutral	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
60															
61		Strongly Against	Strongly Against		Strongly Against						Strongly Against	Strongly Against		Strongly Against	
62	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
63	Neutral	Support	Strongly Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral	Support	Neutral	Support	Support	Support
64	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support		Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
65	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
66	Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Support	Support	Neutral	Against	Support	Support	Support	Support	Support	Support
67	Strongly Support	Against	Strongly Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
68	Neutral	Neutral	Strongly Support	Neutral	Strongly Support	Neutral	Against	Against	Against	Support		Neutral	Neutral	Strongly Support	Neutral

Table A4 Feedback on Potential Flood Modification Options

#	Please rate each of the following potential flood risk reductions to further assist us in preparing a short list of measures.														
	Flood Modification Option														
	Flood detention basins	Levees	Stormwater upgrades	Enlarging channels	Regular maintenance and clearing of the creeks	Culvert/bridge upgrades	Voluntary house raising	Voluntary house flood proofing	Voluntary house purchase	Development /planning controls	Flood forecasting/ warning system	Boom gates/signs at roadway overtopping locations	Upgrade of flood evacuation routes	SES local flood plan updates	Community education
69	Support	Support	Support	Support	Against	Strongly Support	Neutral	Neutral	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
70	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Support		Neutral	Strongly Support	Strongly Support	Support	Strongly Support	Support	Support
71	Neutral	Support	Support	Strongly Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Support
72	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Support	Support	Support	Strongly Support
73			Support		Support						Support	Support		Support	Support
74	Support	Support	Support	Support	Strongly Support	Support	Support	Support	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
75	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
76	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Neutral	Support	Strongly Support	Strongly Support
77	Support	Neutral	Support	Support	Support	Neutral	Against	Against	Against	Neutral	Support	Support	Neutral	Neutral	Neutral
78	Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Strongly Support	Support
79	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Support	Support
80	Neutral	Neutral	Strongly Support	Strongly Support	Unsure	Strongly Support	Neutral	Neutral	Neutral	Neutral	Unsure	Unsure	Unsure	Unsure	Unsure
81															
82	Neutral	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
83	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
84	Support	Unsure	Strongly Support	Unsure	Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Support
85	Support	Support	Support	Support	Support	Support	Support	Support	Neutral	Support	Support	Neutral	Support	Support	Support
86	Support	Support	Support	Support	Support	Support	Support	Support	Neutral	Support	Support	Neutral	Support	Support	Support
87	Strongly Support		Support	Support	Support	Support	Support	Support			Support	Support	Support		Support
88	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Against	Support	Support	Support	Support	Support	Support	Support	Support
89	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
90	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
91	Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Unsure	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral
92	Support	Support	Support	Support	Support	Support	Neutral	Neutral	Support	Support	Support	Support	Support	Support	Support
93	Neutral	Neutral	Neutral		Strongly Support	Strongly Support	Unsure	Strongly Support	Unsure	Neutral	Strongly Support	Unsure	Neutral	Strongly Support	Strongly Support
94	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support
95	Neutral	Neutral	Neutral	Neutral	Support	Support	Neutral	Support	Neutral	Neutral	Support	Support	Support	Support	Strongly Support
96			Strongly Support	Strongly Support	Strongly Support	Strongly Support			Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
97	Support	Support	Support		Support	Support	Strongly Against	Strongly Against	Strongly Against	Support	Support	Support	Support	Support	Support
98	Unsure		Strongly Support	Strongly Support	Strongly Support	Strongly Support		Neutral	Support	Support	Support	Support	Neutral	Support	Support
99			Support	Support	Support	Support	Against	Against	Support	Support	Support	Support	Support	Support	Support
100	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support
101	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Strongly Support
102	Unsure	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support

Table A4 Feedback on Potential Flood Modification Options

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103	Unsure	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Neutral	Against	Support	Strongly Support	Neutral	Support	Support	Support
104			Support	Support	Strongly Support	Support		Support			Support	Support	Support	Strongly Support	Support
105	Against	Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Support	Support	Support
106			Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
107	Support	Support	Support	Support	Strongly Support	Support	Unsure	Unsure	Unsure	Unsure	Support	against	Strongly Support	Support	Support
108	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
109	Strongly Support	Strongly Support	Strongly Support	Strongly Support							Strongly Support		Strongly Support	Strongly Support	Strongly Support
110	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
111	Unsure	Unsure	Support	Support	Support	Unsure	Against	Against	Against	Support	Support	Neutral	Support	Support	Neutral
112	Support	Support	Support	Support	Strongly Support	Strongly Support	Unsure	Unsure	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
113		Support	Neutral	Support	Strongly Support	Neutral	Unsure	Unsure	Against	Support	Support	Support	Neutral	Neutral	Support
114	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
115	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support
116	Strongly Support	Neutral	Support	Neutral	Neutral	Neutral	Support	Support	Neutral	Support	Strongly Support	Neutral	Support	Strongly Support	Support
117	Neutral	Support	Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
118	Support	Neutral	Strongly Support	Neutral		Strongly Support	Neutral	Neutral	Strongly Support	Neutral	Support	against	Support	Support	Support
119	Neutral	Neutral	Support	Neutral	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Support	Support	Strongly Support	Strongly Support
120	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Neutral
121	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
122	Unsure	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Strongly Support	Unsure	Unsure	Strongly Support	Support	Support	Support	Strongly Support
123	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Against	Against	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
124				Neutral	Neutral	Neutral									
125	Neutral	Neutral	Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Strongly Support	Support	Support	Strongly Support
126	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Support	Support	Strongly Support	Support	Support	Support	Support
127	Support	Against	Support	Against	Strongly Support	Support	Strongly Support	Support	Neutral	Support	Strongly Support	Strongly Support	Support	Support	Strongly Support
128	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
129	Support	Against	Strongly Support	Unsure	Strongly Support	Support	Neutral	Neutral	Neutral	against	Strongly Support	against	Neutral	Strongly Support	Neutral
130	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
131	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Unsure	Support	Support	Unsure	Support	Support	Support
132			Support		Support	Support	Support	Neutral	Support	Support	Support	Support	Support	Support	Support
133	Strongly Support	Support	Strongly Support	Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support
134	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Support	Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Support
135	Strongly Support		Strongly Support								Strongly Support	Strongly Support	Strongly Support	Strongly Support	
136				Strongly Support	Strongly Support										

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137	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure	Unsure
138	Neutral	Neutral	Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral	Strongly Support	Support	Strongly Support	Strongly Support	Support
139	Unsure	Unsure	Support	Strongly Support	Strongly Support	Support	Unsure	Unsure	Unsure	Support	Strongly Support	Support	Support	Strongly Support	Support
140	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Strongly Support	Support	Support
141	Strongly Support	Neutral	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Support	Support
142	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Against	Strongly Against	Strongly Against	Strongly Support	Strongly Support	Strongly Against	Strongly Support	Strongly Support	Strongly Support
143	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
144	Support	Unsure	Strongly Support	Support	Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Unsure	Support	Strongly Support	Strongly Support
145	Support	Support	Support		Support	Support	Neutral	Neutral	Neutral	Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support
146	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Strongly Support	Strongly Support	Support	Support	Support	Support
147	Support	Support	Support	Support	Support	Strongly Support	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
148	Neutral	Against	Support	Support	Support	Support	Against	Support	Against	Support	Support	Support	Support	Support	Support
149	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support	Support
150		Strongly Support		Strongly Support		Strongly Support					Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
151	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support										
152	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Support	Support	Support	Strongly Support	Support	Support
153	Unsure	Unsure	Strongly Support	Unsure	Strongly Support	Strongly Support	Unsure	Unsure	Against	Strongly Support	support	Unsure	Unsure	Support	Neutral
154	Neutral	Neutral	Strongly Support	support	support	Strongly Support	Neutral	Neutral	Neutral	Neutral	Strongly Support	support	Strongly Support	Strongly Support	Neutral
155	Strongly Support	support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
156				Strongly Support		Strongly Support									
157	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Support	Support	Support	Unsute	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
158	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
159	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support
160	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
161	Support	Unsure	Support	Unsure	Support	Unsure	Unsure	Unsure	Unsure	Unsure	Strongly Support	Unsure	Unsure	Unsure	Unsure
162	Strongly Support	Strongly Support	Strongly Support	Unsure	Strongly Support	Strongly Support	Unsure	Support	Unsure	Unsure	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support
163	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
164	Neutral	Support	Strongly Support	Unsure	Support	Strongly Support	Strongly Against	Against	Neutral	Support	Strongly Support	Unsure	Support	Strongly Support	Unsure
165	Support	Support	Support	Strongly Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Support	Support	Support
166	Neutral	Neutral	Support	Neutral	Support	Neutral	Strongly Against	Against	Strongly Against	Neutral	Support	Support	Neutral	Support	Neutral
167	Support	Support	Support	Support	Support	Support	Support	Support	Support	Neutral	Strongly Support	against	Strongly Support	Strongly Support	Support
168	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Unsure	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
169															
170	Support	Support	Support	Support	Strongly Support	Support	Neutral	Support	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Neutral

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#	Please rate each of the following potential flood risk reductions to further assist us in preparing a short list of measures.														
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171	Neutral	Neutral	Strongly Support	Against	Support	Support	Neutral	Neutral	Neutral	Support	Support	Neutral	Support	Strongly Support	Strongly Support
172	Strongly Support		Strongly Support	Strongly Support	Strongly Support					Strongly Support		Strongly Support		Strongly Support	
173	Support	Neutral	Strongly Support	Strongly Support	Strongly Support	Neutral	Support	Against	Strongly Support	Strongly Support	Unsure	Support	Support	Support	Support
174	Neutral	Neutral	Support	Strongly Support	Support	Neutral	Neutral	Neutral	Support	Support	Support	Strongly Support	Support	Support	Support
175	Unsure	Unsure	Strongly Support	Unsure	Support	Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support	Strongly Support
176	Support	Support	Strongly Support	Support	Strongly Support	Strongly Support	Support	Support	Support	Support	Strongly Support	Strongly Support	Strongly Support	Support	Support
177	Against	Support	Support	Support	Against	Neutral	Strongly Against	Strongly Against	Strongly Against	Neutral	Strongly Support	Unsure	Unsure	Strongly Support	Strongly Support
178	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Against	Against	Against	Strongly Support	Strongly Support	Support	Strongly Support	Strongly Support
179	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Neutral	Neutral	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
180	Support	Support	Support	Support	Support	Support	Unsure	Unsure	Unsure	Strongly Support	Strongly Support	Support	Unsure	Support	Support
181	Strongly Support		Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support
182	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Neutral	Support	Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Strongly Support	Support

APPENDIX B

AUSTRALIAN RAINFALL & RUNOFF 2016 ASSESSMENT

1 ARR2016 AND ARR1987 HYDROLOGIC AND HYDRAULIC ASSESSMENT

1.1 Overview

Flood behaviour across the Central Coast Council LGA for the past three decades has been defined based on guidance contained in the 1987 version of 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (Engineers Australia) (in this report refer to as ARR1987). The 'Wallarah Creek Flood Study' (CSS, 2016) was also developed based on ARR1987.

In December 2016, a revised version of Australian Rainfall and Runoff was released (Geoscience Australia, 2016) (in this report refer to as ARR2016). Therefore, investigations were completed to determine the impact that the revised hydrologic procedures may have on design flood estimates across the Wallarah Creek catchments. The main goal of this assessment was to determine if the revised ARR2016 procedures would provide improved estimates of design flood behaviour for application as part of the Wallarah Creek Floodplain Risk Management Study.

The outcomes of the assessment are summarised in the following sections as follows:

- Section 1.2: Provides a comparison between the various ARR1987 and ARR2016 hydrologic inputs (e.g., design rainfall);
- Section 1.3: Provides a comparison between the ARR1987 and ARR2016 hydrologic results (e.g., peak discharges); and,
- Section 1.4: Summarises how the differences in hydrologic results will impact hydraulic results (e.g., peak flood levels and extents).

1.2 Hydrologic Inputs

1.2.1 Rainfall

Australian Rainfall & Runoff 1987

Design rainfall is one of the primary hydrologic inputs for simulating design floods and is established through statistical analysis of historic rainfall records. Design rainfall for the 20%, 5% and 1% AEP events were extracted at the centroid of the catchment from the Bureau of Meteorology's ARR1987 intensity-frequency-duration page and are presented in **Table 1**.

The 'Wallarah Creek Flood Study' (CSS, 2016), determined that the 1.5 hour and 2-hour storm duration produced the highest 1% AEP flood levels across most of the catchment. The 1.5-hour storm generally dominates in areas of shallow flow while the 2-hour storm duration dominates along the upstream sections of major creek as well as major overland flow paths. The 90-minute storm is generally critical in urbanised areas while the 360-minute storm duration dominates along the downstream sections of the catchment.

Table 1 Design rainfall depths for the Wallarah Creek Catchment from ARR1987 and ARR2016

Duration	Design Rainfall Depths (mm)								
	20% AEP			5% AEP			1% AEP		
	ARR1987	ARR2016	Difference (%)	ARR1987	ARR2016	Difference (%)	ARR1987	ARR2016	Difference (%)
5 min	11.9	12.4	4	15.4	18.2	15	19.95	26.2	24
10 min	18.3	19.5	6	23.8	28.5	17	30.93	41.3	25
15 min	23.0	24.4	6	30.0	35.7	16	39.03	51.8	25
30 min	32.8	33.7	3	42.8	49.5	13	55.99	71.9	22
1 hour	45.1	44.4	-1	59.1	65.2	9	77.56	94.3	18
2 hours	60.8	57.1	-6	80.1	83.5	4	105.42	120	12
3 hours	72.2	66.1	-9	95.3	96.3	1	125.69	138	9
6 hours	96.8	85.8	-13	128	124	-3	169.57	176	4
12 hours	129	113	-15	172	161	-7	228.3	228	0
24 hours	171	148	-15	228	212	-7	303.86	300	-1
48 hours	218	189	-15	293	274	-7	392.65	387	-1
72 hours	246	213	-15	332	311	-7	445.67	438	-2

Australian Rainfall & Runoff 2016

Revised design rainfall was established as part of the 2016 revision of Australian Rainfall and Runoff. This revised design rainfall takes advantage of more rainfall gauges and approximately 30 years of additional data, as well as more advanced statistical techniques. Accordingly, the revised ARR2016 rainfall information should provide a more statistically robust estimate of design rainfall for the catchment.

Design rainfall for the 20%, 5% and 1% AEP events were extracted at the centroid of the catchment from the Bureau of Meteorology's ARR2016 intensity-frequency-duration page. The ARR2016 rainfall depths are presented in **Table 1** alongside the ARR1987 design rainfall depths for comparison purposes.

The rainfall information presented in **Table 1** shows that the ARR2016 rainfall depths are typically lower than the equivalent ARR1987 rainfall depths for longer events i.e. for events with duration more than 6 hours. The rainfall comparison shows that as the severity of the event reduces, the magnitude of the differences for events with duration 6 hours and longer increases. For example, the differences between ARR1987 and ARR2016 rainfall depths for storms with 6 hours and longer duration is more significant in the 20% AEP event with than the 1% AEP event. On the other hand, comparison of the estimated rainfall depths of two methods indicates that for storms with duration 3 hours and shorter the magnitude of differences increased for severer events (**Plate 1**).

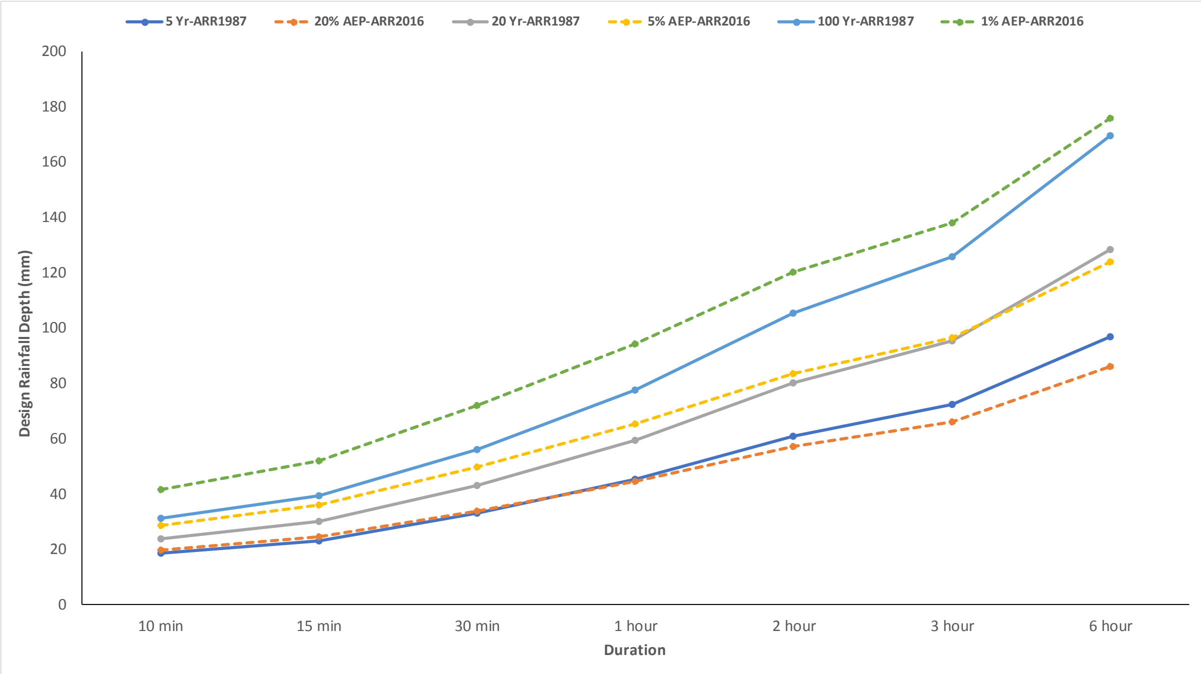


Plate 1 Comparison of ARR1987 and ARR2016 rainfall depths for the Wallarah Creek Catchment

The biggest difference between ARR1987 and ARR2016 rainfall depths occurs for storm durations between 5 min and 1 hour. For these durations, the ARR2016 rainfall depths are approximately 23% higer than the ARR1987 rainfall depths.

1.2.2 Rainfall Losses

Australian Rainfall & Runoff 1987

During a typical rainfall event, not all of the rain falling on a catchment is converted to runoff. Some of the rainfall may be intercepted and stored by vegetation, some may be stored in small depression areas and some may infiltrate into the underlying soils.

ARR1987 recommends the “Initial-Continuing” loss model to represent rainfall losses. This loss model assumes that a specified amount of rainfall is lost during the initial saturation or wetting of the catchment (referred to as the “Initial Loss”). Further losses are applied at a constant rate to simulate infiltration and interception once the catchment is saturated (referred to as the “Continuing Loss Rate”). The initial and continuing losses are effectively deducted from the total rainfall over the catchment, leaving the residual rainfall to be distributed across the catchment as runoff.

The adopted ARR1987 rainfall losses are provided below. As shown, separate initial and continuing loss rates were applied to pervious and impervious surfaces to reflect the significant variation in rainfall loss potential across these different surfaces. However, it is noted that the ARR1987 rainfall losses are “static” and do not vary with respect to storm duration or storm intensity.

- ARR1987 Rainfall Losses for <u>Pervious</u> Surfaces:
  - Initial Loss = 10 mm
  - Continuing Loss Rates = 2.5 mm /hour
- ARR1987 Rainfall Losses for <u>Impervious</u> Surfaces:

- Initial Loss = 0 mm
- Continuing Loss Rates = 0 mm /hour

Australian Rainfall & Runoff 2016

ARR2016 introduced a revised approach for defining rainfall losses for design flood simulations. Although the same initial/continuing loss approach is retained in ARR2016, ARR2016 employs a variable initial rainfall loss (referred to as the "burst" loss) that varies accordingly to the storm severity and duration.

Initial Losses

The ARR2016 initial rainfall losses are calculated by subtracting median pre-burst rainfall depths 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 (i.e., the median pre-burst rainfall depth is intended to reflect the "lead up" rainfall). Accordingly, the ARR2016 approach for calculating the design initial rainfall losses is considered to more closely mimic actual rainfall events.

Unlike ARR1987, which typically applies the same rainfall losses across large geographic areas, ARR2016 provides regionalised estimates of storm rainfall loss and median pre-burst rainfall. This information is available for download from the ARR2016 Data Hub and is intended to reflect the potentially large differences in catchment characteristics (e.g., soils types) and associated rainfall losses. The ARR2016 data hub information for the Wallarah Creek Catchment is provided at the end of this Appendix.

The data hub rainfall loss information for the Wallarah Creek Catchment indicates a rural initial loss of 49 mm. However, the data hub notes that these rainfall losses are applicable for rural catchments only. A review of Section 3.5.3.2.1 of Book 5 of ARR2016 suggests that for catchments with an urban component, the pervious storm initial loss should be 60 to 80% of the rural storm initial loss to account for the reduced infiltration potential across catchments with an urban proportion (most notably from indirectly connected impervious areas). For this study, the 60% factor was adopted providing an adjusted "storm" initial loss of 23.4 mm (39 mm x 0.6).

To convert the adjusted "storm" initial loss to a "burst" initial loss, it is necessary to subtract the median pre-burst rainfall depths obtained from the Data Hub (which varies based on storm duration and AEP) from the storm loss. For example, the "burst" initial loss for the 1% AEP, 120-minute storm would be calculated as:

- Burst initial loss = adjusted storm initial loss – median pre-burst rainfall depth

  Burst initial loss = 49 mm – 1.0 mm

  Burst initial loss = 48 mm

It was noted that no pre-burst rainfall losses are provided on the 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. The resulting "burst" initial rainfall losses for the study area are summarised in **Table 2**.

Table 2 Pervious Burst Losses

Storm Duration (hours)	Burst Rainfall Loss (mm)		
	20% AEP	5% AEP	1% AEP
<1	42.7	41.5	49
1	42.7	41.5	49
2	40.7	42.6	48
3	41.5	37.7	41
6	26.6	11.8	31
12	38.2	32.2	16.1
24	43.6	38.7	25.5

As shown in **Table 2**, the ARR2016 pervious burst loss varies between 11.8 mm and 49 mm with a value of between 37.7 to 41.5 mm for the most commonly critical storm duration of 3 hours compare to the adopted ARR1987 pervious initial loss of 10 mm.

For impervious areas, Section 3.5.3.1.2 of Book 5 of ARR2016 recommends a storm initial loss of 1 mm. However, the storm loss of 1 mm needs to be adjusted to a burst loss by subtracting the pre burst rainfall. This yielded an impervious burst loss of 0 mm for all storm durations. This is slightly lower than the ARR1987 impervious initial loss of 1 mm.

Continuing Loss Rates

The data hub rainfall loss information for the Wallarah Creek Catchment indicates a rural continuing loss rate of 3.0 mm /hr. However, as for the storm losses discussed above, this loss rate in only applicable to rural catchments. Section 3.5.3.2.2 of Book 5 of ARR2016 recommends a continuing loss rate for south-eastern Australia of between 1 and 3 mm/hour for catchments with an urban proportion (with a value of 2.5 mm/hour being recommended for most applications). A 2.5 mm/hr continuing loss rates is considered appropriate as this was utilised as part of the 'Wallarah Creek Flood Study' and generated reasonable calibration results. Therefore, the pervious continuing loss rates are identical for both ARR1987 and ARR2016.

For impervious areas, Section 3.5.3.1.2 of Book 5 of ARR2016 recommends a continuing loss rate of 0 mm/hr. The continuing loss rate of 0 mm/hr was adopted directly allowing the impervious continuing loss rate to be identical for both ARR1987 and ARR2016.

1.2.3 Temporal Patterns

Australian Rainfall & Runoff 1987

The rainfall depths presented in **Table 1** represent the total rainfall depth falling across the full length of the particular storm duration. Therefore, a temporal pattern must be applied to this rainfall to provide a more realistic description of how the rainfall varies with respect to time through the storm event (i.e., it is unrealistic to assume that the rainfall will be uniformly distributed throughout a storm).

ARR1987 provides temporal patterns for eight different zones across Australia. Two sets of temporal patterns are provided for each zone for each storm duration to describe the temporal distribution of rainfall – one for events more frequent than a 30-year ARI and another one for events less frequent than a 30-year ARI event. These two sets of temporal patterns are further subdivided based upon the storm duration. However, ARR1987 only provides a single temporal pattern to describe the temporal distribution of rainfall for each design storm.

The Wallarah Creek study area falls within zone 1 of the ARR1987 temporal patterns. Therefore, the zone 1 temporal patterns were applied to the appropriate storm frequencies and durations to describe the distribution of rainfall during each event.

Australian Rainfall & Runoff 2016

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). As discussed, ARR1987 used a single temporal pattern for each AEP/storm duration while ARR2016 uses 10 temporal patterns for each AEP/storm duration. This is intended to provide a better representation of the natural variability of rainfall (i.e., no two storms will be exactly the same). However, this does require simulation of ten times more storms under ARR2016 relative to ARR1987.

The temporal patterns for the study area were downloaded from the ARR2016 data hub and were used to simulate the temporal distribution of rainfall for each design storm. 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.

ARR2016 groups the temporal patterns into “frequent”, “intermediate” and “rare” groupings, which were applied to each design storm as follows:

- Frequent temporal patterns: 20% AEP
- Intermediate temporal patterns: 5% AEP
- Rare temporal patterns: 1% AEP

Further discussion on how the suite of ARR2016 temporal patterns was analysed is provided in the following section.

1.3 Hydrologic Results

1.3.1 ARR1987 Hydrology

The XP-RAFTS model was used to simulate rainfall-runoff process for the design 20%, 5% and 1% AEP storms based upon ARR1987 hydrology.

The results from each simulation were reviewed at each sub-catchment in the RAFTS model to determine the “critical” storm duration. In accordance with recommendations in ARR1987, the critical storm duration was defined as the storm duration that produced the highest peak design discharge at each subcatchment outlet. The critical storm durations and peak discharges for each subcatchment with ARR1987 hydrologic conditions are presented at the end of this Appendix.

In general, the critical storm durations across the study area varied between 90 and 180 minutes. The 180-minutes storm duration was the most common critical duration across the study area for most of the design floods. This is consistent with the findings of the 'Wallarah Creek Flood Study'.

1.3.2 ARR2016 Hydrology

The XP-RAFTS model was also used to simulate rainfall-runoff processes based upon the 2016 version of Australian Rainfall and Runoff. The design 20%, 5% and 1% AEP storms were simulated using the XP-RAFTS model.

As outlined in the previous section, a suite of ten temporal patterns were used to represent the temporal variation in rainfall for each design flood frequency and duration. The peak discharges from the full suite of temporal patterns for each design event were reviewed to determine the most representative temporal pattern for each storm duration. The temporal pattern that generated the peak discharge immediately above the adopted mean discharge was selected as the most representative temporal pattern for each subcatchment. This process was completed for all AEPs and storm durations. The peak discharges generated by the representative temporal pattern were then reviewed across all storm durations for a particular AEP and the storm duration that produced the highest peak design discharge was selected as the critical duration and discharge for a particular subcatchment. The resulting critical storm durations and peak discharges for each subcatchment are presented at the end of this Appendix. Discharges at 9 "focus" locations throughout the catchment were also extracted and are presented in **Table 3**. The focus locations are shown in **Plate 2**.

Table 3 ARR2016 and ARR1987 Peak Design Discharges at Focus Locations

ID	Location	Peak Discharge (m^3/s)								
		20% AEP			5% AEP			1% AEP		
		ARR 1987	ARR 2016	Diff. (%)	ARR 1987	ARR 2016	Diff. (%)	ARR 1987	ARR 2016	Diff. (%)
1	Wallarah Creek crossing of Pacific Motorway	20.7	17.6	-18	29.4	29.1	-1	40.0	45.7	12
2	Wallarah Creek crossing of Nikko Rd	72.0	59.0	-22	99.7	91.7	-9	133	138	3
3	Wallarah Creek crossing of Birdwood Dr	201	157	-28	278	249	-12	365	366	1
4	Wallarah Creek crossing of Pacific Hwy	205	159	-29	284	253	-12	372	370	0
5	Wallarah Creek entrance to Budgewoi Lake	209	160	-31	290	254	-14	380	372	-2
6	Spring Creek crossing of Pacific Hwy	94.8	81.3	-17	130	125	-4	176	192	8
7	Detention basin between Pacific Hwy and Wongalaw Ave	2.38	1.63	-46	3.34	2.99	-12	4.23	4.92	14
8	Detention basin between Pacific Hwy and Newton Pl	4.08	3.42	-19	6.11	5.68	-8	8.02	9.27	13
9	Detention basin between Pacific Hwy and Blueridge Dr	2.63	2.12	-24	4.33	4.38	1	6.65	7.60	13

The results of the hydrologic analysis indicate that the critical durations across the study area typically vary between 10 minutes (for smaller subcatchments in the upper catchment areas) and 6 hours (for the lower catchment areas). Accordingly, the critical ARR1987 storm duration tends to be longer than the critical ARR2016 storm durations.

Box plots for the 1% AEP event were also prepared for the 9 focus locations to better display the full range of results produced as part of the ARR2016 hydrologic analysis. The box plots are provided at the end of this appendix. The box plots show:

- Median discharge for each storm duration (represented by the blue horizontal line contained within each green box);
- Mean discharge for each storm duration (defined by the "✳");
- The first and third quartiles (defined by the green box), which illustrated the 25th percentile and 75th percentile discharge values;
- The highest and lowest discharge value (represented by the "T" attached to the end of the green box)
- The critical storm duration is highlighted in yellow

The peak ARR2016 discharges were reviewed relative to the ARR1987 discharges. This review showed that for the vast majority of subcatchments, the critical ARR2016 discharges for frequent and intermediate events are lower than the critical ARR1987 discharges.

Plate 2 "Focus" locations (yellow) selected for critical duration & temporal pattern analysis

The following average differences in discharges were noted between ARR2016 and ARR1987 when considering all subcatchments:

- 20% AEP: ARR2016 discharges are 19% lower than ARR1987 discharges
- 5% AEP: ARR2016 discharges are 5% lower than ARR1987 discharges
- 1% AEP: ARR2016 discharges are 10% higher than ARR1987 discharges

The differences in peak discharges are considered to be primarily associated with the lower ARR2016 rainfall depths. This was subsequently confirmed through a sensitivity analysis where the ARR1987 rainfall depths were applied to the ARR2016 hydrologic methodology. The differences in peak discharges under this scenario were generally within 15%. The remainder of the differences is considered to be associated with the higher burst initial losses being applied under ARR2016.

As discussed in Section 1.2, although the ARR2016 rainfall depths are lower and the initial rainfall losses are higher relative to ARR1987, the available information suggests that these rainfall and loss estimates are more reliable than the ARR1987 datasets. Accordingly, although ARR2016 provides less conservative discharge estimates, it is considered that they provide an improved estimate of design discharges across the Wallarah Creek catchment.

1.4 Hydraulic Assessment

1.4.1 Introduction

As discussed in the previous section, ARR2016 is predicted to generate lower peak design discharge estimates relative to ARR1987 across the Wallarah Creek catchment. To gain an understanding of how these reductions may impact on flood hydraulics (i.e., flood levels, depths and velocities), the ARR2016 design hydrographs were applied to the TUFLOW model and were used to re-simulate flood behaviour for the 1% AEP flood. The results of the revised simulations were subsequently compared to the 1% AEP flood results based on ARR1987 hydrology so that an understanding of the flood impacts could be quantified. The outcomes of the hydraulic assessment are presented below.

1.4.2 Hydraulics

Australian Rainfall & Runoff 1987

The TUFLOW model was initially used to simulate design flood behaviour for the design 1% AEP event with ARR1987 hydrology. The critical 1.5, 2 and 6-hour storms were routed through the TUFLOW model and the results were combined into a design flood envelope. Peak floodwater depths were extracted from the enveloped results and are presented in **Figure 6** for the 1% AEP flood.

Australian Rainfall & Runoff 2016

The TUFLOW model was then updated to reflect the ARR2016 hydrology and was used to re-simulate the 1%AEP.

The outcomes of the ARR2016 hydrologic analysis were reviewed to determine the total number of unique critical storm durations and temporal patterns that would need to be applied to the TUFLOW model to simulate flood behaviour based upon the ARR2016 hydrology. This determined that there were a large number of unique combinations of temporal patterns when considering all subcatchments in the XP-RAFTS model.

Although the XP-RAFTS model runs in a matter of seconds and can run a large number of storms in a relatively short amount of time, the TUFLOW model takes several hours to run a single storm. Therefore, it was not considered feasible to run all unique combinations of storm durations and temporal patterns through the hydraulic model in a timely manner.

Therefore, the assessment of critical durations and temporal patterns was restricted to a selection of “focus” locations. A focus location was defined as along a major watercourse and at major roadway/railway crossings.

Once the assessment of critical durations and temporal patterns was reduced from every subcatchments (i.e., 324 locations) down to focus locations, the number of unique durations and temporal patterns was significantly reduced. However, this was still considered to be too many simulations to undertake in a timely manner.

Therefore, the critical durations and temporal patterns were further reviewed to determine if a reduced number of durations and temporal patterns could be applied without significantly impacting on the overall hydrologic outcomes. Finally, the 120 minute storm with the 4617 temporal pattern were selected as the storm duration and temporal pattern for further assessment.

The TUFLOW model was subsequently used to simulate design flood behaviour for the design 1% AEP event with the select ARR2016 storm. Peak floodwater depths were extracted from the enveloped results and are presented in **Figures B1.1** to **B1.11**.

Discussion on Flood Impacts

Difference mapping was also prepared to quantify the differences in peak 1% AEP flood levels and extents associated with adopting ARR2016 versus ARR1987 hydrology. The difference map was prepared by subtracting peak water levels generated as part of the ARR1987 model run from the ARR2016 model run. This creates a contour map of predicted changes in flood levels and extents. The flood level difference mapping is provided in **Figures B2.1** to **B2.11**. Negative values indicate ARR2016 is producing lower flood levels relative to ARR1987 while positive values indicate ARR2016 is producing higher flood levels relative to ARR1987.

The difference mapping presented in **Figures B2.1** to **B2.11** shows that the ARR2016 peak 1% AEP flood levels are predominantly lower than the ARR1987 1% AEP discharges. ARR2016 flood levels are typically between 0.1 and 0.2 metres lower than the ARR1987 flood levels along each of the major watercourses except the Wallarah Creek entrance to Budgewoi Lake part. However, the flood level differences approach 0.5 metres in the vicinity of major hydraulic controls, such as the Pacific Motorway, railway and Doyalson Link Road.

1.5 Conclusion and Recommendation

Application of ARR2016 hydrologic procedures to the Wallarah Creek catchment is predicted to generate lower peak discharges during the 20% AEP and 5% AEP floods and higher discharges during the 1% AEP event relative to ARR1987.

The increased design discharges during the 1% AEP flood are predicted to generate higher flood levels across most of the catchment. However, the differences are typically less than 0.2 metres. It could be expected the lower ARR2016 discharges that are predicted during the 20% AEP and 5% AEP would produce lower peak flood levels relative to ARR1987. Accordingly, the impact of ARR2016 varies according to the magnitude of the event under consideration

As ARR87 is predicted to generate more conservative flood estimates during the more frequent events and the differences during the 1% AEP flood are relatively small, it is recommended that ARR1987 be adopted in preference to ARR2016 at this point in time.

1.6 References

- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2016) Australian Rainfall and Runoff: A Guide to Flood Estimation, © Commonwealth of Australia (Geoscience Australia).
- Engineers Australia (1987). Australian Rainfall and Runoff - A Guide to Flood Estimation. Edited by D. Pilgrim.

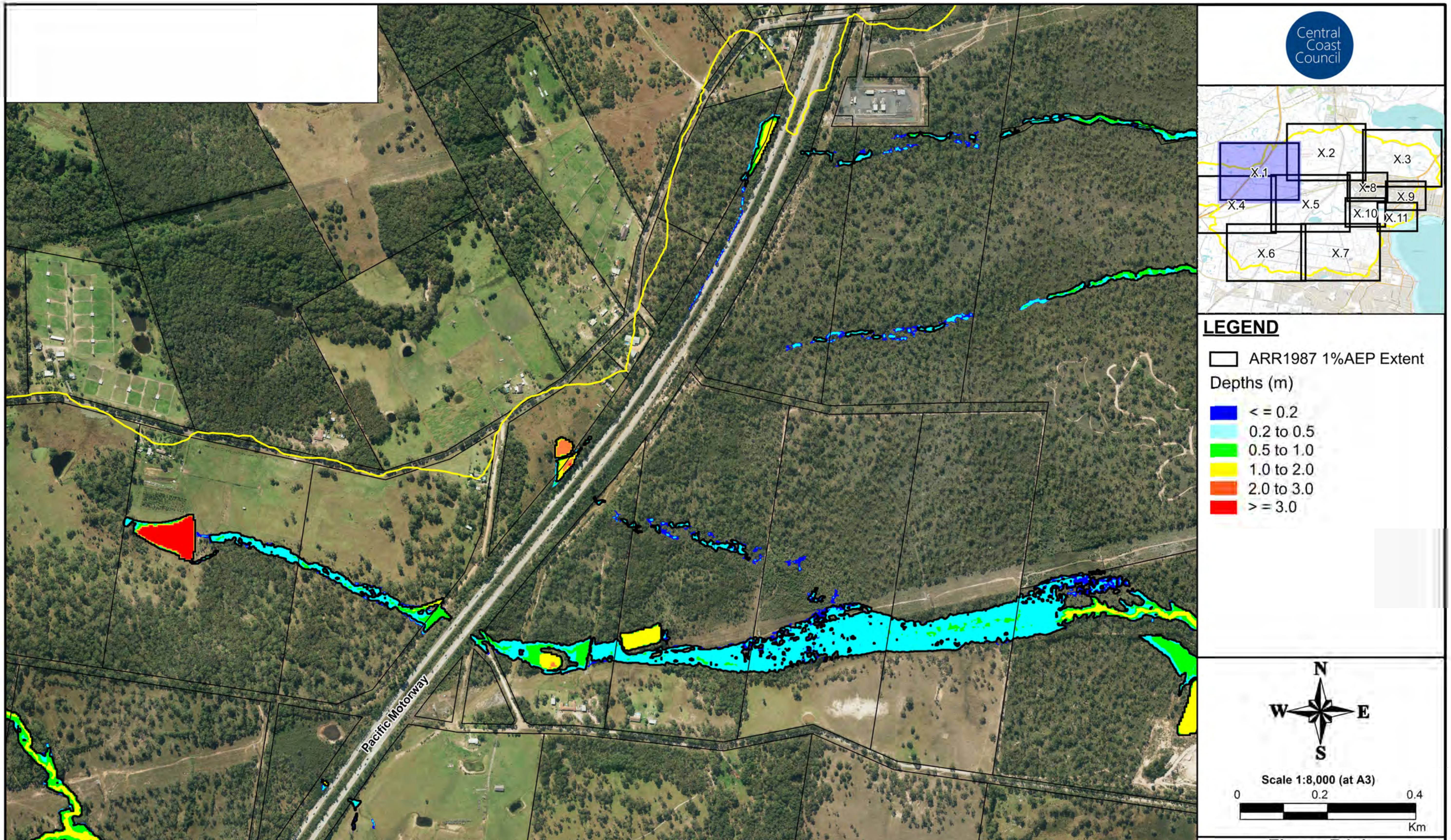
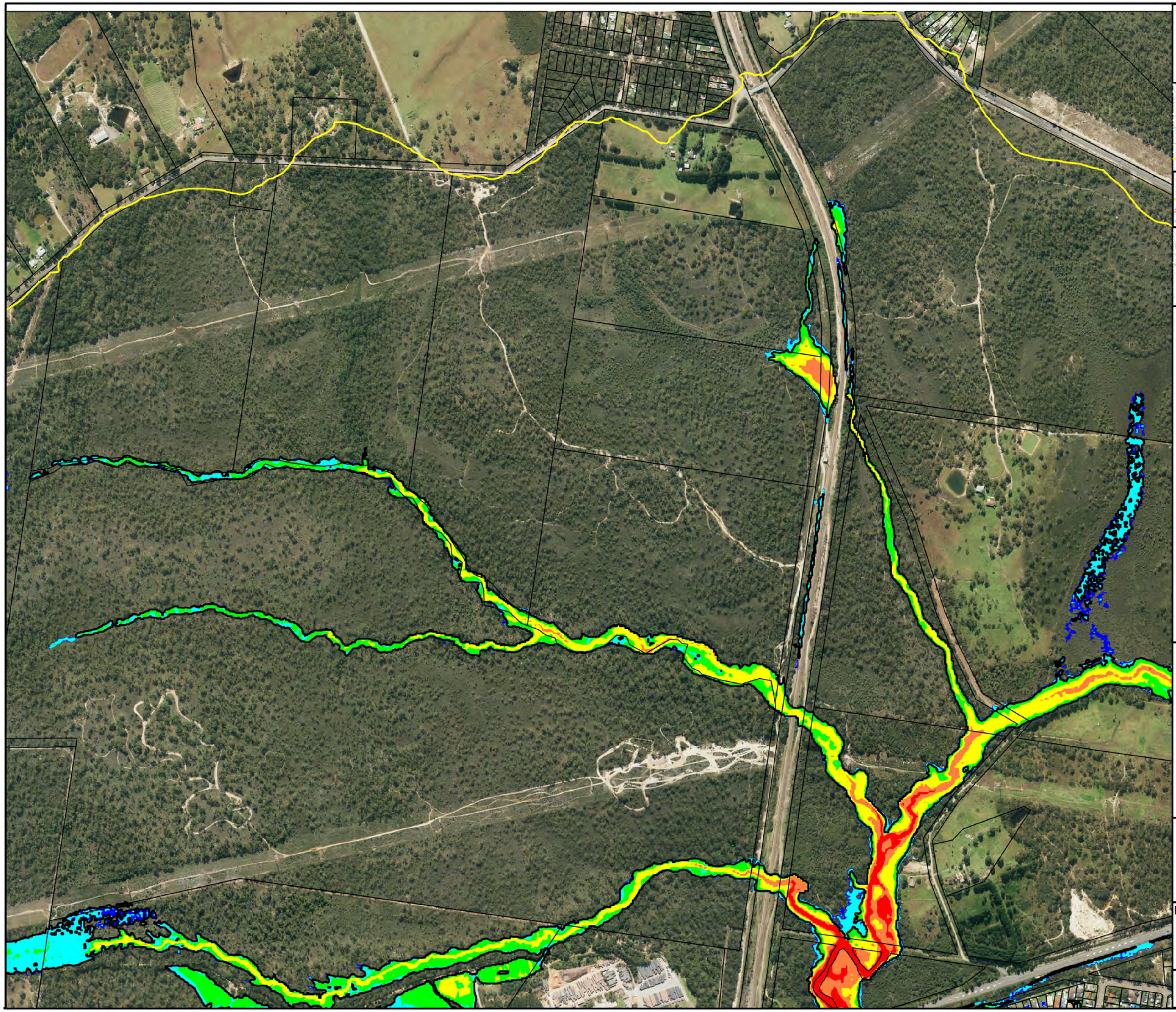


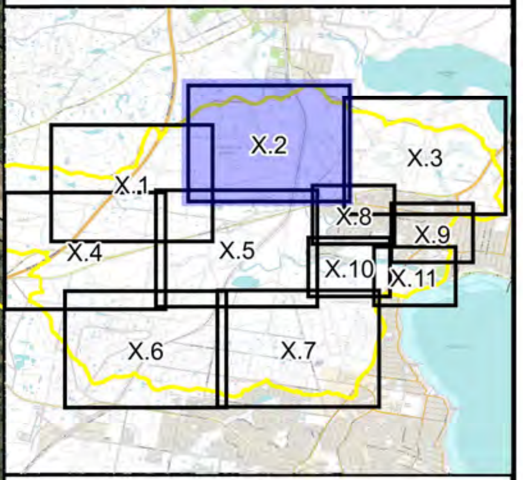
Figure B1.1: Peak Floodwater Depths for the 1% AEP Flood ARR2016

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

File Name: FigB1.1 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N W E S

Scale 1:8,000 (at A3)

0 0.2 0.4 Km

Figure B1.2: Peak Floodwater Depths for the 1% AEP Flood ARR2016

Prepared By:

Catchment Simulation Solutions
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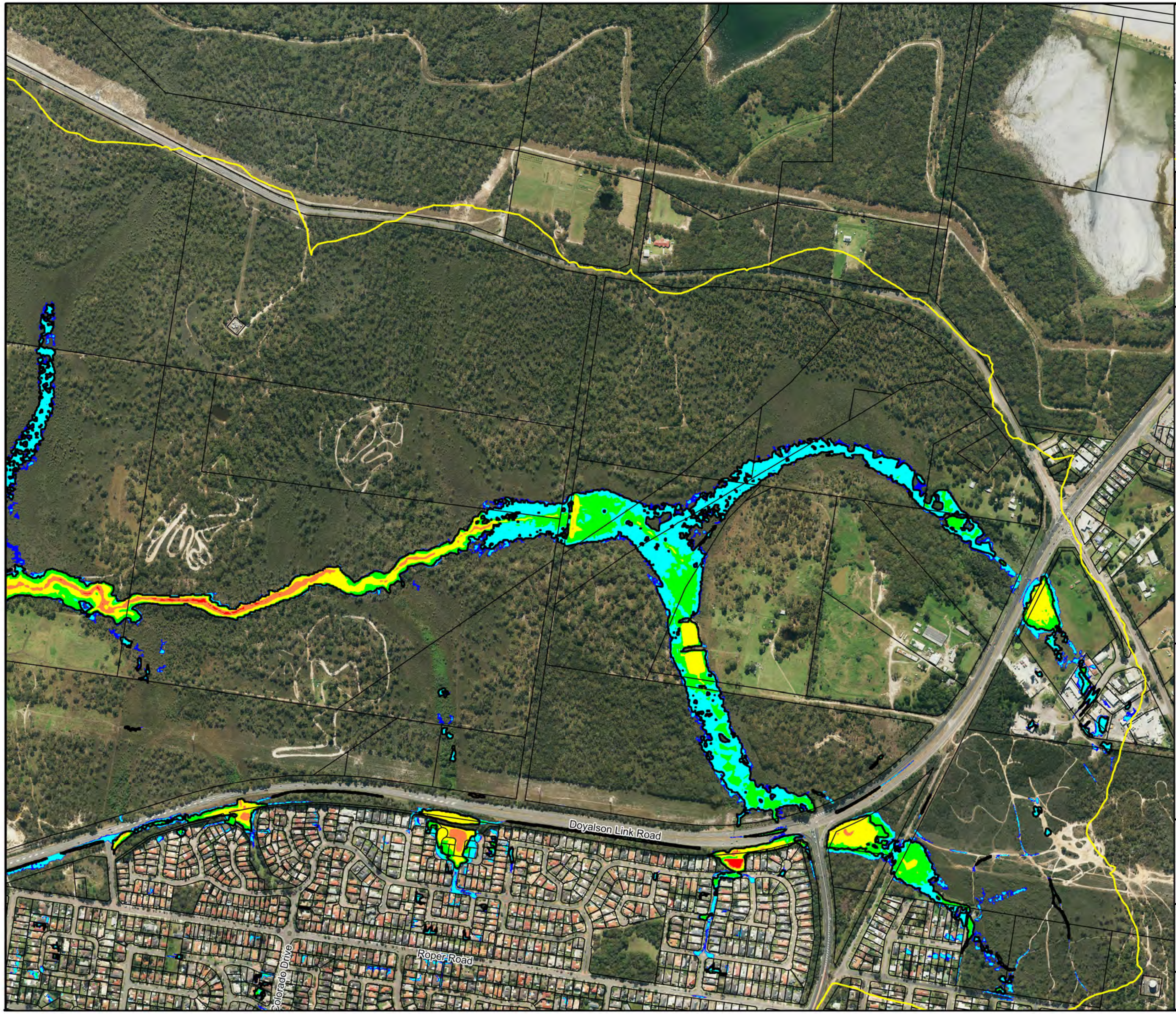
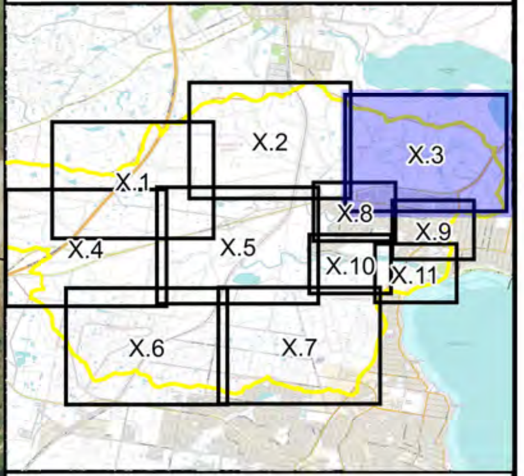
Sydney, NSW 2000

File Name: FigB1.2 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N W E S

Scale 1:8,000 (at A3)

0 0.2 0.4 Km

Figure B1.3: Peak Floodwater Depths for the 1% AEP Flood ARR2016

Prepared By:

Catchment Simulation Solutions
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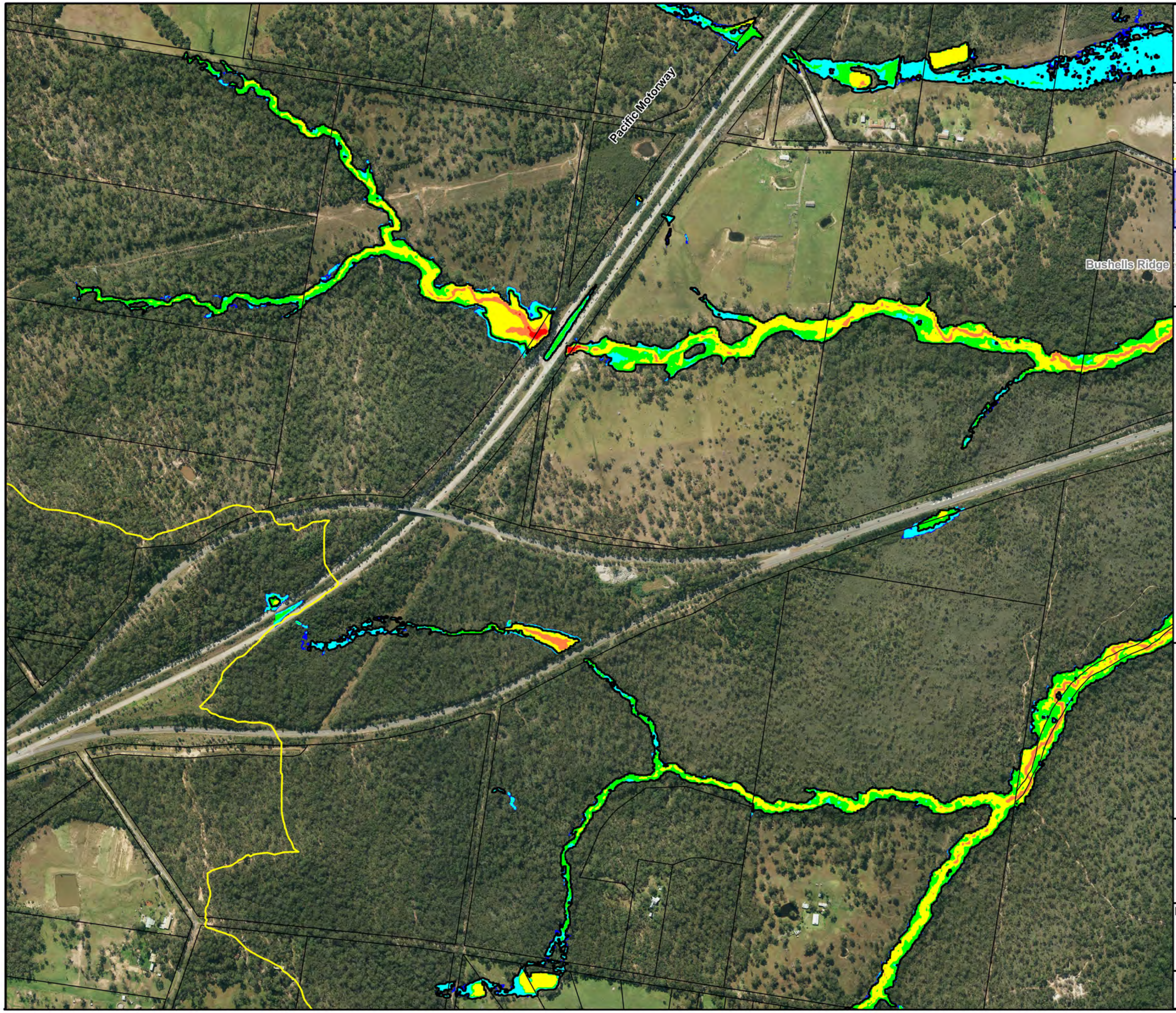
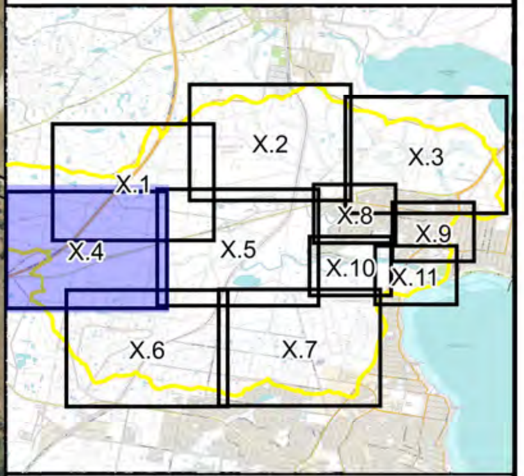
Sydney, NSW 2000

File Name: FigB1.3 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N W E S

Scale 1:8,000 (at A3)

0 0.2 0.4 Km

Figure B1.4: Peak Floodwater Depths for the 1% AEP Flood ARR2016

Prepared By:

Catchment Simulation Solutions
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Sydney, NSW 2000

File Name: FigB1.4 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor

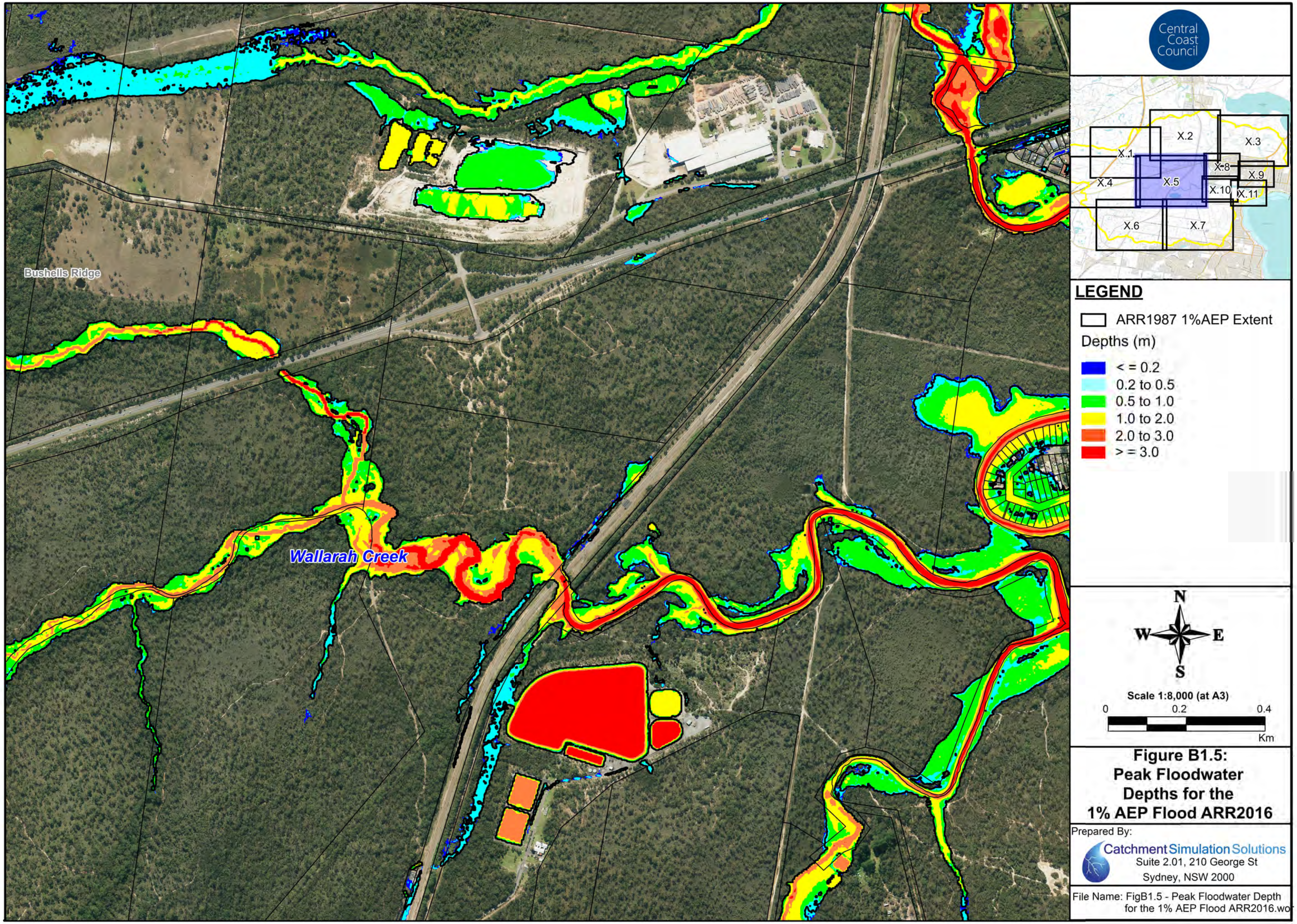
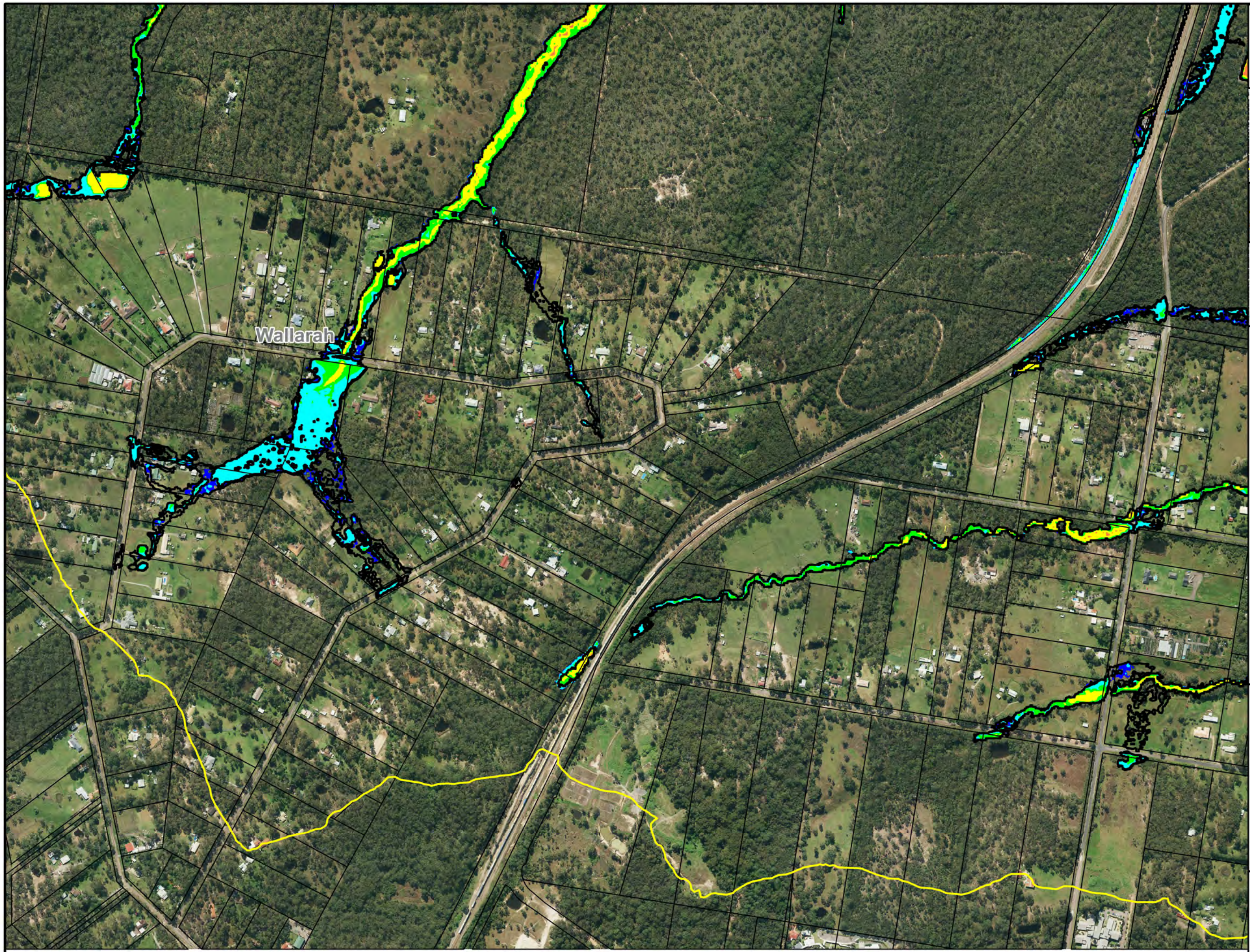
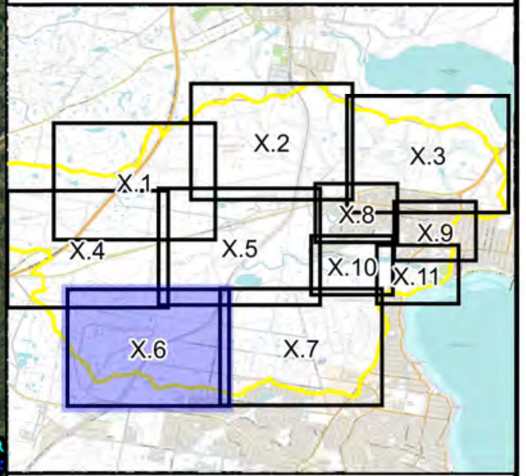


Figure B1.5: Peak Floodwater Depths for the 1% AEP Flood ARR2016



Central Coast Council



LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N
W E
S

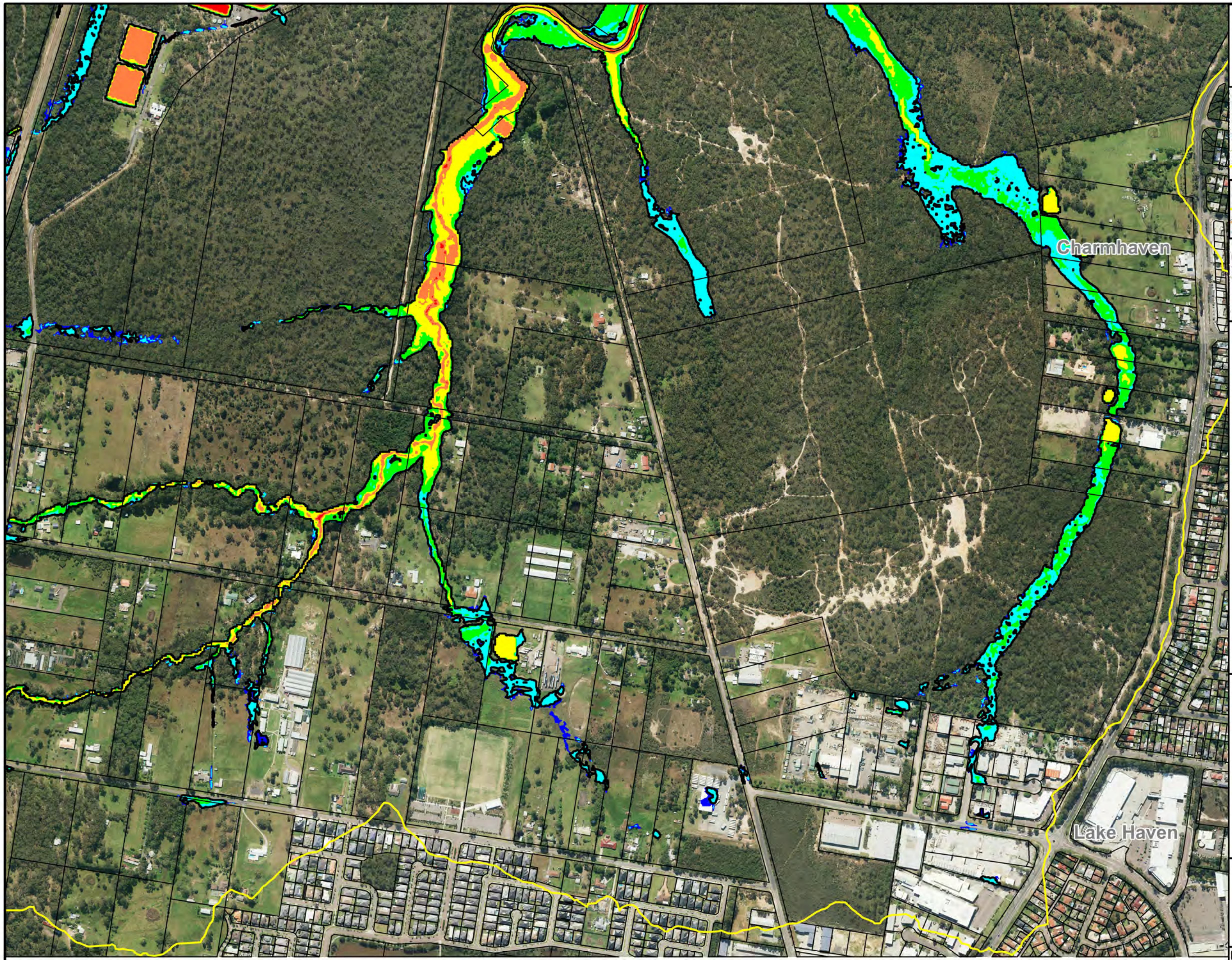
Scale 1:8,000 (at A3)

0 0.2 0.4
Km

**Figure B1.6:
Peak Floodwater
Depths for the
1% AEP Flood ARR2016**

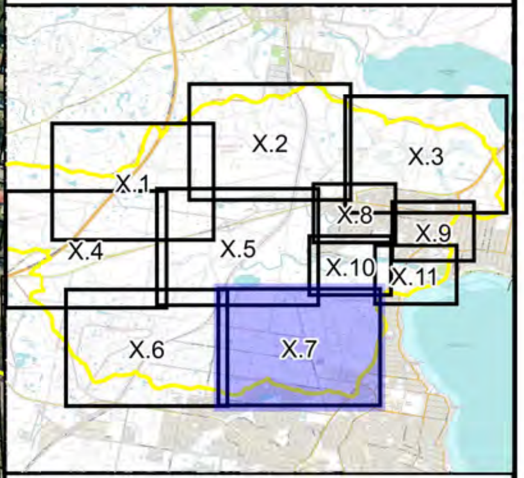
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000

File Name: FigB1.6 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Woongarrah

Central Coast Council



LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N
W E
S

Scale 1:8,000 (at A3)

0 0.2 0.4 Km

Figure B1.7: Peak Floodwater Depths for the 1% AEP Flood ARR2016

Prepared By:

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Suite 2.01, 210 George St
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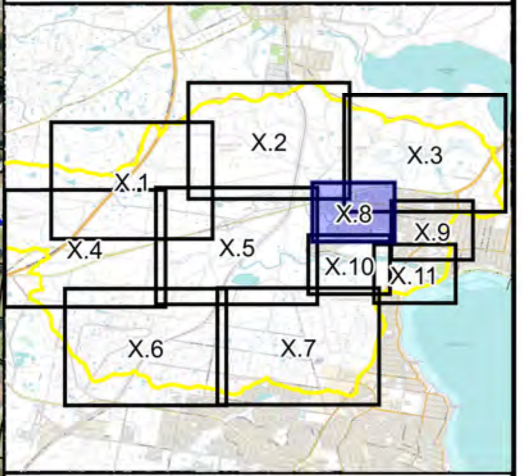
File Name: FigB1.7 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Central Coast Council

LEGEND

ARR1987 1%AEP Extent

Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

N W E S

Scale 1:4,000 (at A3)

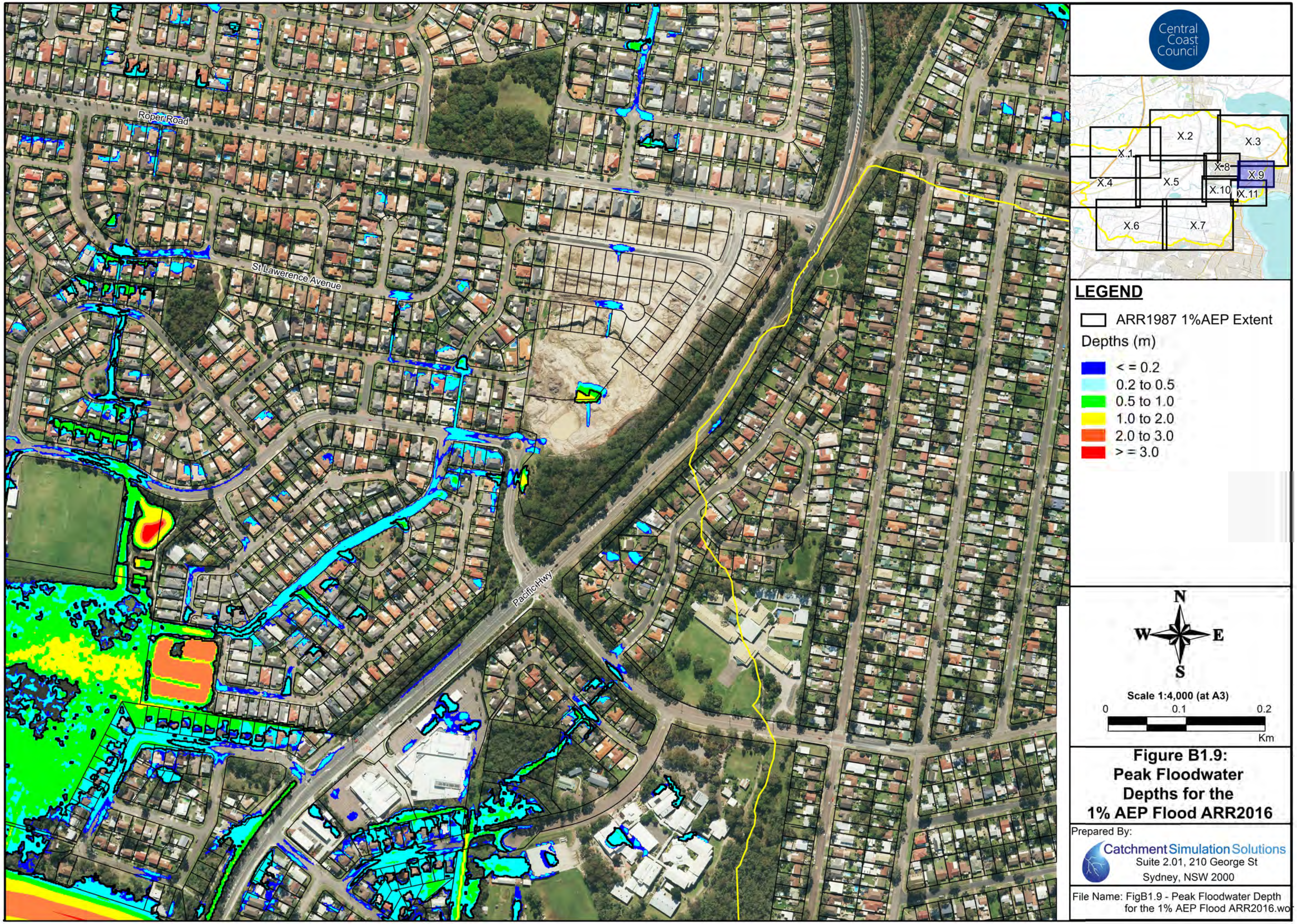
0 0.1 0.2 Km

Figure B1.8: Peak Floodwater Depths for the 1% AEP Flood ARR2016

Prepared By:

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

File Name: FigB1.8 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor


Roper Road
St Lawrence Avenue
Pacific Hwy
Central Coast Council
X.1
X.2
X.3
X.4
X.5
X.6
X.7
X.8
X.9
X.10
X.11
LEGEND
ARR1987 1%AEP Extent
Depths (m)
< = 0.2
0.2 to 0.5
0.5 to 1.0
1.0 to 2.0
2.0 to 3.0
> = 3.0
N
W
E
S
Scale 1:4,000 (at A3)
0
0.1
0.2
Km
Figure B1.9:
Peak Floodwater
Depths for the
1% AEP Flood ARR2016
Prepared By:
Catchment Simulation Solutions
Suite 2.01, 210 George St
Sydney, NSW 2000
File Name: FigB1.9 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor

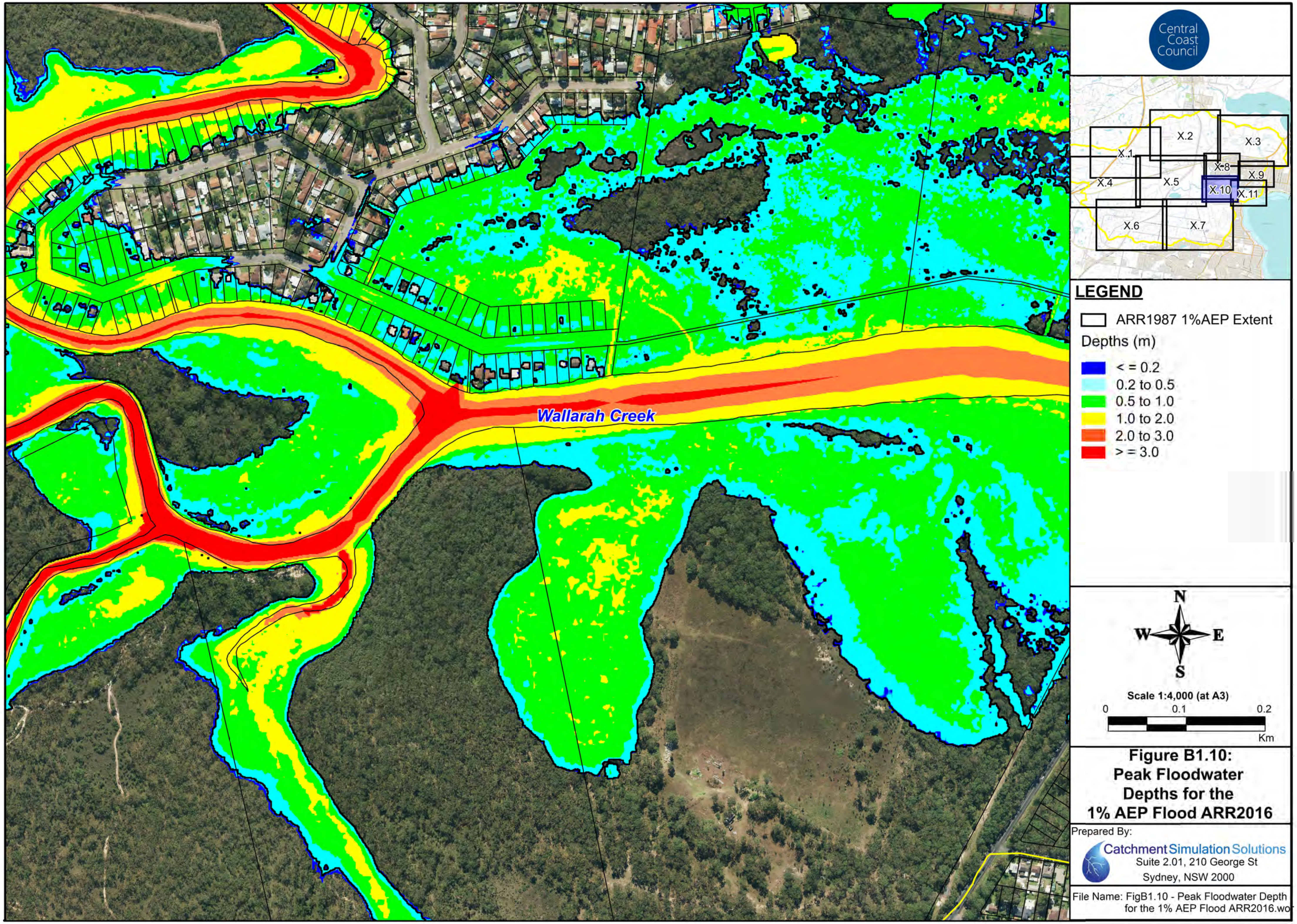
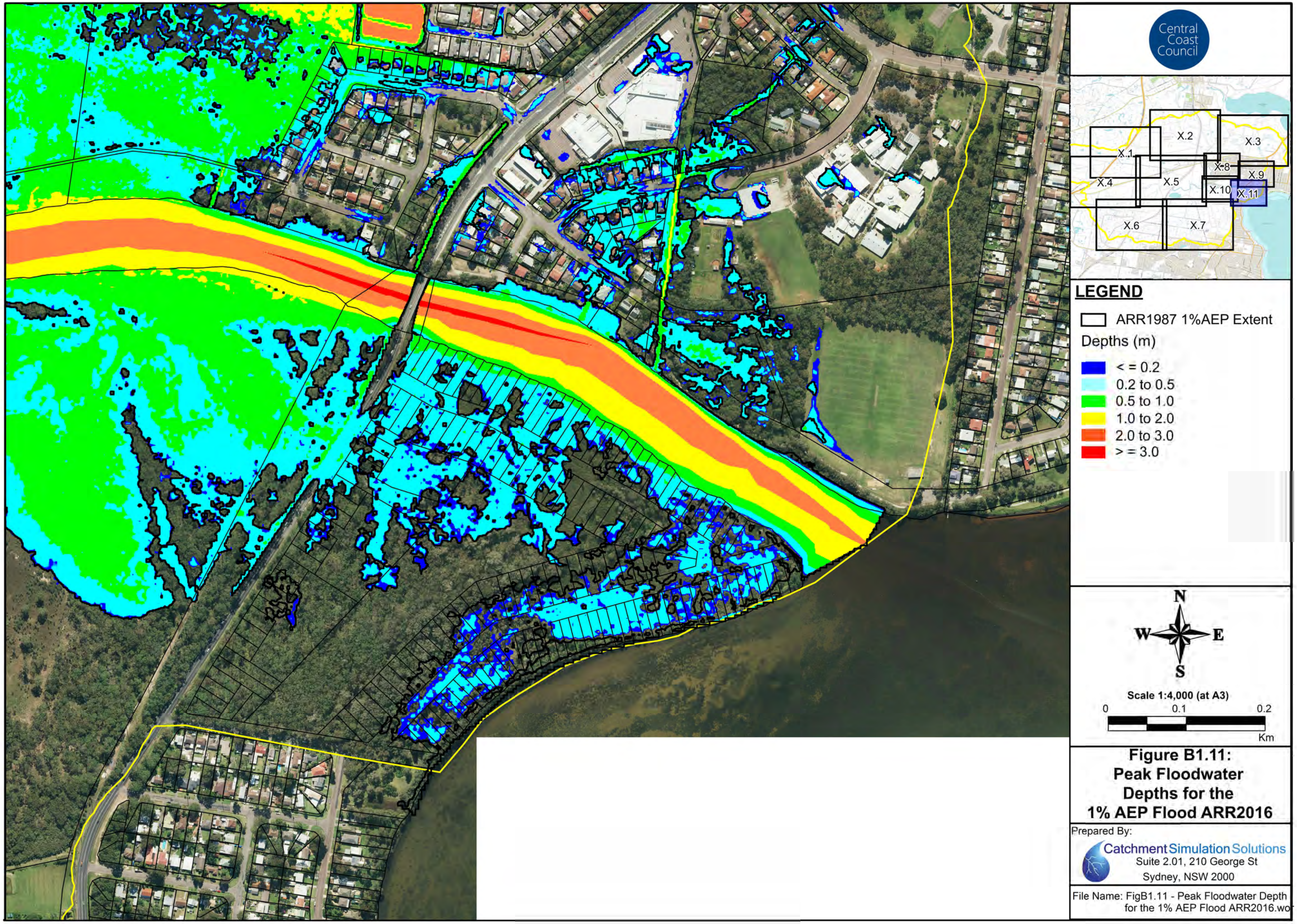


Figure B1.10: Peak Floodwater Depths for the 1% AEP Flood ARR2016



LEGEND

ARR1987 1%AEP Extent

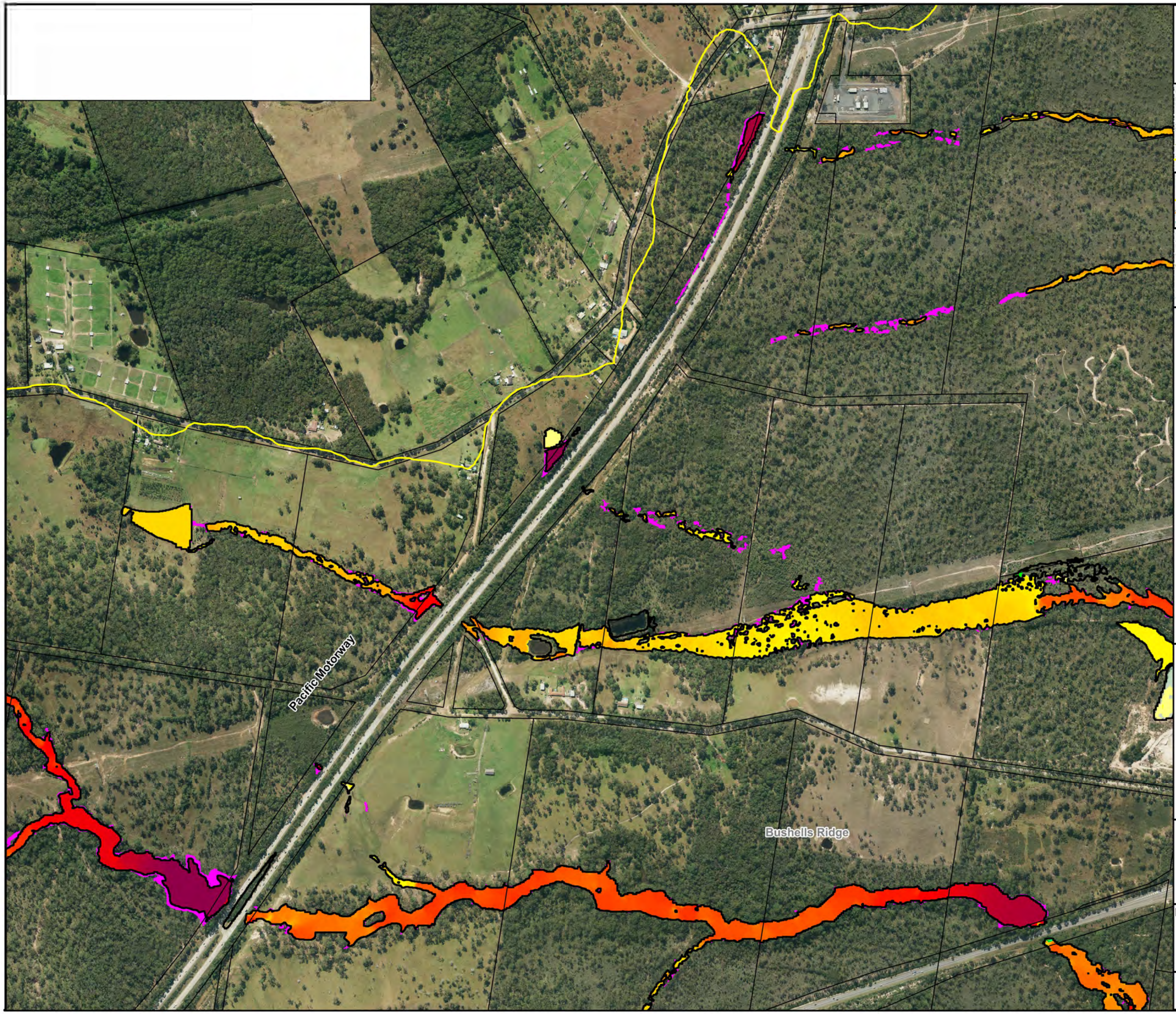
Depths (m)

- < = 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- > = 3.0

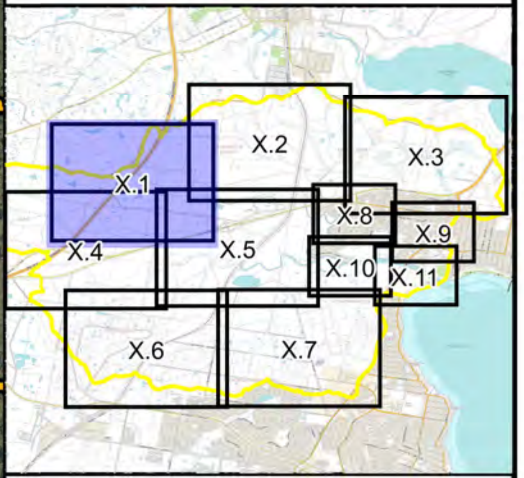
Figure B1.11: Peak Floodwater Depths for the 1% AEP Flood ARR2016

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

File Name: FigB1.11 - Peak Floodwater Depth for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N W E S

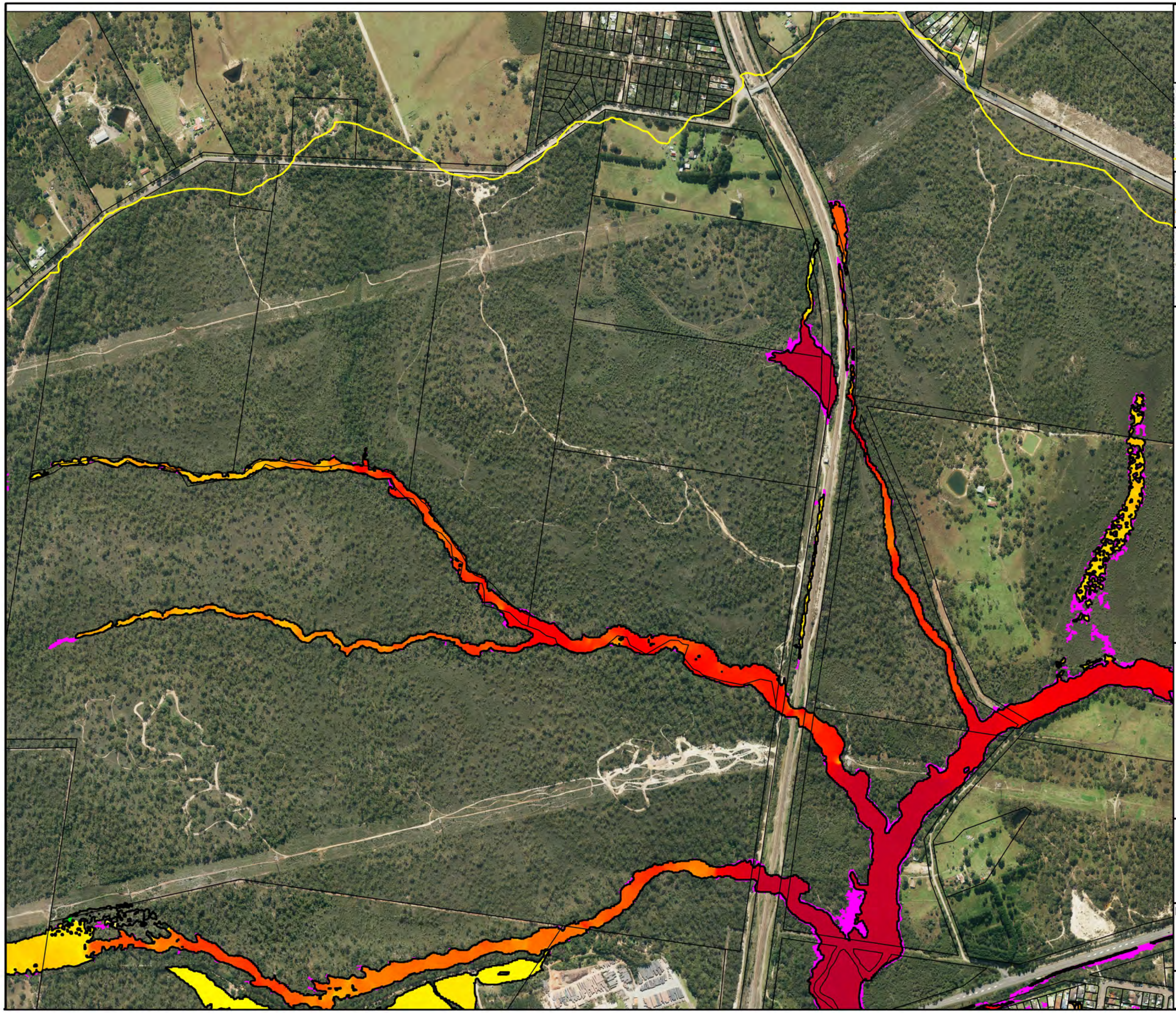
Scale 1:8,000 (at A3)

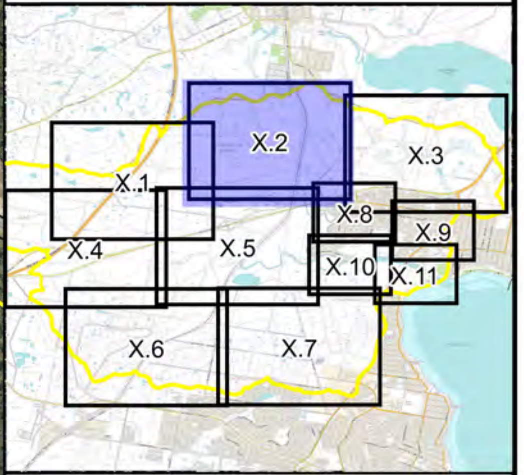
0 0.2 0.4 Km

Figure B2.1: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.1 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor





LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N W E S

Scale 1:8,000 (at A3)

0 0.2 0.4 Km

Figure B2.2: ARR2016 1% AEP Floodwater Differences

Prepared By:

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

File Name: FigB2.2 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor

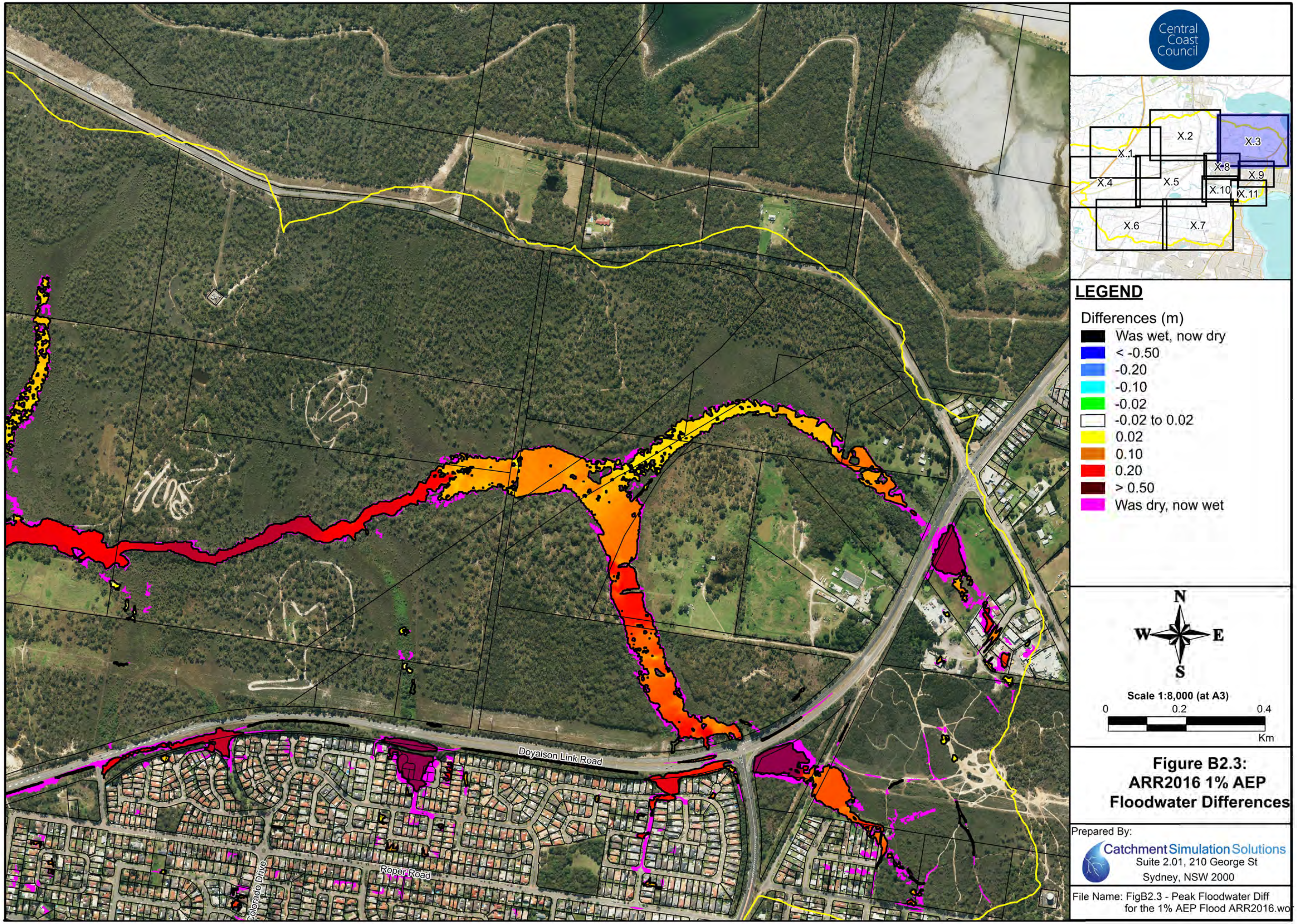


Figure B2.3: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.3 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor

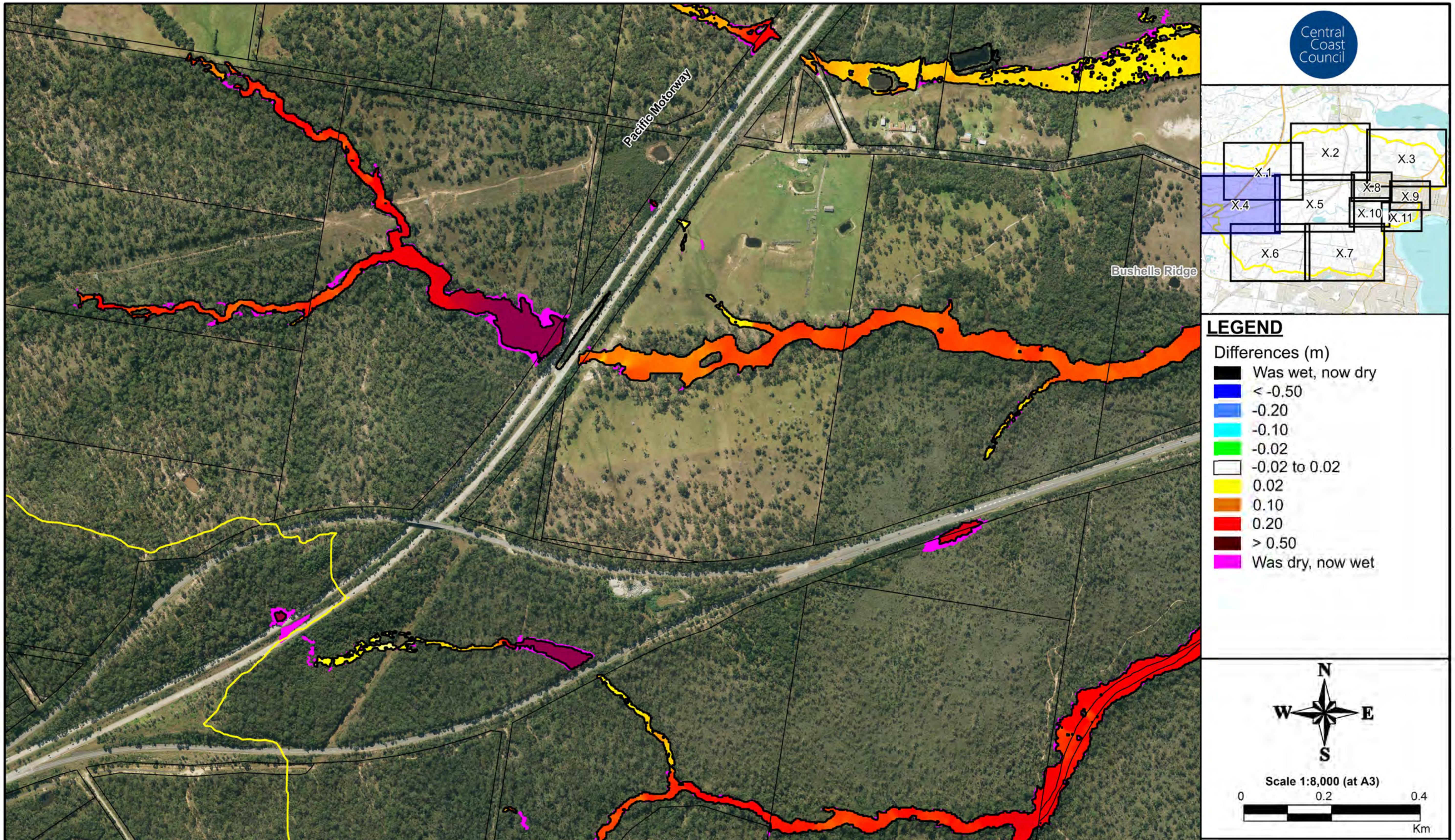


Figure B2.4: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.4 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor

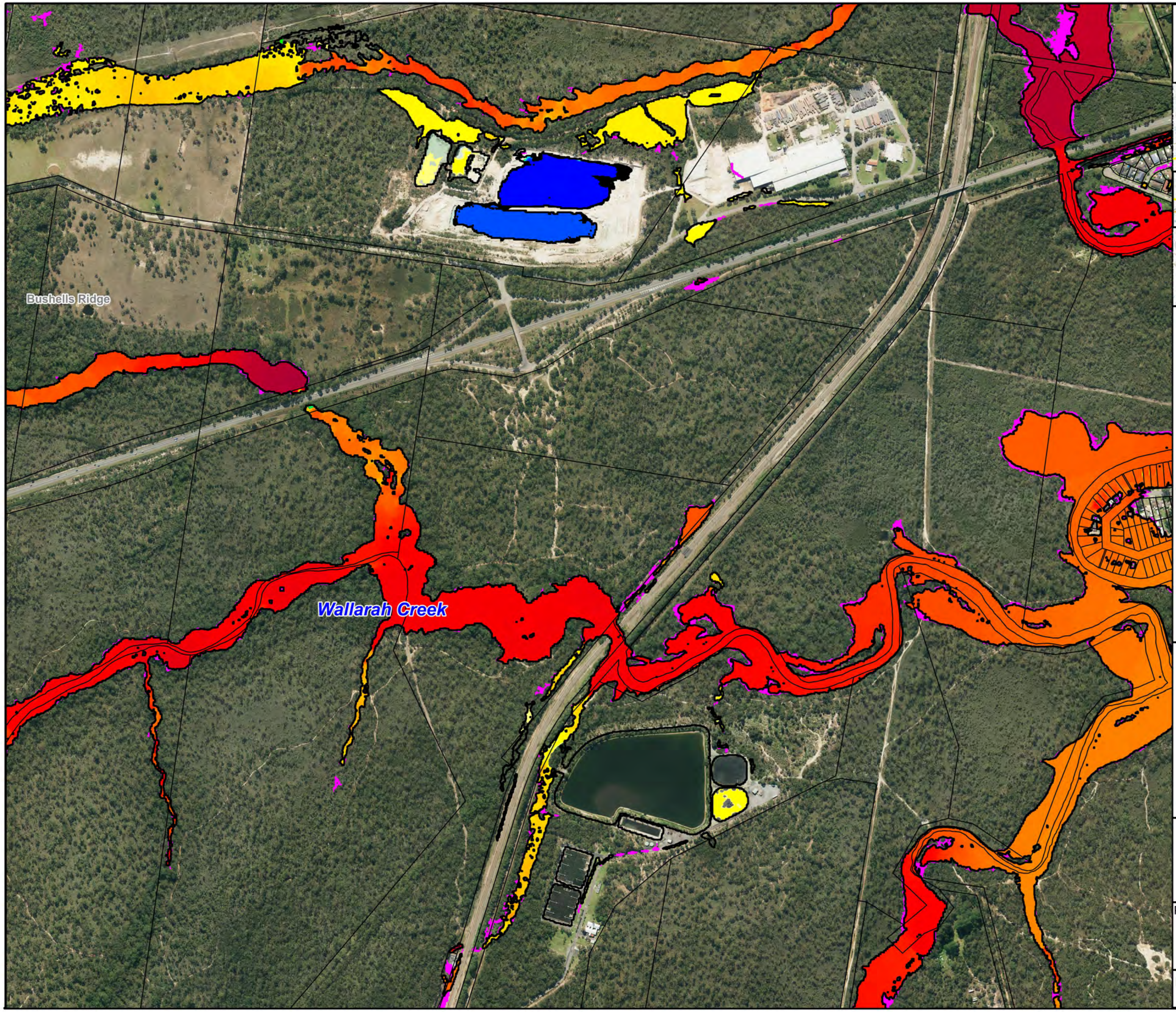
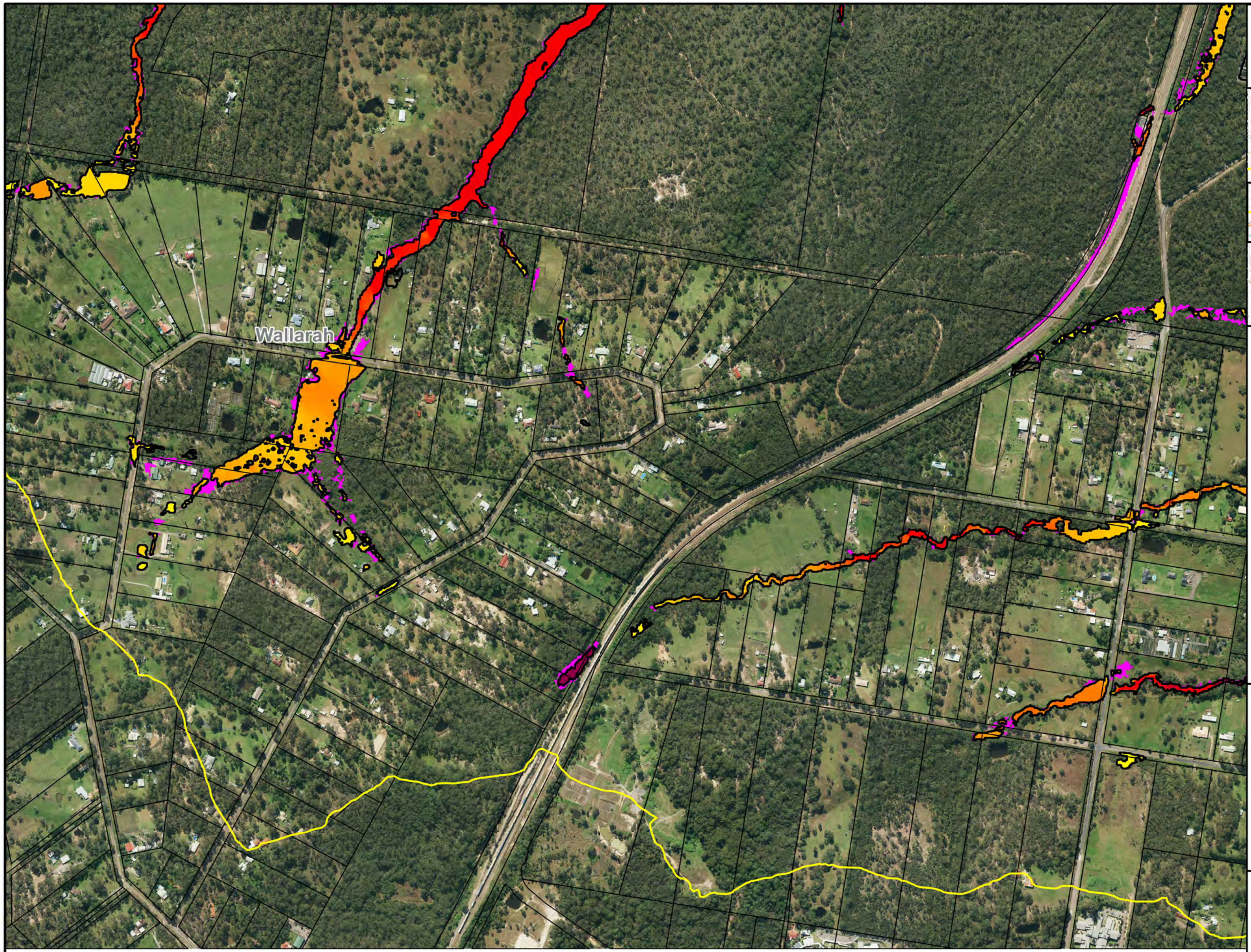


Figure B2.5: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.5 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor



Central Coast Council

LEGEND

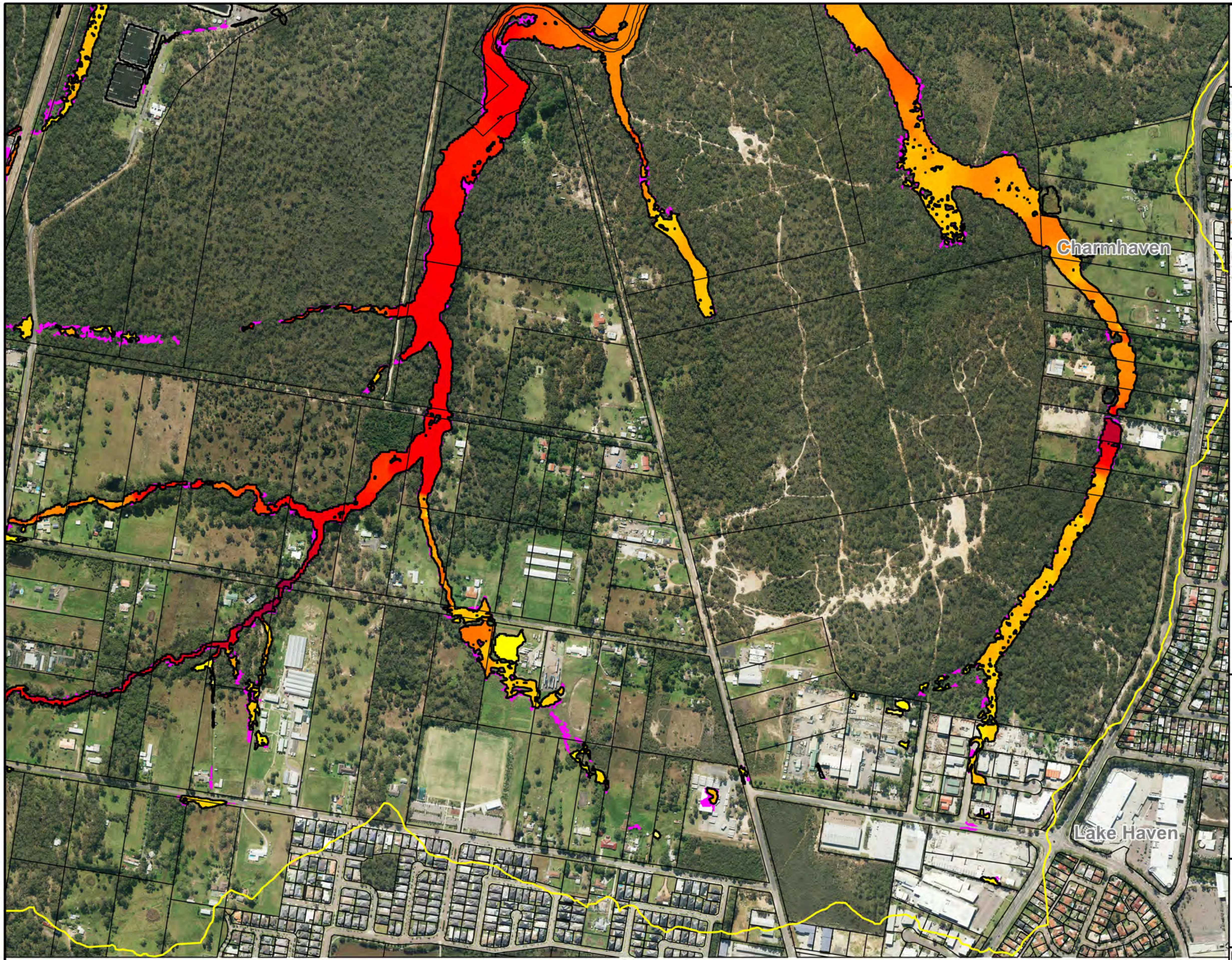
Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

Figure B2.6: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.6 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor



Woongarrah

Central Coast Council

X.1 X.2 X.3 X.4 X.5 X.6 X.7 X.8 X.9 X.10 X.11

LEGEND

Differences (m)
- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N W E S

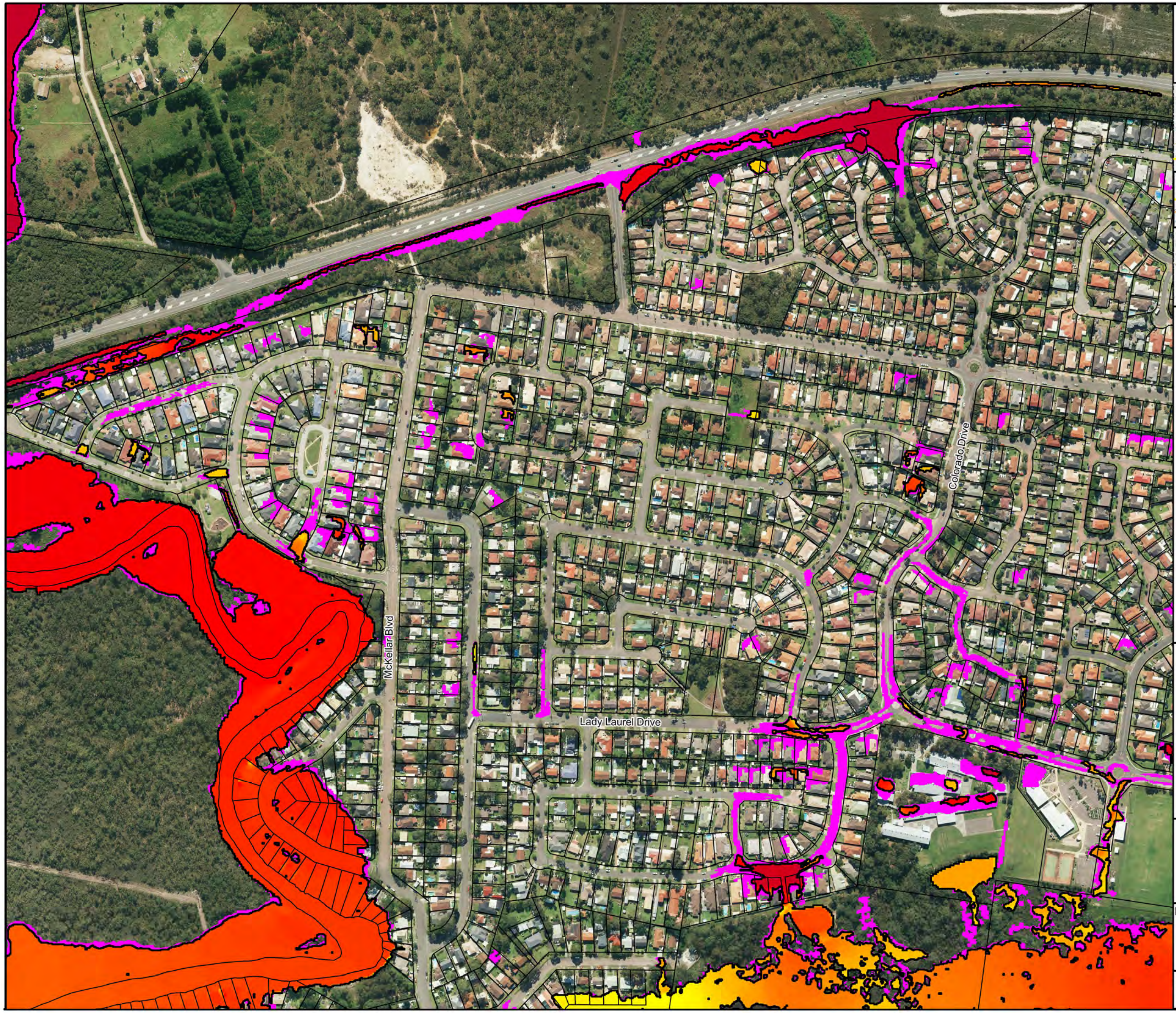
Scale 1:8,000 (at A3)

0 0.2 0.4 Km

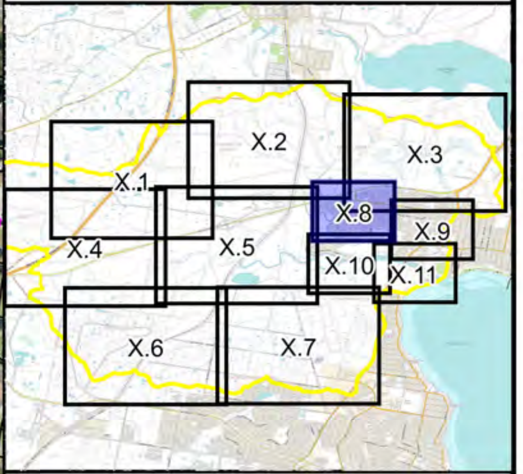
Figure B2.7: ARR2016 1% AEP Floodwater Differences

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

File Name: FigB2.7 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

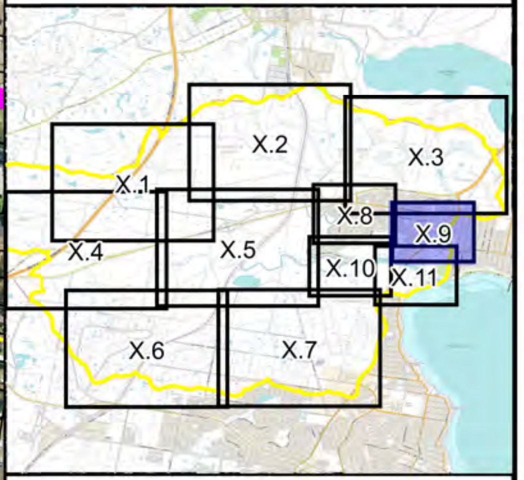
Figure B2.8: ARR2016 1% AEP Floodwater Differences

Prepared By:

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

File Name: FigB2.8 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wo

Central Coast Council



LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

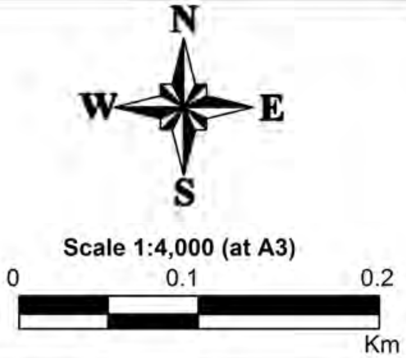
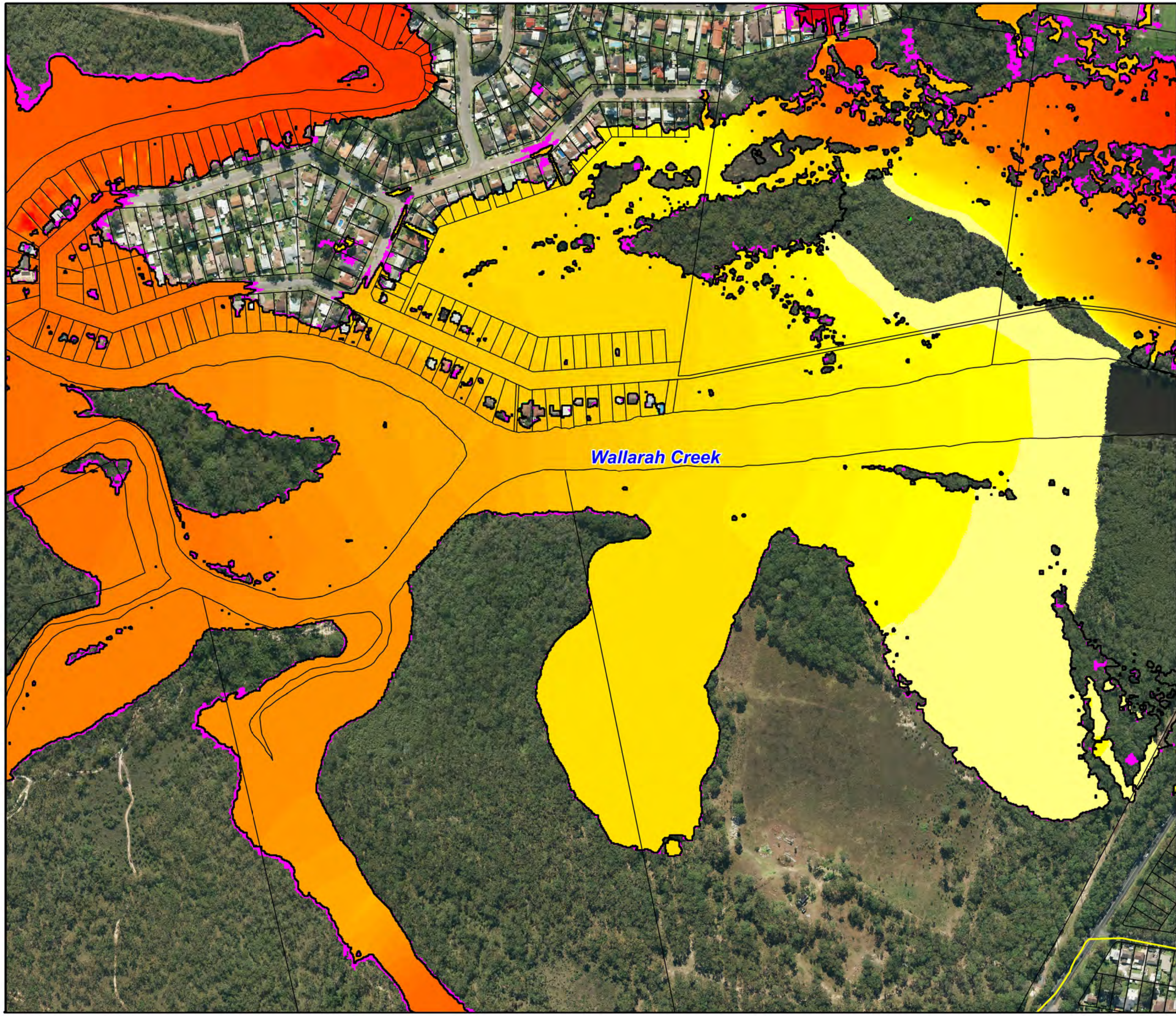


Figure B2.9: ARR2016 1% AEP Floodwater Differences

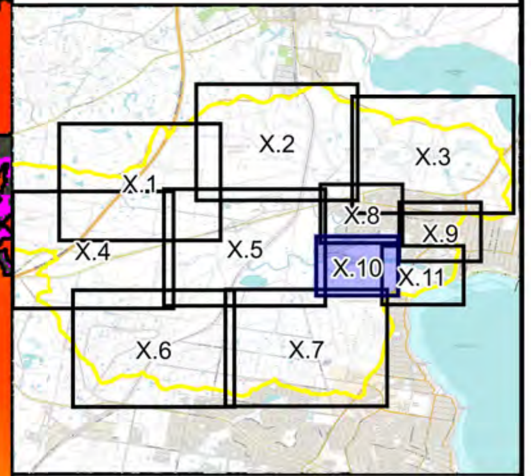
Prepared By:

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

File Name: FigB2.9 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N
W E
S

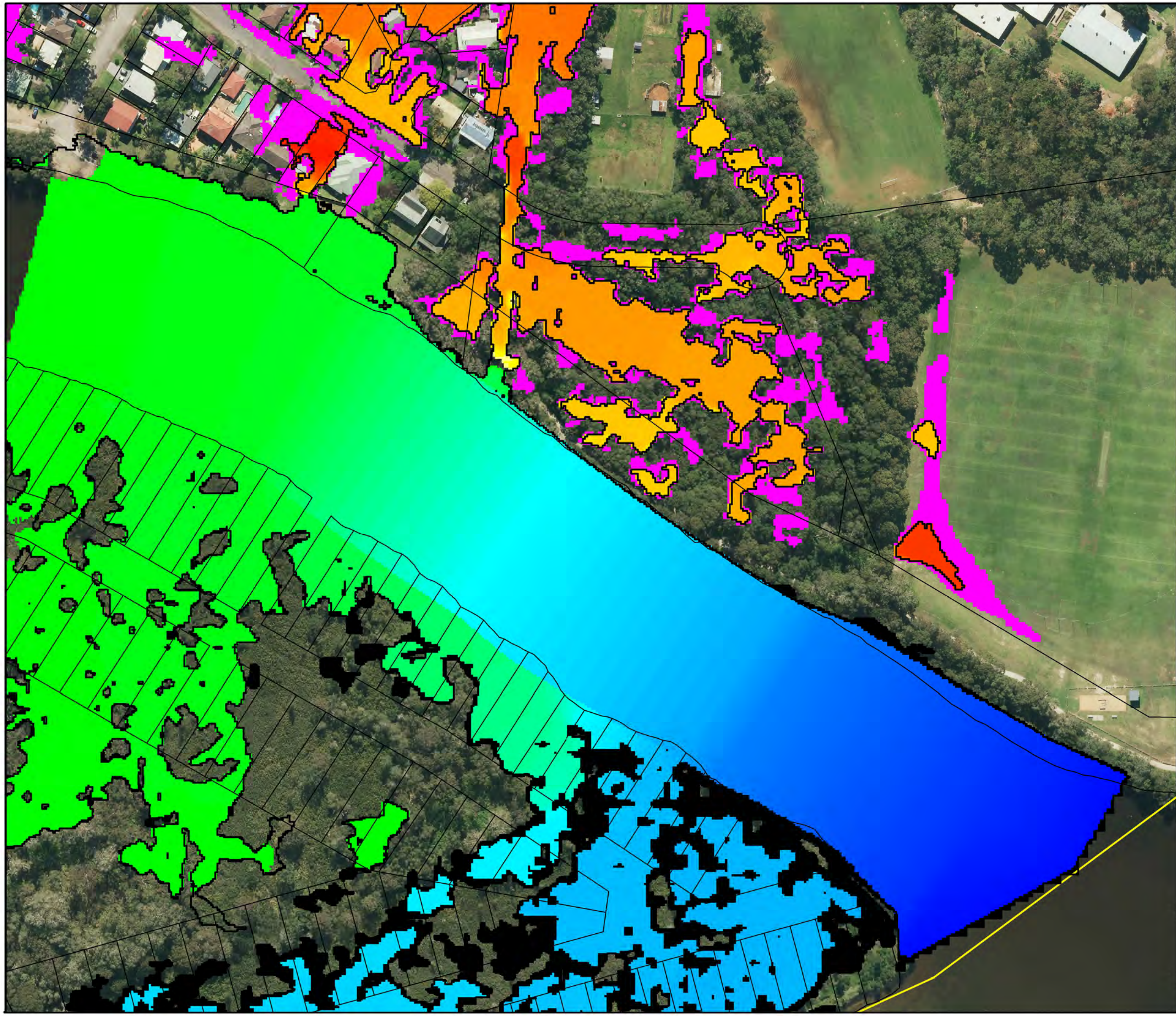
Scale 1:4,000 (at A3)

0 0.1 0.2
Km

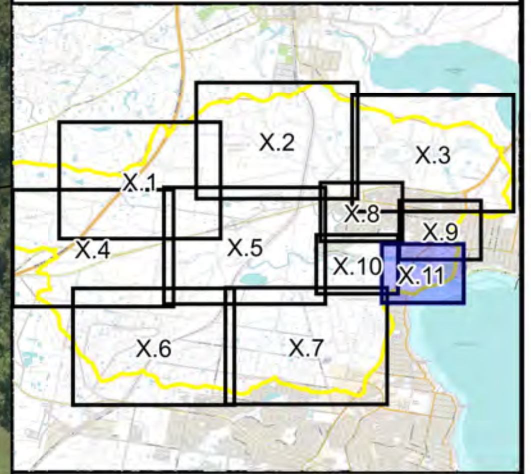
Figure B2.10:
ARR2016 1% AEP
Floodwater Differences

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

File Name: FigB2.10 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor



Central Coast Council



LEGEND

Differences (m)

- Was wet, now dry
- < -0.50
- -0.20
- -0.10
- -0.02
- -0.02 to 0.02
- 0.02
- 0.10
- 0.20
- > 0.50
- Was dry, now wet

N W E S

Scale 1:4,000 (at A3)

0 0.1 0.2 Km

Figure B2.11: ARR2016 1% AEP Floodwater Differences

Prepared By:

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

File Name: FigB2.11 - Peak Floodwater Diff for the 1% AEP Flood ARR2016.wor

ARR2016 Data Hub Download

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	151.496
Latitude	-33.216
Selected Regions	
River Region	
ARF Parameters	
Storm Losses	
Temporal Patterns	
Areal Temporal Patterns	
Interim Climate Change Factors	

Region Information

Data Category	Region
River Region	Macquarie-Tuggerah Lakes
ARF Parameters	SE Coast
Temporal Patterns	East Coast South

Data

River Region

division	South East Coast (NSW)
rivregnum	11
River Region	Macquarie-Tuggerah Lakes

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v1

ARF Parameters

Long Duration ARF

$$Areal\ reduction\ factor = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	SE Coast
a	0.06
b	0.361
c	0.0
d	0.317
e	8.11e-05
f	0.651
g	0.0
h	0.0
i	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are NOT FOR USE in urban areas

id	23564.0
Storm Initial Losses (mm)	49.0
Storm Continuing Losses (mm/h)	3.0

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v1

Temporal Patterns

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v2

Areal Temporal Patterns

code	ECsouth
arealabel	East Coast South

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v2

BOM IFD Depths

Click here to obtain the IFD depths for catchment centroid from the BoM website

No data	No data found at this location!

Layer Info

Time Accessed	13 December 2018 04:23PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	5.3 (0.170)	6.3 (0.141)	6.9 (0.127)	7.5 (0.115)	3.2 (0.040)	0.0 (0.000)
90 (1.5)	6.2 (0.170)	6.0 (0.116)	5.8 (0.092)	5.7 (0.075)	3.4 (0.037)	1.8 (0.016)
120 (2.0)	9.7 (0.242)	8.3 (0.145)	7.3 (0.104)	6.4 (0.076)	3.3 (0.032)	1.0 (0.009)
180 (3.0)	4.5 (0.097)	7.5 (0.113)	9.4 (0.117)	11.3 (0.117)	9.4 (0.079)	8.0 (0.058)
360 (6.0)	11.0 (0.180)	22.4 (0.261)	30.0 (0.288)	37.2 (0.301)	26.2 (0.172)	18.0 (0.102)
720 (12.0)	6.1 (0.076)	10.8 (0.096)	13.8 (0.101)	16.8 (0.104)	26.0 (0.132)	32.9 (0.144)
1080 (18.0)	6.0 (0.063)	12.4 (0.094)	16.7 (0.104)	20.8 (0.110)	28.3 (0.122)	33.9 (0.127)
1440 (24.0)	1.7 (0.016)	5.4 (0.037)	7.9 (0.044)	10.3 (0.049)	17.8 (0.069)	23.5 (0.078)
2160 (36.0)	0.1 (0.001)	3.9 (0.023)	6.4 (0.031)	8.8 (0.036)	8.8 (0.029)	8.8 (0.025)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.2 (0.004)	2.1 (0.006)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

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%)**

Layer Info

Time Accessed	13 December 2018 04:23PM
Version	2016_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values

XP-RAFTS RESULTS

ARR2016 Results for 20% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
1.01	120	4638	2.68	2.71	0.16	2.70
1.02	90	4607	3.98	3.95	0.30	3.99
1.03	45	4552	6.79	6.94	0.32	6.85
1.04	45	4552	8.01	8.19	0.43	8.11
1.05	90	4605	17.39	17.05	1.83	17.55
1.06	60	4579	17.93	17.68	1.36	17.89
1.07	90	4603	19.48	19.57	1.78	19.35
1.08	90	4606	22.07	22.15	1.48	21.95
1.09	90	4600	24.92	24.96	1.21	24.85
1.1	90	4605	25.62	25.79	1.13	25.69
1.11	90	4606	26.34	26.39	1.08	26.34
1.12	90	4605	54.99	55.06	2.22	55.04
1.13	90	4605	57.04	57.12	2.21	57.03
1.14	90	4605	58.95	59.10	2.21	58.98
1.15	90	4605	60.13	60.30	2.20	60.17
1.16	90	4605	60.60	60.78	2.20	60.65
1.17	120	4645	75.82	75.38	3.38	76.17
1.18	120	4632	81.38	80.98	2.07	81.26
1.19	90	4603	157.17	157.11	4.72	157.29
1.2	90	4603	157.77	157.70	4.72	157.89
1.21	90	4603	158.07	158.00	4.72	158.20
1.22	90	4603	158.51	158.45	4.72	158.67
1.23	90	4603	158.76	158.70	4.72	158.91
1.24	90	4603	159.13	159.07	4.72	159.31
1.25	90	4603	159.18	159.12	4.72	159.36
1.26	90	4603	159.55	159.50	4.72	159.74
2.01	60	4577	1.60	1.61	0.12	1.61
2.02	60	4577	3.42	3.46	0.34	3.39
2.03	60	4579	5.33	5.36	0.51	5.47
2.04	60	4577	7.37	7.41	0.68	7.30
3.01	60	4577	1.01	1.03	0.10	1.01
4.01	60	4577	1.22	1.23	0.11	1.22
5.01	45	4550	2.48	2.56	0.25	2.47
6.01	60	4577	1.09	1.10	0.10	1.09
7.01	90	4602	1.74	1.71	0.17	1.78
8.01	60	4581	1.65	1.65	0.15	1.65
8.02	90	4605	3.89	3.90	0.29	4.00
8.03	90	4605	5.38	5.37	0.31	5.49
8.04	90	4605	9.30	9.26	0.40	9.38
8.05	90	4605	11.09	11.00	0.50	11.19
8.06	120	4643	13.40	13.52	1.03	13.46
8.07	90	4602	16.27	16.27	0.66	16.35

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
8.08	90	4600	17.63	17.69	0.81	17.56
8.09	90	4600	17.73	17.78	0.81	17.68
8.1	90	4605	80.61	80.16	4.84	81.30
8.11	90	4605	80.69	80.26	4.83	81.40
8.12	90	4605	81.00	80.59	4.84	81.73
8.13	90	4605	81.15	80.75	4.84	81.90
8.14	90	4605	81.19	80.80	4.84	81.94
8.15	90	4605	81.22	80.83	4.83	81.97
8.16	90	4605	81.22	80.83	4.83	81.98
8.17	90	4605	81.27	80.88	4.84	82.02
8.18	90	4605	81.28	80.89	4.83	82.03
8.19	90	4605	82.18	81.84	4.86	82.99
8.2	90	4605	82.34	82.01	4.86	83.16
8.21	90	4605	82.45	82.14	4.87	83.28
9.01	60	4575	4.08	4.15	0.70	4.01
9.02	120	4636	7.62	7.47	1.23	7.78
9.03	120	4636	14.41	14.23	2.02	14.29
9.04	120	4643	15.83	15.68	2.13	15.76
9.05	90	4606	17.78	17.35	1.66	17.98
9.06	90	4606	18.37	18.04	1.60	18.62
9.07	90	4605	21.27	20.92	1.81	21.62
9.08	90	4605	23.19	22.80	1.90	23.31
9.09	90	4605	27.06	26.96	1.87	27.12
9.1	90	4600	32.61	32.37	1.97	32.42
9.11	90	4600	42.63	42.08	2.63	42.20
9.12	90	4605	63.42	62.33	4.22	62.91
9.13	90	4605	63.69	62.63	4.22	63.22
10.01	20	4451	2.58	2.55	0.31	2.58
10.02	120	4644	4.79	4.79	0.79	4.96
10.03	90	4605	6.07	6.07	0.68	6.31
11.01	45	4552	1.15	1.18	0.06	1.17
12.01	90	4607	1.42	1.41	0.09	1.42
12.02	90	4605	2.47	2.43	0.24	2.46
12.03	90	4605	3.61	3.57	0.32	3.65
12.04	90	4605	5.36	5.21	0.55	5.40
12.05	90	4605	10.94	10.81	0.82	11.15
12.06	90	4605	26.55	26.51	2.17	27.21
12.07	90	4603	29.57	29.76	2.11	29.33
13.01	60	4581	0.89	0.89	0.12	0.89
13.02	90	4602	3.00	3.02	0.18	2.99
13.03	90	4602	3.91	3.92	0.27	3.97
14.01	60	4579	1.73	1.72	0.17	1.76
14.02	60	4579	2.03	2.02	0.21	2.09
14.03	60	4581	4.27	4.28	0.40	4.33

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
14.04	60	4581	6.54	6.55	0.64	6.73
14.05	45	4552	8.94	9.13	0.44	9.08
14.06	45	4552	10.63	10.82	0.47	10.80
14.07	90	4603	14.00	14.11	1.23	13.78
15.01	45	4552	1.49	1.53	0.09	1.52
15.02	60	4577	2.32	2.33	0.23	2.29
16.01	10	4380	1.37	1.35	0.14	1.38
17.01	25	4488	0.58	0.56	0.06	0.60
17.02	90	4602	2.21	2.21	0.23	2.26
18.01	45	4553	1.40	1.42	0.15	1.42
18.02	45	4553	2.11	2.13	0.18	2.12
19.01	45	4553	0.68	0.69	0.08	0.68
19.02	45	4550	1.32	1.32	0.07	1.34
20.01	45	4552	1.46	1.49	0.09	1.48
20.02	90	4602	4.57	4.58	0.18	4.61
20.03	60	4579	7.12	7.14	0.44	7.23
20.04	60	4581	11.69	11.54	0.87	11.64
20.05	90	4605	19.86	19.28	1.83	19.81
20.06	90	4605	20.25	19.74	1.81	20.22
20.07	90	4605	20.69	20.26	1.82	20.64
21.01	45	4552	0.99	0.99	0.03	0.99
21.02	45	4552	1.43	1.45	0.06	1.45
22.01	45	4552	1.08	1.09	0.04	1.09
23.01	20	4450	1.57	1.53	0.20	1.57
23.02	120	4644	3.35	3.34	0.53	3.36
24.01	20	4451	0.25	0.25	0.03	0.25
24.02	90	4605	3.06	3.05	0.25	3.09
24.03	90	4605	4.45	4.35	0.39	4.46
24.04	90	4605	6.62	6.51	0.61	6.74
25.01	30	4519	1.18	1.21	0.13	1.21
25.02	45	4552	2.88	2.92	0.31	2.89
26.01	60	4577	1.48	1.49	0.14	1.47
27.01	20	4445	0.14	0.13	0.01	0.13
27.02	60	4581	2.49	2.47	0.22	2.52
28.01	45	4551	2.09	2.08	0.07	2.10
29.01	60	4581	2.16	2.17	0.16	2.17
30.01	60	4581	1.40	1.41	0.11	1.38
30.02	90	4605	2.99	3.00	0.24	3.05
31.01	20	4450	3.23	3.08	0.29	3.30
31.02	20	4450	3.34	3.19	0.28	3.42
31.03	45	4552	4.57	4.49	0.37	4.50
32.01	60	4577	2.86	2.87	0.26	2.83
33.01	45	4552	1.18	1.21	0.06	1.20
34.01	90	4605	3.89	3.82	0.37	3.85

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
34.02	60	4577	7.79	7.91	0.62	7.84
34.03	90	4605	9.79	9.54	0.83	9.93
35.01	60	4581	2.57	2.57	0.20	2.59
35.02	60	4577	3.68	3.71	0.33	3.67
36.01	120	4645	1.18	1.15	0.18	1.18
36.02	10	4380	4.09	3.97	0.41	4.18
36.03	10	4380	4.13	4.02	0.42	4.21
37.01	60	4577	1.98	1.98	0.17	1.97
37.02	45	4552	5.98	6.11	0.25	6.07
38.01	45	4552	1.04	1.05	0.05	1.05
39.01	90	4602	2.13	2.12	0.16	2.15
39.02	90	4605	2.97	2.94	0.25	2.99
40.01	60	4574	1.49	1.49	0.10	1.50
40.02	90	4605	3.28	3.28	0.29	3.39
40.03	90	4605	5.02	4.97	0.30	5.09
40.04	90	4605	5.11	5.06	0.28	5.19
40.05	90	4605	6.22	6.22	0.32	6.35
40.06	90	4605	15.05	15.02	1.09	15.46
40.07	90	4605	21.12	21.08	1.09	21.55
40.08	90	4605	21.40	21.34	1.09	21.83
40.09	90	4605	22.32	22.22	1.12	22.75
40.1	90	4605	25.65	25.55	1.26	26.02
40.11	90	4605	27.34	27.27	1.33	27.63
40.12	90	4605	31.19	31.15	1.50	31.29
41.01	45	4552	1.20	1.24	0.08	1.24
42.01	45	4552	1.23	1.28	0.11	1.27
43.01	25	4488	1.65	1.61	0.27	1.63
43.02	25	4488	2.43	2.43	0.32	2.43
43.03	45	4552	4.52	4.67	0.45	4.47
44.01	60	4581	2.23	2.24	0.21	2.28
45.01	45	4552	1.94	1.99	0.11	1.98
46.01	60	4581	1.51	1.51	0.17	1.51
47.01	90	4607	2.40	2.37	0.17	2.41
47.02	60	4581	3.57	3.57	0.32	3.67
47.03	45	4552	5.34	5.45	0.29	5.39
47.04	45	4552	9.38	9.35	0.39	9.41
47.05	45	4547	9.58	9.58	0.38	9.62
48.01	120	4640	1.71	1.70	0.14	1.71
48.02	120	4636	2.67	2.67	0.19	2.71
49.01	120	4638	1.42	1.45	0.09	1.44
49.02	90	4605	2.65	2.63	0.18	2.66
50.01	45	4552	0.23	0.23	0.01	0.23
50.02	60	4581	2.10	2.13	0.18	2.11
51.01	25	4488	0.37	0.36	0.03	0.37

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
52.01	45	4551	0.64	0.66	0.03	0.65
53.01	45	4550	1.18	1.22	0.12	1.18
54.01	25	4488	0.88	0.84	0.10	0.88
54.02	60	4575	5.40	5.54	0.57	5.38
54.03	60	4579	6.89	6.96	0.70	7.35
55.01	45	4550	1.02	1.06	0.11	1.02
56.01	45	4552	1.78	1.79	0.07	1.78
56.02	45	4552	2.51	2.57	0.15	2.56
57.01	120	4645	1.18	1.15	0.21	1.21
58.01	60	4574	1.28	1.26	0.20	1.28
59.01	60	4581	1.08	1.09	0.09	1.08
59.02	90	4602	3.13	3.12	0.15	3.15
60.01	20	4450	1.19	1.16	0.15	1.18
61.01	10	4388	4.63	4.61	0.47	4.64
61.02	20	4450	7.22	7.06	0.77	7.08
61.03	45	4545	8.17	8.21	0.58	8.38
61.04	120	4645	10.14	9.96	1.77	10.39
62.01	60	4581	1.32	1.35	0.16	1.28
62.02	10	4391	2.59	2.55	0.07	2.60
63.01	60	4581	1.29	1.29	0.09	1.30
63.02	60	4577	2.86	2.88	0.25	2.82
64.01	20	4450	1.75	1.72	0.23	1.75
65.01	45	4552	1.22	1.23	0.03	1.23
66.01	60	4577	0.74	0.74	0.05	0.74
66.02	60	4577	1.04	1.06	0.08	1.04
67.01	20	4451	0.75	0.75	0.09	0.75
68.01	90	4608	2.30	2.29	0.14	2.30
68.02	90	4605	4.01	3.96	0.22	4.03
69.01	45	4552	1.81	1.83	0.07	1.82
70.01	20	4450	3.93	3.87	0.48	3.90
71.01	120	4636	1.41	1.41	0.04	1.41
72.01	10	4391	2.00	1.92	0.20	2.06
73.01	90	4605	1.37	1.36	0.10	1.37
74.01	10	4391	0.44	0.42	0.05	0.45
75.01	NA	NA	NA	NA	NA	NA
76.01	20	4450	0.94	0.91	0.11	0.92
77.01	20	4450	0.74	0.72	0.09	0.75
78.01	120	4640	1.53	1.50	0.12	1.51
79.01	20	4451	0.69	0.69	0.09	0.70
80.01	20	4450	3.17	3.15	0.39	3.18
80.02	20	4454	7.06	7.16	0.40	7.10
80.03	45	4552	6.73	6.67	0.67	6.70
80.04	20	4451	0.40	0.39	0.05	0.39
80.05	45	4552	11.51	11.95	1.28	11.53

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
81.01	20	4450	2.61	2.57	0.31	2.60
81.02	20	4450	2.72	2.66	0.30	2.71
81.03	20	4448	6.34	6.36	0.41	6.33
82.01	10	4388	4.35	4.33	0.44	4.36
83.01	20	4450	1.53	1.52	0.19	1.55
83.02	20	4450	3.17	3.15	0.13	3.18
83.03	60	4581	5.74	5.91	1.23	5.80
84.01	270	4709	0.89	0.90	0.06	0.90
85.01	20	4450	5.15	5.02	0.61	5.11
85.02	20	4450	3.11	3.02	0.59	3.09
86.01	10	4380	1.63	1.61	0.16	1.64
87.01	10	4391	2.89	2.80	0.30	2.95
88.01	20	4450	1.52	1.51	0.19	1.55
89.01	20	4450	1.14	1.11	0.14	1.11
90.01	180	4673	0.94	0.92	0.06	0.93
91.01	10	4380	0.94	0.93	0.10	0.95
92.01	10	4380	0.82	0.81	0.08	0.83
93.01	10	4391	0.61	0.60	0.06	0.61
94.01	10	4391	0.90	0.89	0.09	0.90
94.02	10	4380	2.00	1.96	0.16	1.99
95.01	10	4391	0.06	0.06	0.01	0.07
96.01	120	4645	2.09	2.07	0.06	2.11
97.01	10	4391	0.17	0.17	0.02	0.17
98.01	10	4380	1.43	1.41	0.14	1.45
99.01	10	4391	1.03	1.02	0.10	1.04
100.01	20	4451	1.96	1.95	0.24	1.97
100.02	45	4547	2.51	2.53	0.23	2.49
101.01	10	4380	1.05	1.05	0.11	1.05
101.02	10	4380	1.48	1.46	0.06	1.49
102.01	10	4380	0.70	0.68	0.07	0.70
103.01	25	4481	0.39	0.38	0.04	0.39
104.01	20	4451	0.17	0.17	0.02	0.18
_junc_10	90	4605	26.55	26.46	1.33	26.83
_junc_100	10	4391	2.00	1.92	0.20	2.06
_junc_102	90	4605	81.22	80.83	4.83	81.97
_junc_103	90	4605	81.23	80.84	4.83	81.98
_junc_11	120	4645	9.27	9.07	1.77	9.53
_junc_12	90	4605	30.36	30.33	1.50	30.48
_junc_13	90	4605	4.86	4.75	0.49	4.88
_junc_14	90	4605	24.49	24.28	2.11	25.08
_junc_15	90	4605	9.20	9.08	0.79	9.37
_junc_16	10	4391	3.47	3.41	0.19	3.54
_junc_17	90	4603	159.55	159.50	4.72	159.74
_junc_18	10	4391	1.93	1.91	0.19	1.94

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_19	120	4632	81.34	80.94	2.08	81.22
_junc_2	90	4605	14.79	14.75	1.08	15.18
_junc_20	120	4645	75.80	75.36	3.39	76.16
_junc_21	90	4603	159.18	159.12	4.72	159.36
_junc_22	90	4605	28.64	28.78	2.12	29.28
_junc_23	90	4603	157.02	156.96	4.72	157.13
_junc_24	90	4605	56.34	56.42	2.21	56.33
_junc_25	90	4603	157.76	157.69	4.72	157.88
_junc_26	90	4605	82.45	82.14	4.87	83.28
_junc_29	90	4603	158.51	158.45	4.72	158.67
_junc_3	60	4581	4.10	4.11	0.39	4.14
_junc_30	90	4603	159.12	159.06	4.72	159.30
_junc_31	90	4603	158.76	158.70	4.72	158.91
_junc_32	90	4605	60.33	60.51	2.20	60.37
_junc_33	90	4605	54.71	54.79	2.22	54.79
_junc_34	60	4577	2.50	2.51	0.21	2.49
_junc_35	45	4552	11.24	11.69	1.29	11.28
_junc_36	90	4605	81.98	81.64	4.85	82.79
_junc_37	20	4449	5.39	5.47	0.79	5.28
_junc_38	10	4389	6.25	6.20	0.24	6.23
_junc_39	90	4605	25.90	26.01	1.11	25.92
_junc_4	60	4581	6.52	6.53	0.64	6.70
_junc_40	90	4605	23.62	23.56	1.31	23.86
_junc_41	90	4605	18.81	18.84	1.82	19.15
_junc_42	60	4579	17.66	17.44	1.38	17.67
_junc_43	90	4606	20.43	20.51	1.54	20.43
_junc_44	60	4577	4.49	4.54	0.44	4.44
_junc_45	60	4579	6.87	6.90	0.61	7.02
_junc_46	60	4577	2.81	2.84	0.23	2.82
_junc_47	60	4579	15.21	15.23	1.54	15.57
_junc_48	45	4552	7.72	7.91	0.41	7.82
_junc_49	90	4600	12.53	12.44	0.44	12.44
_junc_5	90	4605	20.80	20.76	1.09	21.24
_junc_50	90	4605	3.57	3.57	0.23	3.57
_junc_51	45	4552	5.95	6.08	0.31	6.00
_junc_52	90	4605	63.66	62.61	4.22	63.20
_junc_53	90	4605	8.09	8.08	0.37	8.09
_junc_54	90	4602	14.62	14.55	0.52	14.63
_junc_55	90	4605	10.65	10.58	0.45	10.77
_junc_56	90	4605	80.46	79.99	4.84	81.11
_junc_57	90	4605	62.90	61.75	4.20	62.29
_junc_58	90	4600	41.94	41.30	2.62	41.51
_junc_59	90	4605	25.74	25.58	1.86	25.87
_junc_6	45	4552	7.72	7.87	0.38	7.80

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_60	90	4605	20.20	19.68	1.82	20.17
_junc_61	90	4605	31.89	31.65	1.99	31.68
_junc_62	90	4605	20.84	20.51	1.77	21.26
_junc_63	90	4606	18.35	18.02	1.61	18.60
_junc_64	90	4605	21.91	21.52	1.87	22.13
_junc_65	90	4606	17.43	16.96	1.69	17.64
_junc_66	90	4605	18.07	17.48	1.77	17.94
_junc_67	60	4581	13.43	13.54	1.42	13.24
_junc_68	120	4643	15.11	14.98	2.08	14.98
_junc_69	120	4636	5.60	5.62	0.89	5.72
_junc_7	90	4605	22.23	22.14	1.13	22.67
_junc_70	60	4574	9.81	9.76	0.71	9.87
_junc_71	90	4607	6.34	6.28	0.43	6.31
_junc_72	45	4552	3.84	3.88	0.14	3.85
_junc_73	90	4605	7.47	7.22	0.75	7.33
_junc_74	45	4550	7.53	7.62	0.40	7.50
_junc_8	90	4605	25.17	25.06	1.22	25.59
_junc_9	90	4606	12.56	12.62	1.22	12.97

ARR2016 Results for 5% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
1.01	90	4595	4.36	4.44	0.25	4.40
1.02	60	4570	6.29	6.33	0.36	6.22
1.03	60	4568	11.22	11.34	0.90	11.30
1.04	60	4475	13.09	13.28	1.09	13.13
1.05	60	4475	28.92	29.44	2.01	29.08
1.06	60	4475	29.52	29.99	1.95	29.68
1.07	60	4475	31.46	31.87	1.95	31.72
1.08	60	4572	34.49	34.70	1.92	34.60
1.09	90	4594	37.90	37.30	1.93	37.47
1.1	90	4594	38.94	38.69	1.95	38.75
1.11	120	4629	40.05	40.39	2.96	40.17
1.12	90	4564	83.54	84.19	4.73	82.93
1.13	90	4564	86.68	87.41	4.63	86.27
1.14	180	4639	90.15	92.15	4.80	91.71
1.15	180	4668	92.98	94.75	4.63	94.56
1.16	180	4668	94.06	95.81	4.56	95.34
1.17	180	4639	121.94	122.03	4.82	123.22
1.18	180	4667	131.95	131.97	3.92	132.09
1.19	180	4639	248.97	250.36	10.20	249.09
1.2	180	4639	250.15	251.48	10.19	250.42
1.21	180	4639	250.82	252.04	10.16	251.41
1.22	180	4668	251.70	252.96	10.11	252.19
1.23	180	4668	252.23	253.53	10.10	252.65
1.24	180	4668	253.48	255.63	9.78	253.11
1.25	180	4668	253.62	255.83	9.74	253.16
1.26	180	4668	254.45	256.70	9.73	253.90
2.01	60	4565	2.65	2.73	0.19	2.72
2.02	60	4569	5.71	5.87	0.45	5.82
2.03	60	4569	8.94	9.14	0.70	9.00
2.04	60	4475	12.47	12.66	0.91	12.59
3.01	60	4569	1.68	1.74	0.14	1.71
4.01	60	4475	2.04	2.11	0.16	2.02
5.01	30	4511	3.88	3.82	0.27	3.92
6.01	60	4569	1.82	1.88	0.15	1.85
7.01	60	4565	2.83	2.90	0.18	2.87
8.01	60	4475	2.67	2.71	0.24	2.71
8.02	60	4568	6.17	6.28	0.32	6.25
8.03	60	4572	8.41	8.49	0.35	8.42
8.04	90	4594	14.41	14.39	0.84	14.61
8.05	90	4589	17.05	17.11	1.02	17.46
8.06	120	4623	20.95	21.25	1.25	20.96
8.07	120	4622	25.13	25.10	1.33	25.18

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
8.08	120	4629	27.06	27.24	1.35	27.08
8.09	120	4629	27.24	27.43	1.35	27.28
8.1	60	4475	123.86	123.86	4.83	124.72
8.11	60	4475	123.92	123.93	4.82	124.79
8.12	60	4475	124.30	124.32	4.83	125.18
8.13	60	4475	124.44	124.47	4.83	125.34
8.14	60	4475	124.48	124.51	4.83	125.38
8.15	60	4475	124.50	124.53	4.83	125.40
8.16	60	4475	124.51	124.54	4.83	125.41
8.17	60	4475	124.56	124.59	4.83	125.46
8.18	60	4475	124.56	124.59	4.83	125.46
8.19	60	4475	125.71	125.76	4.84	126.64
8.2	60	4475	125.92	125.97	4.85	126.85
8.21	60	4475	126.05	126.10	4.85	126.99
9.01	60	4565	6.12	6.05	0.68	6.16
9.02	60	4568	13.18	13.39	1.42	13.21
9.03	60	4475	24.57	25.36	2.24	24.69
9.04	60	4475	26.86	27.62	2.19	26.97
9.05	60	4569	29.83	30.21	2.14	29.85
9.06	60	4475	30.59	30.86	2.09	30.60
9.07	60	4475	33.70	33.04	1.94	33.82
9.08	60	4573	36.49	36.03	2.02	36.17
9.09	60	4573	42.05	41.54	1.72	41.93
9.1	60	4573	50.59	49.92	2.31	50.31
9.11	60	4573	66.34	65.29	3.07	65.98
9.12	60	4475	99.47	99.04	4.81	100.18
9.13	60	4475	99.73	99.29	4.81	100.43
10.01	45	4542	4.01	3.84	0.55	3.99
10.02	60	4568	7.73	7.96	0.58	7.89
10.03	60	4572	10.06	10.19	0.69	10.12
11.01	45	4541	1.85	1.81	0.13	1.86
12.01	60	4565	2.28	2.31	0.07	2.30
12.02	60	4569	4.11	4.20	0.29	4.16
12.03	60	4572	5.96	6.02	0.43	6.01
12.04	60	4475	8.99	9.07	0.62	8.97
12.05	60	4573	17.53	17.50	0.95	17.66
12.06	60	4475	42.97	42.92	2.34	43.23
12.07	60	4573	47.04	46.75	2.40	47.29
13.01	45	4541	1.47	1.42	0.13	1.45
13.02	90	4595	4.63	4.64	0.35	4.67
13.03	60	4573	6.08	6.11	0.28	6.06
14.01	45	4539	2.83	2.83	0.17	2.85
14.02	60	4569	3.35	3.40	0.30	3.36
14.03	60	4568	7.09	7.29	0.53	7.29

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
14.04	60	4569	10.91	11.17	0.82	11.12
14.05	60	4475	14.91	15.09	1.14	14.84
14.06	60	4475	17.93	18.09	1.34	18.03
14.07	60	4573	23.15	22.94	1.43	23.17
15.01	45	4478	2.46	2.39	0.18	2.45
15.02	60	4475	3.87	3.97	0.32	3.96
16.01	15	4408	2.07	2.10	0.18	2.10
17.01	20	4436	0.94	0.93	0.08	0.95
17.02	60	4568	3.59	3.61	0.28	3.60
18.01	45	4478	3.09	3.00	0.35	3.07
18.02	45	4536	4.34	4.17	0.51	4.38
19.01	30	4509	1.10	1.11	0.11	1.10
19.02	45	4540	2.12	2.10	0.10	2.10
20.01	45	4478	2.41	2.35	0.18	2.43
20.02	60	4572	7.15	7.18	0.22	7.17
20.03	60	4567	11.37	11.35	0.71	11.41
20.04	60	4475	18.89	19.40	1.40	18.99
20.05	60	4475	32.26	32.90	2.08	32.41
20.06	60	4475	32.69	33.24	1.97	32.91
20.07	60	4475	33.29	33.79	1.97	33.57
21.01	45	4540	1.61	1.61	0.08	1.62
21.02	60	4475	2.34	2.39	0.21	2.34
22.01	45	4539	1.78	1.77	0.11	1.78
23.01	20	4444	2.51	2.43	0.35	2.56
23.02	60	4572	5.46	5.45	0.40	5.50
24.01	15	4414	0.39	0.39	0.03	0.39
24.02	60	4570	5.02	5.12	0.29	4.98
24.03	60	4569	7.37	7.57	0.49	7.49
24.04	60	4475	10.81	11.00	0.68	11.00
25.01	45	4536	1.92	1.84	0.23	1.99
25.02	45	4542	4.46	4.32	0.36	4.40
26.01	60	4569	2.46	2.54	0.19	2.51
27.01	15	4412	0.21	0.21	0.02	0.20
27.02	45	4539	3.97	3.96	0.23	3.98
28.01	45	4539	3.34	3.33	0.21	3.35
29.01	60	4565	3.50	3.60	0.26	3.57
30.01	60	4565	2.27	2.30	0.21	2.29
30.02	60	4475	4.90	4.99	0.31	4.87
31.01	20	4434	5.45	5.41	0.77	5.49
31.02	20	4434	5.62	5.56	0.76	5.68
31.03	25	4470	7.23	7.26	0.80	7.35
32.01	45	4540	4.73	4.75	0.28	4.74
33.01	45	4541	1.91	1.88	0.13	1.93
34.01	60	4565	6.52	6.71	0.51	6.63

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
34.02	60	4569	12.99	13.41	0.93	13.35
34.03	60	4569	16.01	16.45	0.98	16.33
35.01	60	4565	4.14	4.26	0.34	4.26
35.02	60	4475	6.04	6.14	0.46	6.04
36.01	120	4621	1.82	1.77	0.15	1.81
36.02	15	4410	6.07	6.11	0.57	6.05
36.03	15	4410	6.17	6.22	0.56	6.15
37.01	60	4565	3.17	3.27	0.24	3.25
37.02	60	4572	9.81	9.99	0.73	9.95
38.01	45	4541	1.66	1.65	0.11	1.68
39.01	60	4565	3.38	3.43	0.17	3.40
39.02	60	4565	4.75	4.87	0.28	4.85
40.01	60	4565	2.43	2.49	0.21	2.45
40.02	60	4569	5.31	5.43	0.33	5.29
40.03	60	4573	7.95	7.92	0.36	8.01
40.04	60	4573	8.02	7.97	0.34	8.05
40.05	90	4594	9.53	9.52	0.60	9.71
40.06	60	4573	23.92	23.80	1.18	23.99
40.07	60	4475	32.87	32.33	1.47	33.33
40.08	60	4475	33.24	32.72	1.45	33.67
40.09	60	4570	34.64	34.17	1.49	34.39
40.1	60	4475	39.90	39.27	1.51	40.31
40.11	60	4475	42.32	41.78	1.39	42.61
40.12	60	4573	47.93	47.78	1.38	48.04
41.01	45	4541	1.94	1.89	0.13	1.92
42.01	45	4542	1.97	1.95	0.15	1.97
43.01	20	4435	2.91	2.87	0.49	2.99
43.02	20	4435	4.25	4.24	0.62	4.42
43.03	45	4536	7.33	7.06	0.71	7.72
44.01	60	4569	3.61	3.73	0.28	3.67
45.01	45	4541	3.03	2.99	0.19	3.04
46.01	45	4541	2.45	2.42	0.20	2.46
47.01	60	4570	3.81	3.82	0.20	3.81
47.02	60	4568	5.82	5.87	0.41	5.82
47.03	60	4475	8.82	8.94	0.71	8.79
47.04	60	4475	15.44	15.16	1.10	15.71
47.05	60	4475	15.73	15.38	1.10	16.00
48.01	120	4630	2.76	2.74	0.18	2.76
48.02	120	4628	4.24	4.19	0.25	4.29
49.01	90	4595	2.35	2.39	0.12	2.37
49.02	60	4569	4.30	4.37	0.24	4.35
50.01	45	4541	0.37	0.36	0.03	0.36
50.02	45	4540	3.32	3.29	0.16	3.35
51.01	20	4436	0.61	0.61	0.04	0.61

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
52.01	45	4541	1.05	1.02	0.08	1.05
53.01	30	4513	1.89	1.88	0.15	1.88
54.01	20	4435	1.43	1.42	0.15	1.42
54.02	60	4475	8.32	8.28	0.70	8.38
54.03	60	4565	10.83	11.02	0.89	10.80
55.01	30	4513	1.62	1.61	0.13	1.62
56.01	45	4541	2.88	2.85	0.19	2.90
56.02	45	4542	4.07	3.97	0.22	4.15
57.01	60	4567	1.80	1.75	0.16	1.83
58.01	45	4542	2.12	2.04	0.22	2.16
59.01	60	4565	1.73	1.76	0.16	1.75
59.02	60	4568	4.81	4.88	0.17	4.86
60.01	20	4444	1.90	1.85	0.28	1.93
61.01	15	4410	7.08	7.17	0.62	6.98
61.02	25	4473	10.98	10.76	1.45	11.12
61.03	45	4544	12.69	11.81	1.67	13.40
61.04	60	4573	15.59	16.21	1.56	15.89
62.01	60	4565	2.06	2.09	0.20	2.08
62.02	10	4379	3.79	3.77	0.05	3.79
63.01	60	4565	2.14	2.21	0.18	2.19
63.02	60	4475	4.79	4.92	0.39	4.78
64.01	20	4444	2.69	2.66	0.43	2.74
65.01	45	4540	2.04	2.06	0.10	2.05
66.01	60	4565	1.23	1.27	0.09	1.26
66.02	60	4569	1.77	1.81	0.13	1.78
67.01	45	4542	1.19	1.15	0.16	1.20
68.01	60	4570	3.55	3.54	0.16	3.57
68.02	90	4589	6.27	6.36	0.52	6.22
69.01	45	4541	2.90	2.89	0.17	2.91
70.01	15	4410	6.00	6.11	0.58	5.90
71.01	120	4624	2.40	2.40	0.07	2.41
72.01	15	4410	3.05	3.13	0.28	3.08
73.01	60	4570	2.23	2.24	0.13	2.24
74.01	15	4410	0.66	0.67	0.06	0.67
75.01	15	4381	0.00	0.00	0.00	0.00
76.01	15	4410	1.44	1.47	0.13	1.42
77.01	15	4410	1.14	1.17	0.11	1.12
78.01	120	4630	2.50	2.48	0.16	2.49
79.01	20	4444	1.07	1.06	0.18	1.08
80.01	15	4410	4.83	4.93	0.46	4.75
80.02	20	4436	10.34	10.00	1.09	10.40
80.03	25	4470	10.17	10.20	0.65	10.18
80.04	15	4410	0.61	0.62	0.05	0.60
80.05	45	4536	18.19	17.77	1.78	17.95

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
81.01	15	4410	3.98	4.08	0.39	3.94
81.02	15	4410	4.15	4.28	0.36	4.17
81.03	20	4440	9.46	9.34	0.86	9.55
82.01	15	4410	6.62	6.68	0.57	6.54
83.01	15	4410	2.34	2.41	0.23	2.34
83.02	25	4471	4.72	4.71	0.47	4.81
83.03	45	4542	9.34	9.18	1.77	9.73
84.01	180	4659	1.55	1.55	0.07	1.54
85.01	15	4410	7.88	8.09	0.74	7.81
85.02	15	4410	5.74	5.96	0.74	5.67
86.01	15	4411	2.42	2.44	0.21	2.42
87.01	15	4410	4.45	4.56	0.40	4.44
88.01	15	4410	2.34	2.41	0.22	2.35
89.01	15	4413	1.75	1.77	0.16	1.84
90.01	180	4659	1.59	1.64	0.15	1.61
91.01	15	4411	1.43	1.44	0.12	1.43
92.01	15	4410	1.23	1.23	0.10	1.22
93.01	15	4410	0.92	0.94	0.08	0.91
94.01	15	4411	1.36	1.37	0.11	1.37
94.02	15	4415	2.98	2.97	0.22	3.03
95.01	15	4412	0.09	0.09	0.01	0.09
96.01	60	4475	2.22	2.24	0.10	2.22
97.01	15	4410	0.26	0.27	0.02	0.26
98.01	15	4410	2.12	2.14	0.19	2.12
99.01	15	4411	1.53	1.54	0.12	1.53
100.01	20	4444	2.96	2.95	0.50	2.98
100.02	45	4544	3.95	3.62	0.57	4.49
101.01	15	4408	1.59	1.60	0.14	1.59
101.02	10	4373	2.22	2.20	0.05	2.21
102.01	15	4408	1.06	1.07	0.09	1.07
103.01	25	4476	0.64	0.64	0.06	0.65
104.01	20	4444	0.28	0.27	0.05	0.28
_junc_10	60	4475	41.14	40.60	1.39	41.43
_junc_100	15	4410	3.05	3.13	0.28	3.08
_junc_102	60	4475	124.51	124.54	4.83	125.41
_junc_103	60	4475	124.51	124.54	4.83	125.41
_junc_11	60	4573	14.48	15.09	1.56	14.77
_junc_12	60	4573	46.74	46.56	1.38	46.81
_junc_13	60	4569	8.16	8.27	0.58	8.19
_junc_14	60	4475	40.02	40.02	2.31	40.17
_junc_15	60	4573	14.92	14.93	0.94	15.09
_junc_16	60	4475	5.35	5.22	0.62	5.22
_junc_17	180	4668	254.45	256.70	9.73	253.90
_junc_18	15	4411	2.89	2.91	0.23	2.89

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_19	180	4667	131.90	131.92	3.92	132.03
_junc_2	60	4573	23.54	23.46	1.18	23.64
_junc_20	180	4639	121.91	121.99	4.83	123.18
_junc_21	180	4668	253.62	255.82	9.74	253.16
_junc_22	60	4573	45.80	45.60	2.40	46.12
_junc_23	180	4639	248.68	250.11	10.21	248.73
_junc_24	90	4564	85.55	86.27	4.63	85.11
_junc_25	180	4639	250.13	251.46	10.19	250.37
_junc_26	60	4475	126.05	126.10	4.85	126.99
_junc_29	180	4668	251.70	252.96	10.11	252.19
_junc_3	60	4568	6.82	7.01	0.51	6.98
_junc_30	180	4668	253.43	255.56	9.79	253.10
_junc_31	180	4668	252.23	253.53	10.10	252.65
_junc_32	180	4668	93.44	95.21	4.57	94.79
_junc_33	90	4564	83.17	83.82	4.76	82.54
_junc_34	60	4475	4.17	4.32	0.34	4.12
_junc_35	45	4536	17.70	17.20	1.83	17.50
_junc_36	60	4475	125.47	125.51	4.84	126.39
_junc_37	20	4444	9.22	8.90	1.29	9.52
_junc_38	10	4378	9.15	9.23	0.25	9.14
_junc_39	90	4482	39.36	39.29	1.98	39.34
_junc_4	60	4569	10.88	11.14	0.81	11.08
_junc_40	60	4475	36.30	36.27	1.77	36.43
_junc_41	60	4475	30.69	31.14	1.96	30.92
_junc_42	60	4475	29.18	29.66	1.95	29.33
_junc_43	60	4563	32.21	32.50	1.92	32.20
_junc_44	60	4569	7.50	7.70	0.59	7.61
_junc_45	60	4569	11.61	11.79	0.87	11.60
_junc_46	60	4569	4.67	4.82	0.35	4.82
_junc_47	60	4475	25.41	25.83	1.98	25.41
_junc_48	60	4569	12.67	12.76	1.05	12.66
_junc_49	120	4623	19.58	19.87	1.23	19.76
_junc_5	60	4475	32.49	31.86	1.47	32.96
_junc_50	90	4595	5.70	5.80	0.47	5.70
_junc_51	60	4568	9.67	9.75	0.80	9.68
_junc_52	60	4475	99.71	99.27	4.81	100.41
_junc_53	90	4594	12.64	12.68	0.77	12.82
_junc_54	120	4624	22.81	22.91	1.27	22.65
_junc_55	90	4594	16.38	16.43	0.97	16.85
_junc_56	60	4475	123.69	123.69	4.83	124.55
_junc_57	60	4475	98.79	98.39	4.80	99.52
_junc_58	60	4573	65.43	64.35	3.08	64.94
_junc_59	60	4573	40.22	39.83	1.67	40.00
_junc_6	60	4569	12.93	13.15	1.00	13.02

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_60	60	4475	32.65	33.21	2.00	32.86
_junc_61	60	4573	49.66	49.06	2.27	49.47
_junc_62	60	4475	33.13	32.53	1.88	33.06
_junc_63	60	4475	30.57	30.85	2.10	30.59
_junc_64	60	4475	34.60	34.11	1.98	35.18
_junc_65	60	4475	29.41	29.85	2.17	29.50
_junc_66	60	4475	29.51	30.23	2.06	29.47
_junc_67	60	4475	22.96	23.66	2.14	23.00
_junc_68	60	4475	25.70	26.54	2.22	25.81
_junc_69	60	4572	9.26	9.42	0.64	9.39
_junc_7	60	4475	34.50	34.02	1.50	34.98
_junc_70	60	4565	15.81	16.12	1.13	15.91
_junc_71	60	4565	10.12	10.16	0.45	10.13
_junc_72	45	4539	6.15	6.15	0.32	6.15
_junc_73	60	4569	12.47	12.78	0.89	12.73
_junc_74	60	4475	12.33	12.44	0.97	12.43
_junc_8	60	4475	39.19	38.59	1.54	39.64
_junc_9	60	4573	21.02	21.00	1.43	21.17

ARR2016 Results for 1% AEP Event

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
1.01	90	4585	7.10	7.23	0.44	7.17
1.02	60	4558	10.27	10.18	0.66	10.24
1.03	60	4360	17.64	17.48	1.38	17.68
1.04	45	4528	20.45	20.33	0.89	20.72
1.05	60	4360	45.05	44.77	2.50	45.65
1.06	60	4559	45.86	45.61	2.50	46.68
1.07	60	4463	48.68	48.08	2.45	48.95
1.08	60	4559	53.34	52.77	2.36	53.64
1.09	90	4465	59.08	59.87	2.45	59.54
1.1	90	4465	60.65	61.20	2.55	61.17
1.11	90	4562	62.18	62.38	2.74	61.95
1.12	90	4465	128.89	128.44	3.87	129.45
1.13	90	4430	133.39	133.23	3.93	133.39
1.14	90	4430	137.15	137.24	4.05	137.51
1.15	90	4501	139.83	140.00	4.08	139.66
1.16	90	4501	140.85	141.05	4.08	140.70
1.17	120	4618	179.85	177.52	5.75	181.48
1.18	180	4612	193.54	195.65	14.11	190.50
1.19	120	4617	368.28	371.00	21.87	366.40
1.2	120	4617	369.81	372.49	21.85	367.77
1.21	120	4617	370.52	373.19	21.81	368.37
1.22	120	4617	371.60	374.23	21.78	369.29
1.23	120	4617	372.34	374.96	21.78	369.98
1.24	120	4617	373.06	375.63	21.69	370.51
1.25	120	4617	373.16	375.72	21.67	370.57
1.26	120	4617	374.30	376.84	21.66	371.64
2.01	60	4558	4.23	4.15	0.29	4.18
2.02	45	4528	8.98	9.00	0.45	9.07
2.03	45	4496	14.01	14.10	0.60	13.97
2.04	60	4463	19.45	19.04	0.99	19.90
3.01	45	4528	2.71	2.71	0.13	2.74
4.01	45	4528	3.22	3.23	0.15	3.26
5.01	25	4464	6.23	6.20	0.29	6.20
6.01	45	4528	2.90	2.90	0.13	2.94
7.01	60	4558	4.57	4.49	0.30	4.54
8.01	45	4531	4.16	4.16	0.27	4.16
8.02	60	4463	9.93	9.84	0.33	9.91
8.03	60	4558	13.46	13.30	0.37	13.45
8.04	90	4585	22.92	22.94	0.80	23.03
8.05	90	4532	27.20	27.05	0.72	27.24
8.06	90	4501	32.31	32.12	0.56	32.30
8.07	90	4395	38.74	38.38	1.23	38.78

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
8.08	90	4586	41.73	41.75	1.32	41.98
8.09	90	4586	41.97	41.99	1.30	42.20
8.1	60	4463	191.07	189.78	5.58	192.15
8.11	60	4463	191.17	189.87	5.56	192.22
8.12	60	4463	191.73	190.40	5.54	192.72
8.13	60	4463	191.93	190.58	5.52	192.88
8.14	60	4463	191.97	190.62	5.52	192.92
8.15	60	4463	192.00	190.64	5.51	192.94
8.16	60	4463	192.01	190.65	5.51	192.95
8.17	60	4463	192.06	190.70	5.51	193.00
8.18	60	4463	192.07	190.71	5.51	193.01
8.19	60	4463	193.64	192.27	5.49	194.46
8.2	60	4463	193.91	192.55	5.48	194.72
8.21	60	4463	194.08	192.72	5.47	194.87
9.01	20	4371	9.35	9.21	1.46	9.49
9.02	60	4559	20.20	20.01	1.77	20.02
9.03	60	4559	38.23	38.27	2.68	38.85
9.04	60	4405	41.82	41.99	2.61	41.76
9.05	60	4405	46.52	46.32	2.51	46.61
9.06	60	4559	47.77	47.40	2.49	47.73
9.07	60	4405	53.49	53.24	2.32	53.78
9.08	60	4405	57.65	57.09	2.24	57.55
9.09	60	4559	64.76	64.38	2.05	64.62
9.1	60	4556	77.07	76.86	1.50	77.30
9.11	60	4463	101.76	100.91	2.87	101.27
9.12	60	4463	153.58	152.14	5.13	154.92
9.13	60	4463	153.92	152.47	5.11	155.20
10.01	20	4371	6.18	6.12	0.90	6.32
10.02	60	4463	12.12	12.10	0.54	12.11
10.03	60	4558	15.90	16.10	0.93	15.93
11.01	45	4528	2.89	2.90	0.15	2.94
12.01	60	4558	3.66	3.65	0.14	3.66
12.02	60	4405	6.37	6.28	0.44	6.30
12.03	60	4559	9.39	9.24	0.52	9.64
12.04	60	4405	14.07	13.82	0.81	13.85
12.05	60	4463	28.08	27.69	1.09	28.47
12.06	60	4463	66.99	66.63	2.59	67.32
12.07	60	4559	72.93	72.09	2.51	73.43
13.01	30	4503	2.26	2.24	0.11	2.24
13.02	60	4463	7.63	7.56	0.25	7.60
13.03	60	4558	9.98	10.05	0.38	9.99
14.01	45	4496	4.49	4.47	0.29	4.49
14.02	45	4496	5.28	5.31	0.32	5.29
14.03	45	4528	11.05	11.07	0.59	11.20

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
14.04	45	4528	17.04	17.10	0.76	17.33
14.05	45	4534	23.21	23.16	0.81	23.46
14.06	60	4463	27.63	27.42	1.55	27.96
14.07	60	4559	35.81	35.10	1.55	35.97
15.01	30	4498	3.71	3.71	0.16	3.73
15.02	45	4534	6.08	6.09	0.21	6.20
16.01	10	4361	3.03	3.04	0.21	3.07
17.01	20	4399	1.48	1.47	0.11	1.48
17.02	60	4405	5.59	5.55	0.46	5.58
18.01	20	4433	5.43	5.35	0.44	5.44
18.02	20	4433	7.55	7.51	0.49	7.60
19.01	20	4433	1.75	1.75	0.08	1.76
19.02	45	4525	3.33	3.34	0.13	3.33
20.01	30	4502	3.65	3.65	0.17	3.67
20.02	60	4558	11.52	11.46	0.26	11.52
20.03	60	4559	18.08	18.09	0.79	18.16
20.04	60	4405	29.45	29.23	1.62	29.43
20.05	60	4559	50.13	49.36	2.38	51.04
20.06	60	4559	50.72	50.06	2.29	51.52
20.07	60	4559	51.55	51.08	2.29	52.31
21.01	45	4528	2.58	2.59	0.14	2.62
21.02	45	4496	3.72	3.75	0.16	3.69
22.01	45	4528	2.81	2.82	0.15	2.84
23.01	20	4371	4.05	3.89	0.47	4.05
23.02	60	4405	8.66	8.66	0.52	8.72
24.01	15	4400	0.61	0.58	0.07	0.63
24.02	60	4558	8.18	8.06	0.44	8.10
24.03	60	4405	11.83	11.71	0.53	11.83
24.04	60	4463	16.99	16.63	0.88	17.33
25.01	20	4371	3.11	3.06	0.33	3.13
25.02	30	4498	6.86	6.75	0.60	6.89
26.01	45	4496	3.93	3.94	0.19	3.91
27.01	10	4356	0.32	0.32	0.01	0.32
27.02	45	4496	6.43	6.42	0.40	6.45
28.01	45	4496	5.35	5.38	0.37	5.38
29.01	45	4531	5.70	5.73	0.27	5.68
30.01	60	4558	3.50	3.52	0.24	3.47
30.02	60	4405	7.80	7.76	0.48	7.87
31.01	20	4404	8.66	8.14	1.32	9.02
31.02	20	4404	8.92	8.35	1.35	9.27
31.03	20	4404	11.36	10.68	1.36	11.58
32.01	45	4528	7.67	7.65	0.48	7.68
33.01	45	4528	2.99	3.00	0.15	3.03
34.01	60	4558	10.45	10.29	0.73	10.37

Subcatch ID	ARR2016 Discharge Statistics for <u>All</u> Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
34.02	60	4558	20.61	20.30	1.47	20.36
34.03	60	4559	25.34	24.85	1.50	26.06
35.01	45	4528	6.76	6.76	0.37	6.78
35.02	45	4528	9.57	9.59	0.38	9.69
36.01	90	4532	2.87	2.85	0.23	2.85
36.02	20	4371	8.92	8.24	1.75	9.61
36.03	20	4371	9.10	8.42	1.77	9.77
37.01	45	4531	5.19	5.22	0.28	5.20
37.02	60	4463	15.36	15.19	0.85	15.34
38.01	45	4528	2.64	2.64	0.14	2.68
39.01	60	4558	5.55	5.50	0.31	5.54
39.02	60	4405	7.76	7.71	0.42	7.74
40.01	60	4405	3.82	3.80	0.27	3.83
40.02	60	4463	8.37	8.23	0.34	8.29
40.03	60	4558	12.66	12.63	0.44	12.63
40.04	60	4558	12.82	12.84	0.42	12.80
40.05	60	4463	15.19	15.14	0.38	15.22
40.06	60	4360	37.01	36.95	1.16	37.19
40.07	60	4559	51.29	51.08	1.21	51.54
40.08	60	4556	51.83	51.67	1.24	51.70
40.09	60	4556	54.01	53.81	1.19	53.85
40.1	60	4559	62.24	61.83	1.34	62.78
40.11	60	4559	66.04	65.66	1.34	66.36
40.12	60	4559	74.70	74.34	1.43	74.72
41.01	45	4528	2.98	2.99	0.15	3.04
42.01	30	4498	3.03	3.01	0.22	3.06
43.01	20	4404	4.72	4.44	0.70	4.92
43.02	20	4433	6.93	6.64	0.96	6.76
43.03	45	4534	11.42	11.41	0.57	11.50
44.01	45	4528	5.89	5.89	0.34	5.95
45.01	45	4528	4.83	4.84	0.29	4.91
46.01	45	4496	3.73	3.71	0.27	3.74
47.01	60	4558	6.22	6.16	0.37	6.24
47.02	60	4405	9.13	9.05	0.62	9.12
47.03	45	4528	13.62	13.56	0.56	13.88
47.04	60	4559	23.63	23.12	1.22	23.88
47.05	60	4559	24.12	23.54	1.20	24.34
48.01	90	4588	4.28	4.32	0.24	4.29
48.02	90	4585	6.65	6.60	0.30	6.62
49.01	90	4584	3.73	3.79	0.20	3.75
49.02	60	4405	6.79	6.81	0.28	6.90
50.01	30	4502	0.59	0.59	0.04	0.59
50.02	45	4528	5.20	5.26	0.19	5.21
51.01	20	4428	0.97	0.97	0.06	0.97

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
52.01	45	4528	1.64	1.63	0.10	1.64
53.01	25	4464	2.97	2.95	0.14	2.95
54.01	20	4404	2.27	2.24	0.21	2.30
54.02	60	4557	13.13	13.10	0.71	13.18
54.03	60	4360	16.97	16.82	0.88	16.89
55.01	25	4464	2.58	2.55	0.13	2.57
56.01	45	4496	4.53	4.55	0.30	4.54
56.02	45	4534	6.27	6.28	0.29	6.39
57.01	60	4558	2.84	2.82	0.17	2.83
58.01	20	4433	3.26	3.18	0.36	3.23
59.01	45	4531	2.74	2.74	0.17	2.76
59.02	60	4559	7.84	7.83	0.16	7.88
60.01	20	4371	3.06	2.96	0.37	3.09
61.01	10	4354	10.37	10.21	0.74	10.35
61.02	20	4371	16.94	16.48	2.43	16.83
61.03	20	4371	19.00	18.52	2.44	18.87
61.04	60	4405	23.91	23.75	1.86	23.84
62.01	45	4531	3.16	3.16	0.25	3.18
62.02	10	4361	5.60	5.51	0.19	5.69
63.01	45	4531	3.36	3.38	0.15	3.37
63.02	45	4528	7.50	7.49	0.34	7.51
64.01	20	4367	4.28	4.16	0.59	4.33
65.01	45	4528	3.21	3.22	0.16	3.25
66.01	45	4531	2.00	2.02	0.09	2.01
66.02	45	4496	2.84	2.85	0.11	2.84
67.01	20	4367	1.86	1.84	0.26	1.88
68.01	60	4558	5.85	5.84	0.31	5.87
68.02	60	4558	10.21	10.23	0.35	10.19
69.01	45	4496	4.62	4.64	0.29	4.62
70.01	20	4359	8.79	8.30	1.51	9.14
71.01	120	4499	3.81	3.78	0.23	3.82
72.01	10	4357	4.52	4.40	0.38	4.44
73.01	60	4558	3.52	3.49	0.20	3.52
74.01	10	4355	0.97	0.94	0.07	0.96
75.01	10	4354	0.00	0.00	0.00	0.00
76.01	20	4359	2.12	2.03	0.38	2.18
77.01	10	4357	1.69	1.65	0.15	1.67
78.01	90	4588	3.81	3.84	0.17	3.80
79.01	20	4371	1.70	1.66	0.25	1.70
80.01	10	4357	7.12	6.92	0.58	6.97
80.02	20	4399	15.56	15.32	2.09	15.93
80.03	20	4399	15.23	15.29	1.58	15.58
80.04	20	4359	0.91	0.90	0.15	0.93
80.05	20	4433	28.42	27.91	1.26	28.76

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
81.01	10	4361	5.86	5.71	0.45	6.13
81.02	20	4404	6.13	5.75	0.97	6.30
81.03	20	4404	14.14	13.67	1.35	14.09
82.01	10	4354	9.70	9.57	0.68	9.70
83.01	10	4357	3.46	3.37	0.28	3.39
83.02	20	4399	7.17	7.02	0.64	7.20
83.03	20	4404	15.29	14.92	1.45	15.22
84.01	180	4648	2.48	2.48	0.15	2.48
85.01	10	4355	11.55	11.18	0.88	11.37
85.02	10	4355	9.30	8.95	0.87	9.07
86.01	10	4363	3.56	3.59	0.29	3.57
87.01	10	4357	6.63	6.44	0.54	6.47
88.01	10	4357	3.47	3.38	0.28	3.39
89.01	20	4371	2.66	2.59	0.45	2.65
90.01	120	4499	2.56	2.56	0.11	2.59
91.01	10	4365	2.07	2.09	0.17	2.08
92.01	10	4354	1.78	1.78	0.13	1.81
93.01	10	4355	1.34	1.31	0.09	1.35
94.01	10	4361	2.01	2.01	0.16	2.04
94.02	10	4365	4.41	4.41	0.30	4.44
95.01	10	4355	0.14	0.14	0.01	0.14
96.01	45	4531	2.35	2.37	0.10	2.34
97.01	20	4371	0.41	0.41	0.07	0.42
98.01	10	4361	3.11	3.14	0.25	3.11
99.01	10	4354	2.28	2.28	0.18	2.30
100.01	20	4371	4.73	4.66	0.70	4.77
100.02	25	4462	5.98	5.99	0.49	6.02
101.01	10	4365	2.33	2.35	0.17	2.32
101.02	10	4365	3.29	3.29	0.08	3.30
102.01	10	4365	1.56	1.56	0.12	1.56
103.01	20	4433	1.04	1.02	0.08	1.04
104.01	20	4371	0.44	0.43	0.06	0.44
_junc_10	60	4559	64.03	63.66	1.33	64.38
_junc_100	10	4357	4.52	4.40	0.38	4.44
_junc_102	60	4463	192.01	190.65	5.51	192.95
_junc_103	60	4463	192.01	190.65	5.51	192.95
_junc_11	60	4405	21.96	21.81	1.85	21.90
_junc_12	60	4559	72.77	72.44	1.42	72.79
_junc_13	60	4558	12.77	12.54	0.80	12.55
_junc_14	60	4360	62.80	62.48	2.62	63.18
_junc_15	60	4463	23.87	23.53	1.08	24.29
_junc_16	20	4404	7.89	7.52	0.93	8.11
_junc_17	120	4617	374.30	376.84	21.66	371.64
_junc_18	10	4354	4.29	4.30	0.34	4.36

Subcatch ID	ARR2016 Discharge Statistics for <u>All</u> Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_19	180	4612	193.46	195.56	14.11	190.38
_junc_2	60	4360	36.43	36.35	1.18	36.55
_junc_20	120	4618	179.82	177.49	5.75	181.45
_junc_21	120	4617	373.15	375.72	21.67	370.57
_junc_22	60	4463	71.13	70.44	2.53	70.99
_junc_23	120	4617	367.95	370.69	21.90	366.14
_junc_24	90	4430	131.74	131.54	3.89	131.69
_junc_25	120	4617	369.78	372.47	21.85	367.76
_junc_26	60	4463	194.08	192.72	5.47	194.87
_junc_29	120	4617	371.60	374.23	21.78	369.29
_junc_3	45	4531	10.61	10.67	0.60	10.55
_junc_30	120	4617	373.04	375.61	21.70	370.50
_junc_31	120	4617	372.34	374.96	21.78	369.98
_junc_32	90	4501	140.11	140.30	4.07	139.95
_junc_33	90	4465	128.39	127.89	3.90	128.84
_junc_34	45	4528	6.57	6.58	0.31	6.63
_junc_35	20	4433	27.96	27.46	1.26	28.29
_junc_36	60	4463	193.33	191.96	5.49	194.17
_junc_37	20	4404	15.21	14.83	1.45	15.14
_junc_38	20	4404	13.71	13.31	1.37	13.74
_junc_39	90	4562	61.25	61.65	2.65	61.47
_junc_4	45	4528	16.99	17.04	0.76	17.27
_junc_40	90	4465	56.07	56.65	2.48	56.39
_junc_41	60	4463	47.57	47.12	2.48	48.09
_junc_42	60	4559	45.36	45.18	2.50	46.22
_junc_43	60	4559	49.90	49.32	2.39	50.34
_junc_44	45	4496	11.82	11.89	0.56	11.77
_junc_45	60	4559	18.14	17.79	1.00	18.65
_junc_46	45	4531	7.43	7.47	0.31	7.40
_junc_47	60	4559	39.69	39.11	2.37	40.66
_junc_48	45	4528	19.86	19.71	0.95	20.06
_junc_49	90	4430	30.63	30.40	0.55	30.60
_junc_5	60	4559	50.66	50.36	1.17	50.78
_junc_50	60	4558	9.21	9.18	0.49	9.21
_junc_51	45	4528	15.18	15.14	0.99	15.31
_junc_52	60	4463	153.90	152.44	5.12	155.18
_junc_53	90	4585	20.09	20.13	0.85	20.01
_junc_54	90	4501	35.17	34.76	1.11	34.79
_junc_55	90	4532	26.17	25.97	0.73	26.27
_junc_56	60	4463	190.85	189.57	5.60	191.97
_junc_57	60	4463	152.58	151.18	5.14	154.01
_junc_58	60	4463	100.46	99.65	2.83	100.04
_junc_59	60	4557	62.27	61.57	2.17	62.30
_junc_6	45	4534	20.16	20.24	0.87	20.55

Subcatch ID	ARR2016 Discharge Statistics for All Durations and Temp. Patterns					
	Critical Duration (mins)	Adopted Temp. Pattern	Discharge (m^3/s)			
			Average	Median	Standard Dev	Adopted
_junc_60	60	4559	50.67	49.96	2.30	51.49
_junc_61	60	4556	75.78	75.71	1.60	76.28
_junc_62	60	4556	52.62	52.40	2.36	52.77
_junc_63	60	4559	47.74	47.38	2.49	47.71
_junc_64	60	4405	54.72	54.28	2.28	54.85
_junc_65	60	4405	45.80	45.70	2.54	45.86
_junc_66	60	4559	46.14	45.46	2.40	47.18
_junc_67	60	4559	35.53	35.47	2.57	36.22
_junc_68	60	4405	40.01	40.15	2.66	39.80
_junc_69	60	4558	14.59	14.71	0.81	14.59
_junc_7	60	4556	53.81	53.60	1.20	53.63
_junc_70	60	4558	24.96	24.96	1.31	25.03
_junc_71	60	4557	16.17	16.22	0.58	16.15
_junc_72	45	4496	9.93	9.98	0.64	9.91
_junc_73	60	4558	19.88	19.58	1.36	19.61
_junc_74	45	4525	18.89	18.91	0.46	18.86
_junc_8	60	4559	61.20	60.76	1.33	61.77
_junc_9	60	4559	32.42	31.83	1.50	32.59

ARR2016 Box Plots

APPENDIX C

FLOOD DAMAGE CALCULATIONS

Catchment Simulation Solutions
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C1 FLOOD DAMAGE COST CALCULATIONS

1.1 Introduction

In an effort to quantify the financial impact that flooding has on residents and business owners within the Wallarah Creek catchment, the number of properties subject to over floor flooding and the flood damage cost that would likely be incurred during the full range of modelled design floods was calculated. The approach that was adopted to estimate the flood damage costs is presented below.

1.2 Property Database

A property database was developed as part of the study to enable 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 lowset);
- Residential building material type (e.g., brick, weatherboard); and,
- Commercial or industrial property contents value (normal or high value).

In general, the information listed above was populated using a “drive by” survey. Further information regarding how the floor level information was collected using the drive by survey technique is provided below.

1.3 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 above ground (calculated in step 1) to the ground elevation (calculated in step 2).

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.

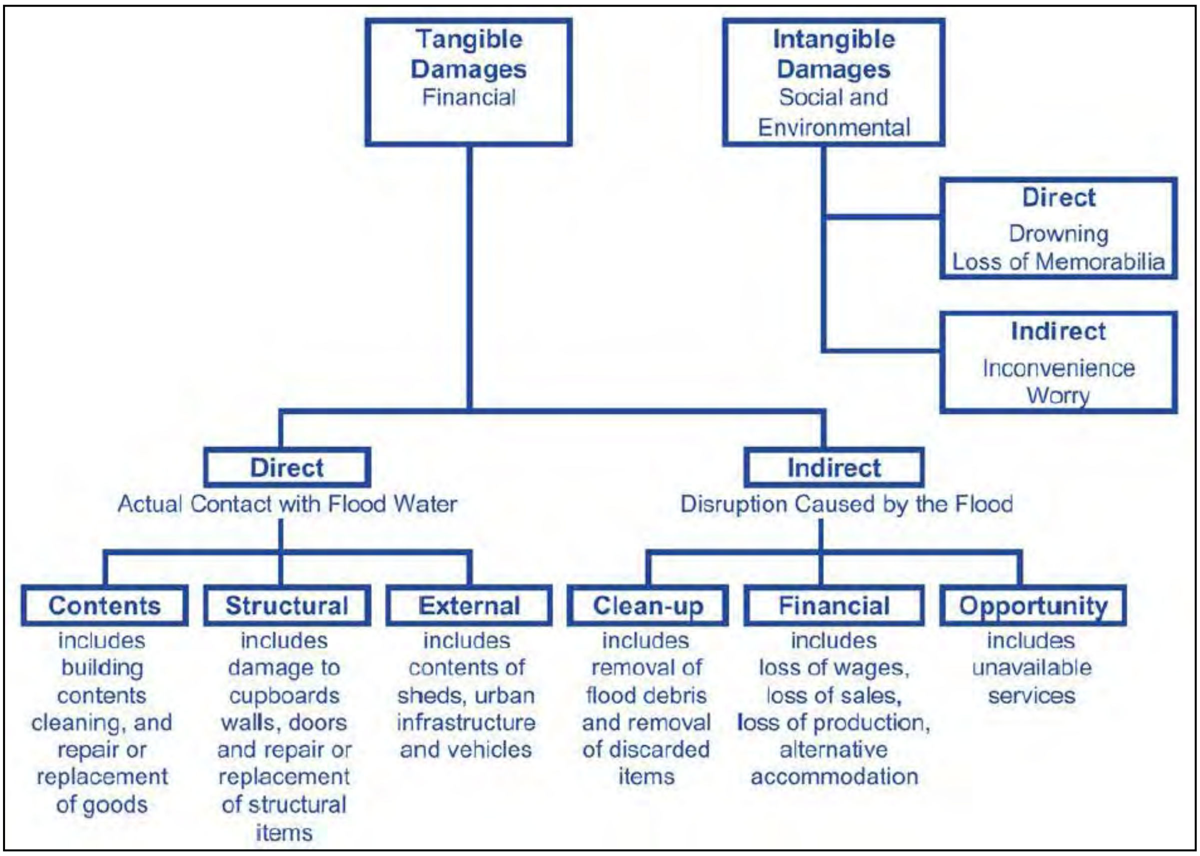


Plate 1 Flood Damage Categories (NSW Government, 2005)

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 tangible 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 Wallarah Creek 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 urban sections of the Wallarah Creek catchment. 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. To confirm the suitability of this value, 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 0.72 metres. Accordingly, the 'single-storey high set' damage curves were adjusted so that damage commenced when the flood level was 0.7 metres below the floor level.

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 building floor area of 170 m^2 was adopted as being representative 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).

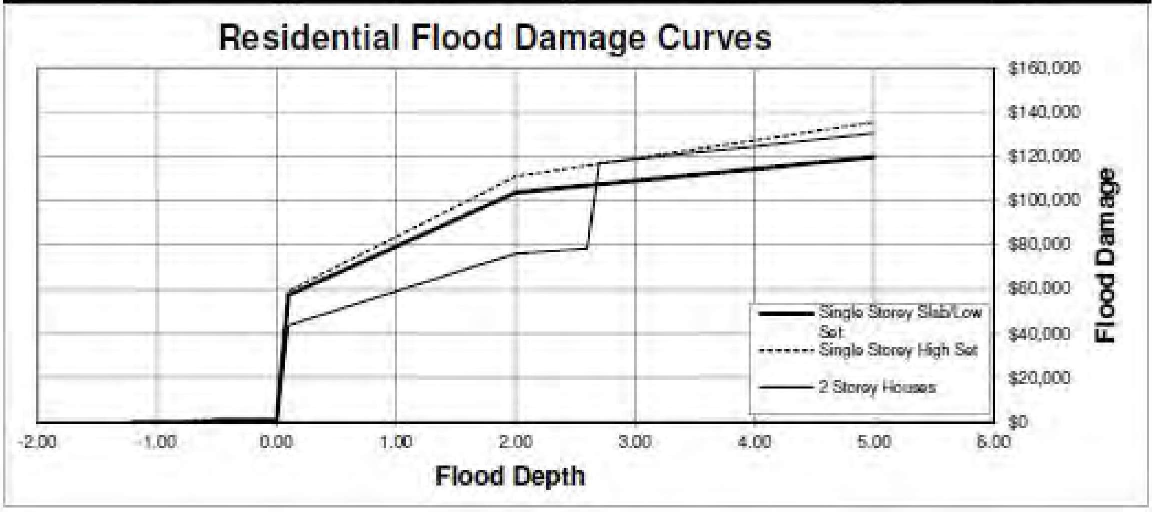
SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT							
Version 3.00 October 2007							
PROJECT		**DETAILS**		**DATE**		**JOB No.**	
Wallarah FPRMS		Residential Damages (190m2)		6/03/2018		xx	
BUILDINGS							
Regional Cost Variation Factor	1.02	From Rawlinsons					
Post late 2001 adjustments	1.79	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 Houses Affected		Factor	Regional Town 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	170	m^2	240 m^2 is Base				
Building Size Adjustment	0.7						
Total Building Adjustment Factor	**1.10**						
CONTENTS							
Average Contents Relevant to Site	$ 42,500		Base for 240 m^2 house	$ 60,000			
Post late 2001 adjustments	1.79	From above					
Contents Damage Repair Limitation Factor	0.75	due to no insurance	short duration			long duration	
Sub-Total Adjustment Factor	1.34	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	**1.34**	AFD = Above Floor Depth					
Total Contents Adjustment Factor AFD > TTBH	**1.34**						
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	1.79	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			

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.

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	$0	$0	$0
-1.10	$0	$0	$0
-1.00	$0	$0	$0
-0.90	$0	$0	$0
-0.80	$0	$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	$59,268	$57,389	$43,770
0.20	$61,989	$59,826	$45,476
0.30	$64,710	$62,263	$47,182
0.40	$67,431	$64,701	$48,888
0.50	$70,153	$67,138	$50,595
0.60	$72,874	$69,575	$52,301
0.70	$75,595	$72,013	$54,007
0.80	$78,316	$74,450	$55,713
0.90	$81,037	$76,887	$57,419
1.00	$83,759	$79,325	$59,125
1.10	$86,480	$81,762	$60,831
1.20	$89,201	$84,199	$62,537
1.30	$91,922	$86,637	$64,244
1.40	$94,644	$89,074	$65,950
1.50	$97,365	$91,511	$67,656
1.60	$100,086	$93,949	$69,362
1.70	$102,807	$96,386	$71,068
1.80	$105,529	$98,823	$72,774
1.90	$108,250	$101,260	$74,480
2.00	$110,971	$103,698	$76,186
2.10	$111,790	$104,233	$76,561
2.20	$112,610	$104,769	$76,936
2.30	$113,429	$105,304	$77,311
2.40	$114,249	$105,840	$77,686
2.50	$115,068	$106,375	$78,060
2.60	$115,887	$106,910	$78,435
2.70	$116,707	$107,446	$116,991
2.80	$117,526	$107,981	$117,580
2.90	$118,345	$108,517	$118,169
3.00	$119,165	$109,052	$118,758
3.10	$119,984	$109,588	$119,347
3.20	$120,803	$110,123	$119,936
3.30	$121,623	$110,658	$120,525
3.50	$123,262	$111,729	$121,703
4.00	$127,358	$114,407	$124,648
4.50	$131,455	$117,084	$127,593
5.00	$135,552	$119,761	$130,538



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).

Due to close proximity of the Wallarah Creek catchment 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 2018 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the catchment.

In order to apply the damage curves, it was necessary to categorise each commercial/industrial property according to the value of the contents (i.e., normal or 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.

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.

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.

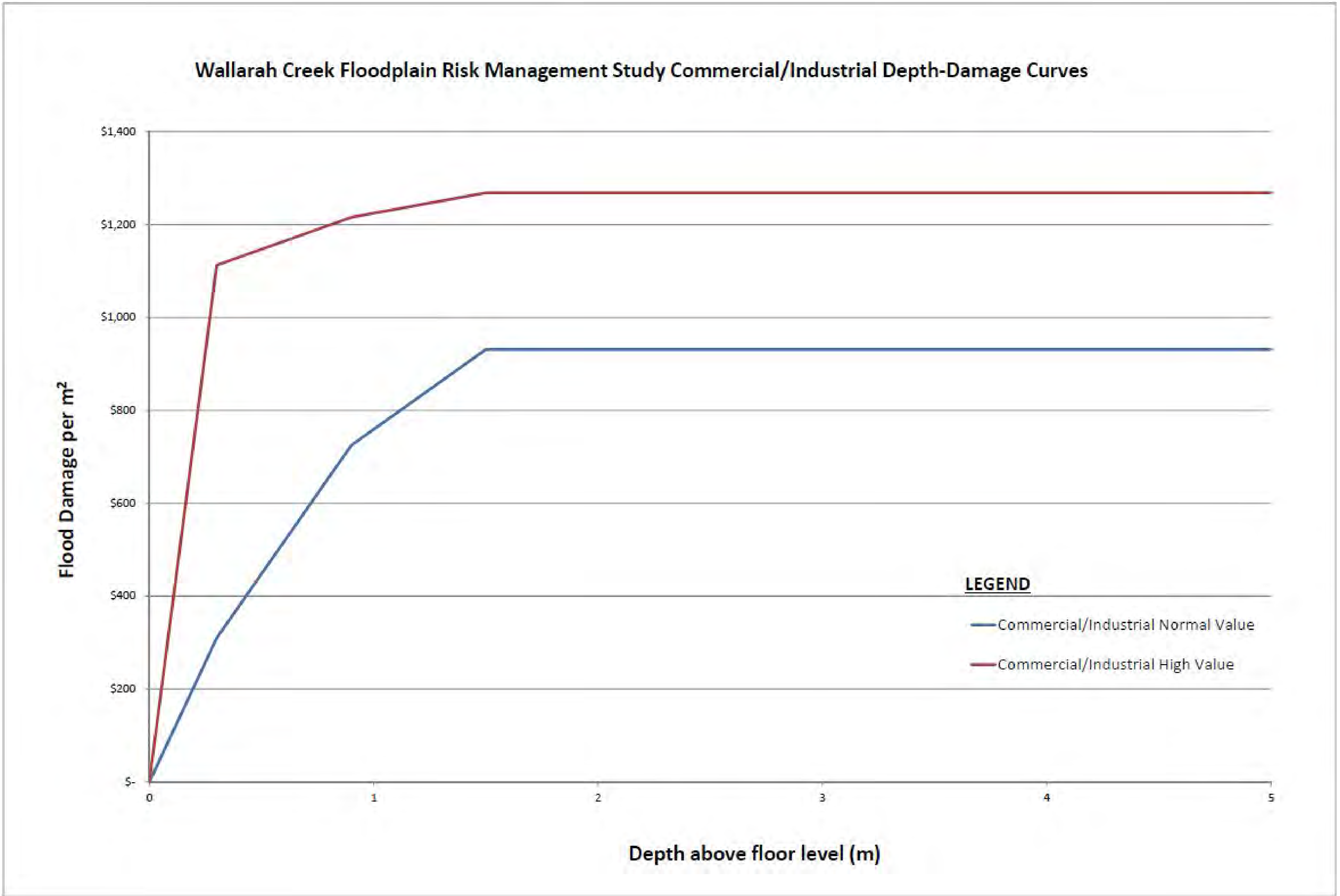
1.4.4 Potential versus Actual Damages

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 Wallarah Creek 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 results 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.



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

The flood damage estimates for each design flood are summarised in **Table 3**. The number of buildings that are predicted to incur damage (including those inundated above floor level) are summarised in **Table 4** and **Table 5**.

Table 3 Summary of Flood Damages for Existing Conditions

Flood Damage Component	Flood Damages (2018 dollars, rounded to nearest $1,000)			
	20% AEP	5% AEP	1% AEP	PMF
Residential	$88,000	$792,000	$1,981,000	$38,281,000
Commercial.	$0	$15,000	$21,000	$687,000
Industrial	$0	$0	$0	$3,000
Infrastructure	$13,000	$121,000	$300,000	$5,845,000
TOTAL	$101,000	$928,000	$2,302,000	$44,816,000

Table 4 Number of Properties Predicted to Experience Flood Damage

Flood Event	Number of Properties Damaged		
	Residential	Commercial/ Industrial	Total Number
20% AEP	17	0	17
5% AEP	78	1	79
1% AEP	122	1	123
PMF	602	12	614

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

Flood Event	Number of Buildings with Above Flood Inundation		
	Residential	Commercial/ Industrial	Total Number
20% AEP	2	0	2
5% AEP	15	1	16
1% AEP	45	1	46
PMF	527	12	539

The results presented in **Table 3** shows that a 1% AEP flood has the potential to cause over $2 million in damages. In general, damage to residential property is the primary contributor to the total damage bill for each event.

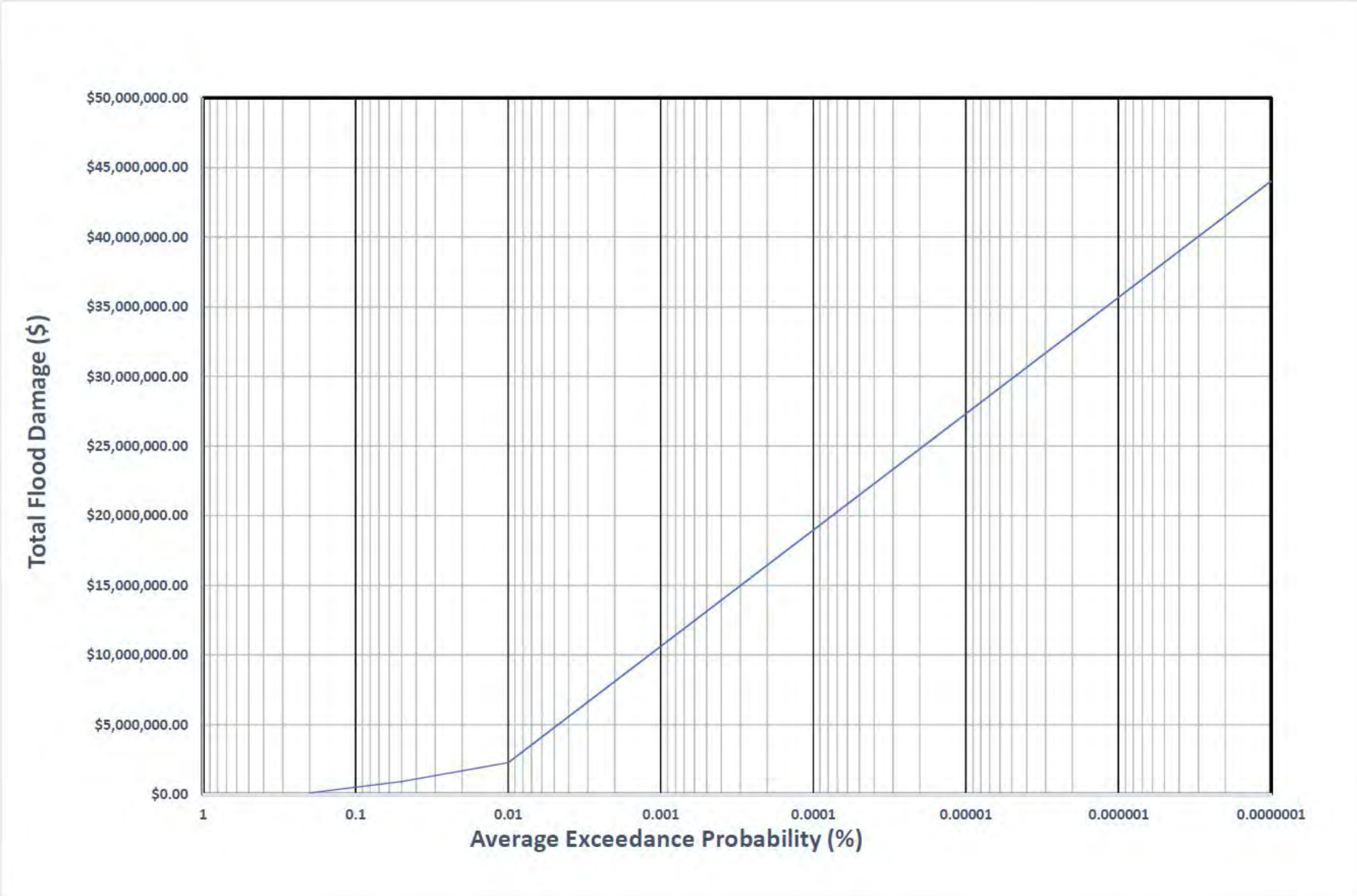
1.5.2 Average Annual Damages

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 Wallarah Creek catchment was determined to be $371,000.

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 estimates only and do not take into account future fluctuations in property and asset values. Therefore, the damage estimates should only be considered an approximation.


Total Flood Damage ($)
$50,000,000.00
$45,000,000.00
$40,000,000.00
$35,000,000.00
$30,000,000.00
$25,000,000.00
$20,000,000.00
$15,000,000.00
$10,000,000.00
$5,000,000.00
$0.00
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0000001
Average Exceedance Probability (%)

REFERENCES

- Natural Resources and Mines (2002). *Guidance on the Assessment of Tangible Flood Damages*.
- Catchment Simulation Solutions (2018). *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

RAFTS Model Outputs for Future Catchment Conditions

Future Development Results for the 20% AEP Event

	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
1.01	2.83	4.37	54.4%
1.02	4.06	7.09	74.6%
1.03	6.57	11.50	75.0%
1.04	7.57	13.30	75.7%
1.05	17.10	29.00	69.6%
1.06	17.70	29.70	67.8%
1.07	19.40	30.80	58.8%
1.08	22.60	32.90	45.6%
1.09	26.30	34.90	32.7%
1.1	27.50	35.60	29.5%
1.11	28.80	36.50	26.7%
1.12	59.20	70.00	18.2%
1.13	62.10	72.30	16.4%
1.14	65.00	75.40	16.0%
1.15	67.30	77.70	15.5%
1.16	68.20	78.50	15.1%
1.17	88.10	101.00	14.6%
1.18	94.70	109.00	15.1%
1.19	183.00	234.00	27.9%
1.2	184.00	235.00	27.7%
1.21	185.00	235.00	27.0%
1.22	185.00	236.00	27.6%
1.23	186.00	236.00	26.9%
1.24	188.00	237.00	26.1%
1.25	188.00	237.00	26.1%
1.26	189.00	237.00	25.4%
2.01	1.53	3.02	97.4%
2.02	3.17	6.24	96.8%
2.03	5.01	9.16	82.8%
2.04	7.20	12.40	72.2%
3.01	0.94	1.92	104.3%
4.01	1.12	2.30	105.4%
5.01	2.16	3.10	43.5%
6.01	1.01	2.14	111.9%
7.01	1.68	3.08	83.3%
8.01	1.47	2.06	40.1%
8.02	3.82	5.13	34.3%
8.03	5.62	10.40	85.1%
8.04	9.86	24.10	144.4%
8.05	11.80	29.90	153.4%
8.06	14.50	33.10	128.3%
8.07	17.70	38.10	115.3%

Future Development Results for the 20% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
8.08	19.30	39.90	106.7%
8.09	19.50	40.10	105.6%
8.1	84.50	133.00	57.4%
8.11	84.80	133.00	56.8%
8.12	85.30	134.00	57.1%
8.13	86.10	134.00	55.6%
8.14	86.40	135.00	56.3%
8.15	86.50	135.00	56.1%
8.16	86.60	135.00	55.9%
8.17	86.70	135.00	55.7%
8.18	86.80	135.00	55.5%
8.19	88.10	136.00	54.4%
8.2	88.50	136.00	53.7%
8.21	88.80	137.00	54.3%
9.01	4.14	4.18	1.0%
9.02	7.17	8.54	19.1%
9.03	13.90	19.40	39.6%
9.04	15.50	21.50	38.7%
9.05	17.70	24.10	36.2%
9.06	18.40	24.80	34.8%
9.07	21.40	27.90	30.4%
9.08	23.40	30.10	28.6%
9.09	27.50	34.90	26.9%
9.1	33.10	41.60	25.7%
9.11	43.20	53.20	23.1%
9.12	64.70	97.60	50.9%
9.13	65.20	98.20	50.6%
10.01	2.66	5.00	88.0%
10.02	4.50	7.73	71.8%
10.03	5.83	9.57	64.2%
11.01	1.05	1.92	82.9%
12.01	1.42	1.80	26.8%
12.02	2.42	3.07	26.9%
12.03	3.56	4.83	35.7%
12.04	5.25	7.50	42.9%
12.05	11.40	14.20	24.6%
12.06	27.20	34.00	25.0%
12.07	30.80	37.60	22.1%
13.01	0.81	1.04	27.9%
13.02	3.07	3.28	6.8%
13.03	3.97	4.35	9.6%
14.01	1.59	1.89	18.9%

Future Development Results for the 20% AEP Event

	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
14.02	1.90	2.22	16.8%
14.03	3.99	4.80	20.3%
14.04	6.09	7.32	20.2%
14.05	8.40	10.30	22.6%
14.06	10.30	12.70	23.3%
14.07	13.90	17.30	24.5%
15.01	1.36	1.66	22.1%
15.02	2.18	2.61	19.7%
16.01	1.38	1.55	12.3%
17.01	0.56	0.72	30.0%
17.02	2.13	2.43	14.1%
18.01	3.39	3.95	16.5%
18.02	2.20	2.63	19.5%
19.01	0.63	0.82	30.4%
19.02	1.19	1.53	28.6%
20.01	1.33	2.16	62.4%
20.02	4.80	16.90	252.1%
20.03	7.13	25.10	252.0%
20.04	11.50	33.40	190.4%
20.05	20.30	46.70	130.0%
20.06	20.80	47.00	126.0%
20.07	21.40	47.80	123.4%
21.01	0.91	1.90	109.0%
21.02	1.33	2.60	95.5%
22.01	1.01	1.49	47.5%
23.01	1.59	2.00	25.8%
23.02	3.25	12.20	275.4%
24.01	0.25	0.31	24.1%
24.02	3.22	12.60	291.3%
24.03	4.74	14.40	203.8%
24.04	7.33	19.30	163.3%
25.01	1.15	1.71	48.7%
25.02	2.57	4.95	92.6%
26.01	1.37	5.28	285.4%
27.01	0.14	0.15	12.4%
27.02	2.32	2.72	17.2%
28.01	1.93	6.98	261.7%
29.01	2.03	3.13	54.2%
30.01	1.26	2.17	72.2%
30.02	2.92	6.91	136.6%
31.01	4.35	5.01	15.2%
31.02	3.31	4.08	23.3%

Future Development Results for the 20% AEP Event

	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
31.03	4.42	5.57	26.0%
32.01	2.68	9.65	260.1%
33.01	1.09	1.85	69.7%
34.01	3.77	15.10	300.5%
34.02	7.44	21.90	194.4%
34.03	9.59	24.10	151.3%
35.01	2.35	4.12	75.3%
35.02	3.51	6.03	71.8%
36.01	1.13	1.23	8.8%
36.02	4.47	5.27	17.9%
36.03	4.53	5.37	18.5%
37.01	1.80	3.04	68.9%
37.02	5.76	8.54	48.3%
38.01	0.95	1.58	66.7%
39.01	2.08	3.44	65.4%
39.02	2.93	4.67	59.4%
40.01	1.38	1.65	19.6%
40.02	3.23	3.69	14.2%
40.03	5.08	5.79	14.0%
40.04	5.18	5.90	13.9%
40.05	6.45	7.29	13.0%
40.06	15.30	17.70	15.7%
40.07	21.50	24.30	13.0%
40.08	21.80	24.70	13.3%
40.09	22.80	25.80	13.2%
40.1	26.30	29.70	12.9%
40.11	28.40	31.60	11.3%
40.12	33.00	35.90	8.8%
41.01	1.09	1.80	65.1%
42.01	1.99	3.29	65.3%
43.01	2.54	2.85	12.2%
43.02	2.54	3.42	34.6%
43.03	4.17	5.94	42.4%
44.01	2.64	8.17	209.5%
45.01	1.76	2.70	53.4%
46.01	1.36	2.31	69.9%
47.01	2.33	2.63	12.9%
47.02	3.34	3.92	17.4%
47.03	5.04	6.26	24.2%
47.04	9.03	11.60	28.5%
47.05	9.28	11.80	27.2%
48.01	1.79	2.85	59.2%

Future Development Results for the 20% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
48.02	2.89	4.49	55.4%
49.01	1.52	2.88	89.5%
49.02	2.78	4.65	67.3%
50.01	0.21	0.35	68.4%
50.02	1.91	2.44	27.7%
51.01	0.34	0.45	33.1%
52.01	0.60	0.94	57.7%
53.01	1.02	2.82	176.5%
54.01	0.83	1.09	32.0%
54.02	4.77	5.62	17.8%
54.03	6.19	7.20	16.3%
55.01	0.89	1.13	27.7%
56.01	1.64	1.90	15.9%
56.02	2.32	2.82	21.6%
57.01	1.09	1.26	15.6%
58.01	1.21	1.71	41.3%
59.01	0.97	1.13	17.1%
59.02	3.13	3.60	15.0%
60.01	1.20	1.59	32.5%
61.01	4.76	5.64	18.5%
61.02	7.54	10.40	37.9%
61.03	8.66	12.10	39.7%
61.04	10.10	15.10	49.5%
62.01	1.12	1.98	76.8%
62.02	2.52	3.33	32.1%
63.01	1.20	2.08	73.3%
63.02	2.65	4.62	74.3%
64.01	1.81	2.49	37.6%
65.01	1.13	2.03	79.6%
66.01	0.70	0.85	20.6%
66.02	1.01	1.22	20.8%
67.01	0.78	0.96	24.1%
68.01	2.25	3.71	64.9%
68.02	4.09	6.15	50.4%
69.01	1.66	2.75	65.7%
70.01	4.13	4.76	15.3%
71.01	1.66	2.86	72.3%
72.01	2.09	2.27	8.6%
73.01	1.33	1.73	30.1%
74.01	0.46	0.49	7.6%
75.01	0.00	0.00	5.2%
76.01	0.98	1.13	15.4%

Future Development Results for the 20% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
77.01	0.78	0.86	10.5%
78.01	1.62	1.67	3.1%
79.01	0.72	0.88	22.6%
80.01	3.33	3.85	15.6%
80.02	7.26	8.29	14.2%
80.03	7.61	8.67	13.9%
80.04	0.41	0.50	22.1%
80.05	11.50	13.80	20.0%
81.01	2.73	3.16	15.8%
81.02	2.82	3.32	17.7%
81.03	6.32	7.40	17.1%
82.01	4.45	5.11	14.8%
83.01	1.60	1.83	14.4%
83.02	3.23	3.72	15.2%
83.03	5.51	6.93	25.8%
84.01	1.12	1.65	47.3%
85.01	5.36	6.11	14.0%
85.02	3.32	4.09	23.2%
86.01	1.64	1.82	11.0%
87.01	3.06	3.36	9.8%
88.01	1.60	1.79	11.9%
89.01	1.17	1.42	21.4%
90.01	1.13	1.92	69.9%
91.01	0.95	1.21	27.6%
92.01	0.84	0.95	13.2%
93.01	0.63	0.72	14.3%
94.01	0.89	1.01	13.0%
94.02	1.95	2.16	10.8%
95.01	0.06	0.07	5.2%
96.01	2.22	2.25	1.4%
97.01	0.18	0.21	18.3%
98.01	1.44	1.58	9.7%
99.01	1.01	1.11	9.9%
100.01	2.04	2.52	23.5%
100.02	2.60	3.19	22.7%
101.01	1.06	1.21	14.2%
101.02	1.51	1.70	12.6%
102.01	0.72	0.81	13.0%
103.01	0.35	0.49	41.3%
104.01	0.18	0.25	37.6%
_junc_10	27.20	30.50	12.1%
_junc_100	2.09	2.27	8.6%

Future Development Results for the 20% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
_junc_102	86.50	135.00	56.1%
_junc_103	86.60	135.00	55.9%
_junc_11	9.49	14.00	47.5%
_junc_12	31.80	34.80	9.4%
_junc_13	4.74	6.78	43.0%
_junc_14	24.70	31.40	27.1%
_junc_15	9.18	11.50	25.3%
_junc_16	3.34	4.39	31.4%
_junc_17	189.00	237.00	25.4%
_junc_18	1.90	2.12	11.6%
_junc_19	94.60	109.00	15.2%
_junc_2	15.00	17.40	16.0%
_junc_20	88.10	101.00	14.6%
_junc_21	188.00	237.00	26.1%
_junc_22	29.60	36.40	23.0%
_junc_23	183.00	234.00	27.9%
_junc_24	61.00	71.20	16.7%
_junc_25	184.00	235.00	27.7%
_junc_26	88.80	137.00	54.3%
_junc_29	185.00	236.00	27.6%
_junc_3	3.84	4.60	19.8%
_junc_30	188.00	237.00	26.1%
_junc_31	186.00	236.00	26.9%
_junc_32	67.70	78.10	15.4%
_junc_33	58.80	69.70	18.5%
_junc_34	2.29	4.11	79.5%
_junc_35	11.20	13.40	19.6%
_junc_36	87.80	136.00	54.9%
_junc_37	5.43	6.85	26.2%
_junc_38	6.08	7.06	16.1%
_junc_39	28.00	36.10	28.9%
_junc_4	6.08	7.30	20.1%
_junc_40	24.70	34.40	39.3%
_junc_41	18.70	30.30	62.0%
_junc_42	17.40	29.40	69.0%
_junc_43	20.50	31.80	55.1%
_junc_44	4.18	7.90	89.0%
_junc_45	6.68	11.50	72.2%
_junc_46	2.62	5.31	102.7%
_junc_47	14.60	25.70	76.0%
_junc_48	7.31	12.80	75.1%
_junc_49	13.50	31.90	136.3%

Future Development Results for the 20% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
_junc_5	21.10	23.90	13.3%
_junc_50	3.70	6.29	70.0%
_junc_51	5.64	10.00	77.3%
_junc_52	65.20	98.20	50.6%
_junc_53	8.47	22.50	165.6%
_junc_54	15.80	35.40	124.1%
_junc_55	11.20	29.10	159.8%
_junc_56	84.30	133.00	57.8%
_junc_57	64.00	96.70	51.1%
_junc_58	42.40	52.40	23.6%
_junc_59	26.10	33.30	27.6%
_junc_6	7.20	8.73	21.3%
_junc_60	20.70	46.90	126.6%
_junc_61	32.30	40.70	26.0%
_junc_62	20.90	27.40	31.1%
_junc_63	18.40	24.80	34.8%
_junc_64	22.10	28.60	29.4%
_junc_65	17.30	23.70	37.0%
_junc_66	18.20	46.40	154.9%
_junc_67	12.80	17.80	39.1%
_junc_68	14.60	20.40	39.7%
_junc_69	5.36	8.90	66.0%
_junc_7	22.70	25.70	13.2%
_junc_70	9.63	31.60	228.1%
_junc_71	6.48	23.70	265.7%
_junc_72	3.53	5.74	62.6%
_junc_73	7.19	20.90	190.7%
_junc_74	7.08	8.94	26.3%
_junc_8	25.80	29.20	13.2%
_junc_9	12.40	15.40	24.2%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
1.01	5.54	7.79	40.6%
1.02	7.70	12.80	66.2%
1.03	13.10	21.00	60.3%
1.04	15.10	24.10	59.6%
1.05	34.10	53.30	56.3%
1.06	35.40	54.50	54.0%
1.07	38.60	56.70	46.9%
1.08	44.10	60.50	37.2%
1.09	50.10	64.30	28.3%
1.1	52.10	65.70	26.1%
1.11	54.40	67.20	23.5%
1.12	112.00	128.00	14.3%
1.13	117.00	132.00	12.8%
1.14	123.00	138.00	12.2%
1.15	128.00	142.00	10.9%
1.16	130.00	144.00	10.8%
1.17	167.00	182.00	9.0%
1.18	180.00	196.00	8.9%
1.19	340.00	416.00	22.4%
1.2	342.00	418.00	22.2%
1.21	345.00	419.00	21.4%
1.22	346.00	420.00	21.4%
1.23	347.00	420.00	21.0%
1.24	352.00	421.00	19.6%
1.25	353.00	422.00	19.5%
1.26	355.00	423.00	19.2%
2.01	3.09	5.53	79.0%
2.02	6.58	11.40	73.3%
2.03	10.30	17.10	66.0%
2.04	14.50	23.00	58.6%
3.01	1.97	3.54	79.7%
4.01	2.35	4.23	80.0%
5.01	4.61	5.62	21.9%
6.01	2.12	3.93	85.4%
7.01	3.30	5.63	70.6%
8.01	3.04	3.79	24.7%
8.02	7.41	8.97	21.1%
8.03	10.80	16.90	56.5%
8.04	18.80	39.50	110.1%
8.05	22.00	49.50	125.0%
8.06	26.70	55.20	106.7%
8.07	31.90	64.70	102.8%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
8.08	34.60	68.00	96.5%
8.09	35.00	68.40	95.4%
8.1	156.00	233.00	49.4%
8.11	157.00	233.00	48.4%
8.12	158.00	234.00	48.1%
8.13	159.00	235.00	47.8%
8.14	160.00	236.00	47.5%
8.15	160.00	236.00	47.5%
8.16	160.00	236.00	47.5%
8.17	161.00	236.00	46.6%
8.18	161.00	236.00	46.6%
8.19	163.00	239.00	46.6%
8.2	164.00	239.00	45.7%
8.21	165.00	240.00	45.5%
9.01	7.56	7.32	-3.2%
9.02	15.70	18.20	15.9%
9.03	29.30	37.80	29.0%
9.04	32.80	41.30	25.9%
9.05	37.50	45.80	22.1%
9.06	38.80	47.00	21.1%
9.07	44.30	52.40	18.3%
9.08	48.20	56.20	16.6%
9.09	55.20	62.70	13.6%
9.1	64.40	76.50	18.8%
9.11	81.50	97.40	19.5%
9.12	122.00	172.00	41.0%
9.13	123.00	173.00	40.7%
10.01	4.97	8.28	66.6%
10.02	8.83	14.00	58.6%
10.03	11.90	17.40	46.2%
11.01	2.12	3.52	66.0%
12.01	2.76	3.48	26.1%
12.02	4.75	5.97	25.7%
12.03	7.04	9.33	32.5%
12.04	10.60	14.10	33.0%
12.05	21.60	27.00	25.0%
12.06	53.30	64.70	21.4%
12.07	59.60	70.90	19.0%
13.01	1.59	1.93	21.4%
13.02	5.84	6.37	9.1%
13.03	7.50	8.35	11.3%
14.01	3.22	3.58	11.2%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
14.02	3.77	4.33	14.9%
14.03	8.20	9.10	11.0%
14.04	12.60	14.30	13.5%
14.05	17.10	20.10	17.5%
14.06	21.10	24.90	18.0%
14.07	28.40	33.10	16.5%
15.01	2.68	3.25	21.3%
15.02	4.38	5.16	17.8%
16.01	2.44	2.52	3.3%
17.01	1.15	1.26	9.6%
17.02	4.15	4.63	11.6%
18.01	6.08	6.58	8.2%
18.02	5.66	6.65	17.5%
19.01	1.34	1.51	12.7%
19.02	2.56	2.95	15.2%
20.01	2.64	3.99	51.1%
20.02	9.48	27.40	189.0%
20.03	14.20	40.90	188.0%
20.04	22.80	55.10	141.7%
20.05	39.80	78.20	96.5%
20.06	40.90	79.10	93.4%
20.07	42.20	80.50	90.8%
21.01	1.85	3.47	87.6%
21.02	2.67	4.71	76.4%
22.01	2.01	2.85	41.8%
23.01	3.17	3.51	10.7%
23.02	6.66	19.70	195.8%
24.01	0.46	0.54	16.9%
24.02	6.73	20.70	207.6%
24.03	9.40	23.70	152.1%
24.04	14.40	32.10	122.9%
25.01	2.32	3.05	31.5%
25.02	5.43	8.29	52.7%
26.01	2.84	8.58	202.1%
27.01	0.23	0.26	9.4%
27.02	4.62	5.10	10.4%
28.01	3.77	11.30	199.7%
29.01	4.13	5.78	40.0%
30.01	2.62	3.98	51.9%
30.02	5.68	11.50	102.5%
31.01	7.73	8.37	8.3%
31.02	7.16	8.02	12.0%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
31.03	9.54	10.80	13.2%
32.01	5.48	15.70	186.5%
33.01	2.18	3.42	56.9%
34.01	7.72	24.50	217.4%
34.02	15.20	36.30	138.8%
34.03	19.20	40.90	113.0%
35.01	4.92	7.51	52.6%
35.02	6.98	10.60	51.9%
36.01	2.16	2.36	9.3%
36.02	7.57	8.55	12.9%
36.03	7.72	8.71	12.8%
37.01	3.73	5.61	50.4%
37.02	11.60	16.10	38.8%
38.01	1.88	2.97	58.0%
39.01	3.97	6.29	58.4%
39.02	5.70	8.68	52.3%
40.01	2.84	3.14	10.6%
40.02	6.26	7.23	15.5%
40.03	9.81	11.40	16.2%
40.04	10.10	11.60	14.9%
40.05	12.60	14.00	11.1%
40.06	29.00	33.40	15.2%
40.07	40.50	46.30	14.3%
40.08	41.10	46.80	13.9%
40.09	43.00	48.80	13.5%
40.1	49.80	56.40	13.3%
40.11	53.50	60.40	12.9%
40.12	62.30	68.40	9.8%
41.01	2.25	3.34	48.4%
42.01	3.76	5.30	41.0%
43.01	4.41	4.69	6.3%
43.02	5.62	6.31	12.3%
43.03	9.16	11.20	22.3%
44.01	5.24	13.10	150.0%
45.01	3.43	5.00	45.8%
46.01	2.67	4.18	56.6%
47.01	4.48	5.20	16.1%
47.02	6.68	7.51	12.4%
47.03	10.20	12.00	17.6%
47.04	19.00	21.50	13.2%
47.05	19.40	22.00	13.4%
48.01	3.34	5.10	52.7%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
48.02	5.34	8.28	55.1%
49.01	2.93	5.26	79.5%
49.02	5.26	8.74	66.2%
50.01	0.40	0.64	59.7%
50.02	3.81	4.65	22.0%
51.01	0.74	0.84	13.3%
52.01	1.16	1.74	50.0%
53.01	2.24	4.58	104.5%
54.01	1.72	1.93	12.2%
54.02	9.66	10.40	7.7%
54.03	12.50	13.50	8.0%
55.01	1.92	2.19	14.1%
56.01	3.18	3.71	16.7%
56.02	4.59	5.43	18.3%
57.01	2.07	2.26	9.2%
58.01	2.43	3.14	29.2%
59.01	2.03	2.14	5.4%
59.02	6.12	7.07	15.5%
60.01	2.39	2.83	18.4%
61.01	8.52	9.36	9.9%
61.02	14.40	18.10	25.7%
61.03	17.10	21.80	27.5%
61.04	20.80	28.10	35.1%
62.01	2.32	3.52	51.7%
62.02	4.46	5.64	26.5%
63.01	2.50	3.86	54.4%
63.02	5.53	8.65	56.4%
64.01	3.42	4.20	22.8%
65.01	2.32	3.77	62.5%
66.01	1.45	1.62	11.7%
66.02	2.07	2.33	12.6%
67.01	1.48	1.75	18.2%
68.01	4.30	6.71	56.0%
68.02	7.90	11.40	44.3%
69.01	3.23	5.03	55.7%
70.01	7.33	7.91	7.9%
71.01	3.20	5.09	59.1%
72.01	3.52	3.72	5.7%
73.01	2.60	3.28	26.2%
74.01	0.75	0.80	5.6%
75.01	0.00	0.00	5.3%
76.01	1.77	1.95	10.2%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
77.01	1.36	1.45	6.6%
78.01	3.07	3.29	7.2%
79.01	1.38	1.57	13.8%
80.01	5.95	6.39	7.4%
80.02	12.90	13.80	7.0%
80.03	13.50	14.50	7.4%
80.04	0.74	0.85	15.1%
80.05	23.10	25.30	9.5%
81.01	4.87	5.26	8.0%
81.02	5.11	5.56	8.8%
81.03	11.60	12.60	8.6%
82.01	7.87	8.54	8.5%
83.01	2.82	3.01	6.7%
83.02	5.98	6.40	7.0%
83.03	11.70	13.30	13.7%
84.01	2.30	2.87	24.8%
85.01	9.44	10.10	7.0%
85.02	7.34	8.05	9.7%
86.01	2.78	3.09	11.2%
87.01	5.20	5.50	5.8%
88.01	2.77	2.94	6.1%
89.01	2.16	2.48	14.8%
90.01	2.23	3.30	48.0%
91.01	1.62	1.99	22.8%
92.01	1.43	1.61	12.6%
93.01	1.10	1.20	9.1%
94.01	1.55	1.70	9.7%
94.02	3.34	3.63	8.7%
95.01	0.10	0.11	4.9%
96.01	2.47	2.50	1.2%
97.01	0.34	0.39	14.3%
98.01	2.39	2.64	10.5%
99.01	1.73	1.87	8.1%
100.01	3.79	4.39	15.8%
100.02	5.04	5.73	13.7%
101.01	1.87	2.08	11.2%
101.02	2.66	2.90	9.0%
102.01	1.21	1.32	9.1%
103.01	0.78	0.94	20.9%
104.01	0.36	0.40	13.8%
_junc_10	51.40	58.10	13.0%
_junc_100	3.52	3.72	5.7%

Future Development Results for the 1% AEP Event			
	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
_junc_102	160.00	236.00	47.5%
_junc_103	160.00	236.00	47.5%
_junc_11	19.30	25.50	32.1%
_junc_12	60.10	66.20	10.1%
_junc_13	9.59	12.70	32.4%
_junc_14	48.90	60.10	22.9%
_junc_15	17.70	21.80	23.2%
_junc_16	6.19	7.63	23.3%
_junc_17	355.00	423.00	19.2%
_junc_18	3.28	3.57	8.8%
_junc_19	179.00	196.00	9.5%
_junc_2	28.50	32.80	15.1%
_junc_20	167.00	182.00	9.0%
_junc_21	353.00	422.00	19.5%
_junc_22	57.50	69.00	20.0%
_junc_23	340.00	416.00	22.4%
_junc_24	115.00	131.00	13.9%
_junc_25	342.00	418.00	22.2%
_junc_26	165.00	240.00	45.5%
_junc_29	346.00	420.00	21.4%
_junc_3	7.86	8.72	10.9%
_junc_30	352.00	421.00	19.6%
_junc_31	347.00	420.00	21.0%
_junc_32	129.00	143.00	10.9%
_junc_33	111.00	128.00	15.3%
_junc_34	4.82	7.63	58.3%
_junc_35	22.40	24.50	9.4%
_junc_36	163.00	238.00	46.0%
_junc_37	11.40	13.00	14.0%
_junc_38	11.10	12.00	8.1%
_junc_39	53.00	66.40	25.3%
_junc_4	12.50	14.20	13.6%
_junc_40	47.30	63.20	33.6%
_junc_41	37.30	55.70	49.3%
_junc_42	34.80	54.10	55.5%
_junc_43	40.40	58.60	45.0%
_junc_44	8.65	14.60	68.8%
_junc_45	13.50	21.50	59.3%
_junc_46	5.44	9.76	79.4%
_junc_47	29.50	47.20	60.0%
_junc_48	14.60	23.40	60.3%
_junc_49	25.30	53.00	109.5%

Future Development Results for the 1% AEP Event

	Existing Development Conditions	Future Development Conditions	
Subcatchment ID	Existing Discharge (m^3/s)	Discharge for Future Conditions (m^3/s)	Difference to Existing (%)
_junc_5	39.90	45.60	14.3%
_junc_50	7.09	11.30	59.4%
_junc_51	11.10	18.10	63.1%
_junc_52	123.00	173.00	40.7%
_junc_53	16.30	36.50	123.9%
_junc_54	28.70	59.60	107.7%
_junc_55	21.10	47.90	127.0%
_junc_56	156.00	232.00	48.7%
_junc_57	121.00	170.00	40.5%
_junc_58	80.40	95.90	19.3%
_junc_59	52.90	60.60	14.6%
_junc_6	14.80	17.20	16.2%
_junc_60	40.80	78.90	93.4%
_junc_61	63.30	74.60	17.9%
_junc_62	43.40	51.60	18.9%
_junc_63	38.80	46.90	20.9%
_junc_64	45.60	53.60	17.5%
_junc_65	36.70	45.10	22.9%
_junc_66	35.90	77.80	116.7%
_junc_67	27.00	35.00	29.6%
_junc_68	31.10	39.50	27.0%
_junc_69	10.80	16.20	50.0%
_junc_7	42.80	48.60	13.6%
_junc_70	19.10	51.70	170.7%
_junc_71	13.00	38.30	194.6%
_junc_72	7.03	10.60	50.8%
_junc_73	14.60	34.70	137.7%
_junc_74	14.60	16.90	15.8%
_junc_8	48.90	55.30	13.1%
_junc_9	25.40	29.60	16.5%

APPENDIX E

COST ESTIMATES

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM1 - Doyalson Link Road basin		

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$25,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	5,000	5,000	$5,000
B2	**SITE PREPARATION**					**$244,152**
B2.1	Removal of bushland over footprint and staging area	m2	9200	7.92	8.89	$81,753
B2.2	Excavate over site to reduce levels in sand and deposit in material heaps onsite	m3	2760	20.15	22.61	$62,399
B2.3	Appropriate temporary waterway adjustment (Allowance)	lump sum	1	100,000	100,000	$100,000
B3	**EARTHWORKS**					**$304,847**
B3.1	Fill from sourced material offsite	m3	3300	59.00	66.20	$218,453
B3.2	Stabilise embankment with cellular maps allowing vegetation growth	m2	7000	11.00	12.34	$86,394
B4	**DRAINAGE**					**$455,644**
B4.1	1.8H x 2.5W Concrete Culverts including headwall structures	m	80	3,175.00	3,562.35	$284,988
B4.2	Spillway construction	m2	300	507.00	568.85	$170,656
B5	**LANDSCAPING AND REMEDIATION**					**$130,062**
B5.1	Replanting of native vegetation and care for xx weeks	m2	9200	12.60	14.14	$130,062
				SUBTOTAL		**$1,159,706**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$117,971**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$117,971
C2	**PROJECT MANAGEMENT**					**$235,941**
C2.1	Construction management/supervision/consultant fees	%	1	15		$176,956
C2.2	Project Management	%	1	5		$58,985
				SUBTOTAL		**$353,912**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$1,533,618**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$55,200**
D1.1	Structural engineer inspection four times annually (NPV @ 7%)			55,200		$55,200
				SUBTOTAL		**$55,200**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$383,405**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$383,405
E2	**PROJECT SCALE**					**$0**
E2.1	Medium Project Size	%	1	0		$0
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0

Item		Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
		ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$1,970,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM2 - Modify Pinehurst Way detention/water quality basin

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mititgation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$15,000**
B1.1	Site Establishment	lump sum	1	5,000	5,000	$5,000
	- Temporary establishment of ammenities and facilities for staff					
	- Fencing of site; including environmental screening, security and safety considerations.					
	- Protection of existing landscaping, structures and surfaces					
B1.2	Environmental Mitigation	lump sum	1	10,000	10,000	$10,000
	- Noise and vibration screening					
	- Temporary flood mitigation					
	- Erosion and sediment control					
B2	**SITE PREPARATION**					**$77**
B2.1	Creating access to site by removal of light vegetation	m2	130	0.53	0.59	$77
B3	**EARTHWORKS**					**$10,076**
B3.1	Excavate to reduce levels in sand and deposit <15km	m3	72	23.25	26.09	$1,878
B3.2	Stabilise basin spillway with geotextile envelope	m2	130	56.20	63.06	$8,197
B4	**LANDSCAPING AND REMEDIATION**					**$1,838**
B4.1	Replanting of native vegetation	m2	130	12.60	14.14	$1,838
				SUBTOTAL		**$26,991**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$4,199**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$4,199
C2	**PROJECT MANAGEMENT**					**$8,398**
C2.1	Construction management/supervision/consultant fees	%	1	15		$6,299
C2.2	Project Management	%	1	5		$2,100
				SUBTOTAL		**$12,597**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$54,588**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$13,647**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$13,647
E2	**PROJECT SCALE**					**$13,647**
E2.1	Small Project Size	%	1	25		$13,647
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$80,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM3 - Pinehurst Way stormwater upgrades		

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B2	**EARTHWORKS**					**$25,172**
B2.1	Prepare site by demolishing existing pavement	m2	200	3.45	3.87	$774
B2.2	Excavate trench in sand and deposit in material heaps onsite	m3	189	57.40	64.40	$12,172
B2.3	Fill from onsite material heaps	m3	100	8.20	9.20	$920
B2.4	Cartage of leftover materials	m3	89	3.10	3.48	$310
B2.5	Laying a new concrete pavement	m2	200	49.00	54.98	$10,996
B3.1	**DRAINAGE**					**$80,111**
B3.1	0.9m H by 2.4m wide concrete box culvert	m	42	1,700.00	1,907.40	$80,111
				SUBTOTAL		**$125,282**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$14,028**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$14,028
C2	**PROJECT MANAGEMENT**					**$28,056**
C2.1	Construction management/supervision/consultant fees	%	1	15		$21,042
C2.2	Project Management	%	1	5		$7,014
				SUBTOTAL		**$42,085**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$182,367**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$45,592**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$45,592
E2	**PROJECT SCALE**					**$45,592**
E2.1	Small Project Size	%	1	25		$45,592
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$270,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM4 - Brava Avenue floodwall and drainage modifications

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B2	**SITE PREPARATION**					**$714**
B2.1	Grub site to remove light vegetation	m2	1200	0.53	0.59	$714
B3	**EARTHWORKS**					**$57,194**
B3.1	Excavate to reduce levels in sand and deposit <15km	m3	100	23.25	26.09	$2,609
B3.2	Precase concrete wall	m2	175	278.00	311.92	$54,585
B4	**DRAINAGE**					**$15,259**
B4.1	0.6m diameter concrete pipe	m	40	340.00	381.48	$15,259
B5	**LANDSCAPING AND REMEDIATION**					**$16,965**
B5.1	Replanting of native vegetation	m2	1200	12.60	14.14	$16,965
				SUBTOTAL		**$110,131**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$13,013**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$13,013
C2	**PROJECT MANAGEMENT**					**$26,026**
C2.1	Construction management/supervision/consultant fees	%	1	15		$19,520
C2.2	Project Management	%	1	5		$6,507
				SUBTOTAL		**$54,039**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$184,171**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$73,668**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	40		$73,668
E2	**PROJECT SCALE**					**$46,043**
E2.1	Small Project Size	%	1	25		$46,043
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	0	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$300,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM5 - Creek maintenance/removal of dense vegetation		

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment: 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$30,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	20,000	20,000	$20,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$30,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$110,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	100,000	100,000	$100,000
B2	**REMOVAL OF DENSE VEGETATION**					**$701,570**
B2.1	Removal of bushland adjacent to the creek	m2	79,000.00	7.92	8.88	$701,570
				SUBTOTAL		**$811,570**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$84,157**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$84,157
C2	**PROJECT MANAGEMENT**					**$168,314**
C2.1	Construction management/supervision/consultant fees	%	1	15		$126,235
C2.2	Project Management	%	1	5		$42,078
				SUBTOTAL		**$252,471**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$1,094,041**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$600,000**
D1.1	Repeat every 10 years at 20% capacity of original volumes (NPV @ 7%)			600,000		$600,000
				SUBTOTAL		**$600,000**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$273,510**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$273,510
E2	**PROJECT SCALE**					**$0**
E2.1	Medium Project Size	%	1	0		$0
E3	**PROJECT SITE CONDITIONS**					**$273,510**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Difficult Site Conditions	%	1	25		$273,510
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$2,240,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM6 - Spring Creek high flow bypass		

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02
Minor Works Adjustment: 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	10,000	10,000	$10,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	20,000	20,000	$20,000
B2	**SITE PREPARATION**					**$71,090**
B2.1	Removal of bushland over footprint and staging area	m2	8000	7.92	8.89	$71,090
B3	**EARTHWORKS**					**$187,823**
B3.1	Excavate to reduce levels in sand and deposit <15km	m3	7200	23.25	26.09	$187,823
B4	**LANDSCAPING AND REMEDIATION**					**$113,098**
B4.1	Replanting of native vegetation	m2	8000	12.60	14.14	$113,098
				SUBTOTAL		**$402,010**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$42,201**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$42,201
C2	**PROJECT MANAGEMENT**					**$84,402**
C2.1	Construction management/supervision/consultant fees	%	1	15		$63,302
C2.2	Project Management	%	1	5		$21,101
				SUBTOTAL		**$126,603**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$548,613**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$137,153**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$137,153
E2	**PROJECT SCALE**					**$137,153**
E2.1	Small Project Size	%	1	25		$137,153
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$820,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM7 - Allambee Crescent embankment and floodgate		

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02
Minor Works Adjustment: 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$10,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	5,000	5,000	$5,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	5,000	5,000	$5,000
B2	**SITE PREPARATION**					**$1,548**
B2.1	Demolish existing footpaths	m2	400	3.45	3.87	$1,548
B3	**EARTHWORKS**					**$56,167**
B3.1	Fill from sourced material offsite	m3	220	69.00	77.42	$17,032
B3.2	Stabilise embankment with cellular maps allowing vegetation growth	m2	160	11.00	12.34	$1,975
B3.3	Lay concrete paving	m2	400	82.80	92.90	$37,161
B4	**DRAINAGE**					**$5,128**
B4.1	Floodgate (Supply and Commision) - to suit 0.6m diameter outlet	each	1	7,000.00	7,854.00	$7,854
B4.2	0.6m diameter concrete pipe	m	10	457.00	512.75	$5,128
				SUBTOTAL		**$72,843**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$8,784**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$8,784
C2	**PROJECT MANAGEMENT**					**$17,569**
C2.1	Construction management/supervision/consultant fees	%	1	15		$13,176
C2.2	Project Management	%	1	5		$4,392
				SUBTOTAL		**$26,353**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$114,196**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$23,528**
D1.1	Floodgate component replacement at year 25 (NPV @ 7%)	item	1	1447		$1,447
D1.2	Floodgate maintenance (inspection/cleaning x 4 times per year x 50 years) (NPV @ 7%)	item	1	22081		$22,081
				SUBTOTAL		**$23,528**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$28,549**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$28,549
E2	**PROJECT SCALE**					**$28,549**
E2.1	Small Project Size	%	1	25		$28,549
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average site conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$190,000**

PRELIMINARY COST ESTIMATE

Description of Works	Revision:	1
FM8 - Enlarge Unnamed Watercourse between Brava and Costa Avenues		

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	20,000	20,000	$20,000
B2	**SITE PREPARATION**					**$44,218**
B2.1	Removal of bushland over footprint and staging area	m2	1600	7.92	8.89	$14,218
B2.2	Appropriate temporary waterway adjustment (Allowance)	lump sum	1	30,000	30,000	$30,000
B3	**EARTHWORKS**					**$20,869**
B3.1	Excavate to reduce levels in sand and deposit <15km	m3	800	23.25	26.09	$20,869
B4	**LANDSCAPING AND REMEDIATION**					**$22,620**
B4.1	Replanting of native vegetation	m2	1600	12.60	14.14	$22,620
				SUBTOTAL		**$117,707**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$13,271**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$13,271
C2	**PROJECT MANAGEMENT**					**$26,541**
C2.1	Construction management/supervision/consultant fees	%	1	15		$19,906
C2.2	Project Management	%	1	5		$6,635
				SUBTOTAL		**$39,812**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$172,519**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$43,130**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$43,130
E2	**PROJECT SCALE**					**$43,130**
E2.1	Small Project Size	%	1	25		$43,130
E3	**PROJECT SITE CONDITIONS**					**$43,130**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Difficult Site Conditions	%	1	25		$43,130
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$300,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM9 - Dredge Wallarah Creek downstream of Spring Creek confluence

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment 1.1

	Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)		**PRE DEVELOPMENT COSTS**					
	A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$35,000**
	A1.1	Geotechnical Report and Assessment	lump sum	1	5,000	5,000	$5,000
	A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
	A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
	A1.4	Ecological Assessment - Marine	lump sum	1	5,000	5,000	$5,000
	A1.5	Ecological Assessment - Flora	lump sum	1	5,000	5,000	$5,000
	A1.6	Waste disposal feasibility assessments	lump sum	2	5,000	5,000	$10,000
	A2	**FEES, LEVIES AND INSURANCE**					**NA**
	A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
	A2.2	- Further fees may be applicable for applications for both the disposal and dewatering of material at local sites. Pricing has been omitted for this initial estimate					
	A3	**PROPERTY ACQUISITIONS**					**$0**
	A3.1	No Property Acquisitions		1	0	0	$0
					SUBTOTAL		**$35,000**
B)		**CONSTRUCTION COSTS**					
	B1	**SITE PREPARATION**					**$106,590**
	B1.1	Dredging barge setup, dismantling and removal	lump sum	1	50,000.00	56,100.00	$56,100
	B1.2	Construction of temporary jetty and access routes	lump sum	1	20,000.00	22,440.00	$22,440
	B1.3	Purchase of skip bins for transport of dredged materials	per item	10	1,500.00	1,683.00	$16,830
	B1.4	Silt curtains	lump sum	1	10,000.00	11,220.00	$11,220
	B2	**DREDGING**					**$20,101,191**
	B2.1	Dredge material and deposit on adjacent land	m3	22500	20.00	22.44	$504,900
	B2.2	Transportation to site for dewatering (<10km)	m3	22500	5.70	6.40	$143,897
	B2.3	Laying and spreading material	m3	22500	11.10	12.45	$280,220
	B2.4	Treatment for upto 2 weeks (including lime supply and treatment)	m3	22500	19.00	21.32	$479,655
	B2.6	Transportation to disposal site (assume no resource recovery) (<10km)	t	35000	15.00	16.83	$589,050
	B2.7	Disposal post-dewatering (Assumed 'Special Wastes' at local waste facility prices)	t	35000	461.00	517.24	$18,103,470
					SUBTOTAL		**$20,207,781**
		TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$20,242,781**
C)		**ONGOING MAINTENANCE COSTS**					
	C1	**MAINTENANCE**					**NA**
	C1.1	- Further dredging will have to be completed to maintain over the 50 year project lifespan. Costs subject to further assessment					
					SUBTOTAL		**NA**
D)		**CONTINGENCY AND PROJECT ADJUSTMENTS**					
	D1	**CONTINGENCIES**					**$5,060,695**
	D1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$5,060,695
	D2	**PROJECT SCALE**					**$0**
	D2.1	Medium Project Scale	%	1	0		$0
	D3	**PROJECT SITE CONDITIONS**					**$5,060,695**
	D3.1	No Congestion Factor	%	1	0		$0
	D3.2	Difficult Environmental Factors	%	1	25		$5,060,695
		ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$30,360,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM10 - Pinehurst Way flow path reshaping

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment: 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$15,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$15,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B2	**EARTHWORKS**					**$13,874**
B2.1	Prepare site by demolishing existing pavement and deposit <15km	m2	200	6.55	7.35	$1,470
B2.2	Excavate to reduce levels in sand and deposit <15km	m3	54	23.25	26.09	$1,409
B2.3	Laying a new concrete pavement	m2	200	49.00	54.98	$10,996
B3	**DRAINAGE**					**$2,244**
B3.1	Adjust existing pits (Allowance)	lump sum	2	1,000.00	1,122.00	$2,244
				SUBTOTAL		**$36,118**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$5,112**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$5,112
C2	**PROJECT MANAGEMENT**					**$10,224**
C2.1	Construction management/supervision/consultant fees	%	1	15		$7,668
C2.2	Project Management	%	1	5		$2,556
				SUBTOTAL		**$15,335**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$66,454**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$16,613**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$16,613
E2	**PROJECT SCALE**					**$16,613**
E2.1	Small Project Size	%	1	25		$16,613
E3	**PROJECT SITE CONDITIONS**					**$0**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$100,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

FM11 - Pinehurst Way modified detention basin, stormwater upgrades and flow path reshaping

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02
Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	0	5,000	5,000	$0
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	2	5,000	5,000	$10,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$20,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B2	**SITE PREPARATION**					**$77**
B2.1	Creating access to site by removal of light vegetation	m2	130	0.53	0.59	$77
B3	**EARTHWORKS**					**$34,814**
B3.1	Prepare site by demolishing existing pavement	m2	200	3.45	3.87	$774
B3.2	Excavate to reduce levels in sand and deposit <15km	m3	60	23.25	26.09	$1,565
B3.3	Excavate trench in sand and deposit in material heaps onsite	m3	189	57.40	64.40	$12,172
B3.4	Fill from onsite material heaps	m3	79	8.20	9.20	$727
B3.5	Cartage of leftover materials	m3	110	3.10	3.48	$383
B3.6	Laying a new concrete pavement	m2	200	49.00	54.98	$10,996
B3.7	Stabilise basin spillway with geotextile envelope	m2	130	56.20	63.06	$8,197
B4	**DRAINAGE**					**$82,355**
B4.1	0.9m H by 2.4m wide concrete box culvert	m	42	1,700.00	1,907.40	$80,111
B4.2	Adjust existing pits (Allowance)	lump sum	2	1,000.00	1,122.00	$2,244
B5	**LANDSCAPING AND REMEDIATION**					**$1,838**
B5.1	Replanting of native vegetation	m2	130	12.60	14.14	$1,838
				SUBTOTAL		**$139,084**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$15,908**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$15,908
C2	**PROJECT MANAGEMENT**					**$31,817**
C2.1	Construction management/supervision/consultant fees	%	1	15		$23,863
C2.2	Project Management	%	1	5		$7,954
				SUBTOTAL		**$47,725**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$206,809**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$51,702**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$51,702
E2	**PROJECT SCALE**					**$51,702**
E2.1	Small Project Size	%	1	25		$51,702
E3	**PROJECT SITE CONDITIONS**					**$0**

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
E3.1	No Congestion Factor	%	1	0		$0
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$310,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

RM5 - Upgrade of Pacific Highway

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$170,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management (allowance)	lump sum	1	150,000	150,000	$150,000
B2	**SITE PREPARATION**					**$125,444**
B2.1	Demolish existing road surface, including dumping of waste material	m2	2200	50.82	57.02	$125,444
B3	**EARTH AND ROADWORKS**					**$249,376**
B3.1	Raise base fill to required elevations and compact (sand) (source <10km)	m3	400	59.00	66.20	$26,479
B3.2	Laying of new roadway (including regrade, new base and seal)	m2	2200	90.30	101.32	$222,897
B4	**DRAINAGE**					**$112,200**
B4.1	Installation of appropriate cross drainage through raised roadway (Allowance)	lump sum	1	100,000.00	112,200.00	$112,200
				SUBTOTAL		**$657,020**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$67,702**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$67,702
C2	**PROJECT MANAGEMENT**					**$135,404**
C2.1	Construction management/supervision/consultant fees	%	1	15		$101,553
C2.2	Project Management	%	1	5		$33,851
				SUBTOTAL		**$223,106**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$900,126**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$241,230**
D1.1	Inspection and Cleaning Program (Part of a regular 5 year total asset O&M plan with additional reactive cleaning) (NPV @ 7%)	per asset	1	215,000	241,230	$241,230
				SUBTOTAL		**$241,230**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$225,031**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$225,031
E2	**PROJECT SCALE**					**$225,031**
E2.1	Small Project Size	%	1	25		$225,031
E3	**PROJECT SITE CONDITIONS**					**$360,050**
E3.1	Heavy Congestion Factor	%	1	40		$360,050
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$1,950,000**

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1

RM6 - Upgrade of Birdwood Drive

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. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1.02

Minor Works Adjustment: 1.1

Item	Description	Unit	Quantity	Base Rate	Adjusted Rate	Amount
A)	**PRE DEVELOPMENT COSTS**					
A1	**DEVELOPMENT OF MANAGEMENT PLANS**					**$20,000**
A1.1	Traffic/Pedestrian Management Plan	lump sum	1	5,000	5,000	$5,000
A1.2	Operational Health, Safety and Rehabilitation Plan	lump sum	1	5,000	5,000	$5,000
A1.3	Quality Assurance and Inspection Test Plan	lump sum	1	5,000	5,000	$5,000
A1.4	Environmental Management Plans	lump sum	1	5,000	5,000	$5,000
A2	**FEES, LEVIES AND INSURANCE**					**NA**
A2.1	- Typically an allowance should be made for costs associated with insurance (eg. Public Liability, Contract Works), Levies (eg. Long Service Levy) and Fees (eg. Permits).					
A3	**PROPERTY ACQUISITIONS**					**$0**
A3.1	No Property Acquisitions		1	0	0	$0
				SUBTOTAL		**$20,000**
B)	**CONSTRUCTION COSTS**					
B1	**PRELIMINARIES**					**$30,000**
B1.1	Site Establishment - Temporary establishment of ammenities and facilities for staff - Fencing of site; including environmental screening, security and safety considerations. - Protection of existing landscaping, structures and surfaces	lump sum	1	10,000	10,000	$10,000
B1.2	Environmental Mitigation - Noise and vibration screening - Temporary flood mitigation - Erosion and sediment control	lump sum	1	10,000	10,000	$10,000
B1.3	Traffic Management	lump sum	1	10,000	10,000	$10,000
B2	**SITE PREPARATION**					**$73,379**
B2.1	Demolish existing road surface, including dumping of waste material	m2	2000	32.70	36.69	$73,379
B3	**EARTH AND ROADWORKS**					**$166,242**
B3.1	Raise base fill to required elevations and compact (sand) (source <10km)	m3	474	59.00	66.20	$31,378
B3.2	Laying of new roadway (including regrade, new base and seal)	m2	2000	60.10	67.43	$134,864
B4	**DRAINAGE**					**$1,795**
B4.1	Adjustment of existing pits	each	4	400.00	448.80	$1,795
				SUBTOTAL		**$271,416**
C)	**MANAGEMENT AND DESIGN**					
C1	**ENGINEERING DESIGN**					**$29,142**
C1.1	Investigation and preparation of engineering design plans	%	1	10		$29,142
C2	**PROJECT MANAGEMENT**					**$58,283**
C2.1	Construction management/supervision/consultant fees	%	1	15		$43,712
C2.2	Project Management	%	1	5		$14,571
				SUBTOTAL		**$107,425**
	TOTAL at 7% NPV (Rounded to nearest $10,000) (excluding ongoing maintenance costs, contingency and project adjustments)					**$398,841**
D)	**ONGOING MAINTENANCE COSTS**					
D1	**MAINTENANCE**					**$0**
D1.1	Assume existing asset O&M management plan is sufficient					$0
				SUBTOTAL		**$0**
E)	**CONTINGENCY AND PROJECT ADJUSTMENTS**					
E1	**CONTINGENCIES**					**$99,710**
E1.1	Total contingency percentage for an estimate with a 90% confidence of not being exceeded	%	1	25		$99,710
E2	**PROJECT SCALE**					**$99,710**
E2.1	Small Project Size	%	1	25		$99,710
E3	**PROJECT SITE CONDITIONS**					**$59,826**
E3.1	Light Congestion Factor	%	1	15		$59,826
E3.2	Average Site Conditions	%	1	0		$0
	ADJUSTED TOTAL at 7% NPV (Rounded to nearest $10,000) **exc GST**					**$660,000**

APPENDIX F

ROADWAY INUNDATION INFORMATION

Impact of Flooding on Transport Links

Road Name	20% AEP Event (Wallarah Creek Bridge Gauge Level - 0.95 mAHD)				5% AEP Event (Wallarah Creek Bridge Gauge Level - 1.19 mAHD)				1% AEP Event (Wallarah Creek Bridge Gauge Level - 1.42 mAHD)				PMF Event (Wallarah Creek Bridge Gauge Level - 2.95 mAHD)			
	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)
ALAN AVE																
ALLAMBEE CR					Y	0:40	0:17	0.22	Y	0:40	1:29	0.24	Y	1:20	6:54	1.78
ALLINGA RD	Y	1:20	10:00	0.29	Y	1:20	10:40	0.38	Y	1:00	11:20	0.43	Y	0:40	>6:20	0.79
ALPINE AVE																
AMAROO CL																
APSLEY CT													Y	0:20	1:16	0.26
ARIZONA RD									Y	0:40	0:09	0.18	Y	0:20	1:07	0.28
AWABA AVE																
BANCROFT CL													Y	0:20	0:44	0.24
BANGALAY CL					Y	0:40	0:08	0.20	Y	0:40	0:20	0.23	Y	0:20	1:56	0.31
BARCOO ST																
BARKER AVE																
BARRA ST																
BARRAGOOLA RD																
BARTON RD																
BARWON CL																
BAYSIDE ST													Y	0:20	1:39	0.29
BEDE WAY																
BELLINGER WAY																
BELYANDO CR													Y	0:20	1:19	0.34
BELYANDO CRES																
BIRDWOOD DR	Y	1:00	7:09	0.43	Y	0:40	8:30	0.79	Y	0:40	9:35	1.09	Y	0:20	>6:58	3.35
BLUE HAVEN WAY													Y	0:20	3:00	0.52
BLUERIDGE DR					Y	0:40	0:20	0.13	Y	0:40	0:40	0.16	Y	0:20	4:38	1.04
BOKHARA AVE													Y	0:20	0:26	0.23
BOTHAM CL	Y	0:40	0:20	0.34	Y	0:40	0:59	0.40	Y	0:40	1:00	0.45	Y	0:20	3:00	0.72
BRAVA AVE									Y	1:00	0:20	0.22	Y	0:20	6:40	0.94
BRUCE CR	Y	1:20	0:40	0.20	Y	1:00	1:11	0.23	Y	1:00	2:04	0.25	Y	0:40	3:00	0.49
BUSHELLS RIDGE RD																
CALLAGHAN DR									Y	0:40	0:09	0.21	Y	0:20	1:53	0.48
CALLEN AVE					Y	0:40	0:08	0.20	Y	0:40	0:20	0.23	Y	0:20	1:55	0.33
CAPRI CL																
CARINYA ST																
CASCADES RD																
CATALINA RD																
CHARMHAVEN AVE																
CHELMSFORD RD	Y	0:20	4:45	0.16	Y	0:20	5:46	0.20	Y	0:40	5:46	0.23	Y	0:20	>2:45	0.40
CLARIDGE CR																
CLARKSON LANE																
COLORADO DR									Y	0:40	0:20	0.28	Y	0:20	2:07	0.70
CORRINDI WAY																
COSTA AVE													Y	0:20	6:24	0.94
CYPRESS CL													Y	0:20	0:08	0.19
DAINTREE CR															0:10	0.23
DASH RD																
DAVID ST					Y	0:40	0:16	0.21	Y	0:40	0:20	0.24	Y	0:20	2:28	0.39
DENMAN ST																
DEPOT RD													Y	0:20	0:53	0.21
DIXIE LANE																
DOYALSON LINK RD													Y	0:20	5:59	0.27
DRYDEN COURT RD																
DUNLOP RD	Y	0:40	0:12	0.22	Y	0:40	0:20	0.25	Y	0:40	0:36	0.27	Y	0:20	3:40	0.61
DWYER ST									Y	0:40	0:20	0.34	Y	0:20	2:07	0.69
ELKINGTON DR													Y	0:20	0:05	0.24
ELLALONG WAY																

Road Name	20% AEP Event (Wallarah Creek Bridge Gauge Level - 0.95 mAHD)				5% AEP Event (Wallarah Creek Bridge Gauge Level - 1.19 mAHD)				1% AEP Event (Wallarah Creek Bridge Gauge Level - 1.42 mAHD)				PMF Event (Wallarah Creek Bridge Gauge Level - 2.95 mAHD)			
	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)
ELM PL																
EMU DR																
EYRE CR																
FAMATA AVE													Y	1:40	6:24	1.41
FIR CT													Y	0:20	0:18	0.17
GOORAMA AVE													Y	0:20	0:17	0.21
GOROKAN RD																
GOSFORD RD																
GRADY CL																
HAKONE RD											0:03	0.14	Y	0:20	2:59	0.43
HARRY CL																
HELIOS ST																
HELMAR CL																
HIAWATHA RD	Y	1:00	1:20	0.10	Y	1:00	1:35	0.12	Y	1:00	1:40	0.16	Y	0:40	2:58	0.56
HIGHVIEW AVE																
HUE HUE RD																
HUNTER ST																
HYAM CL					Y	0:40	0:12	0.27	Y	0:40	0:20	0.31	Y	0:20	3:20	0.58
ILUKA AVE																
JENKINS PL									Y	0:40	0:20	0.17	Y	0:20	1:56	0.50
JETTY AVE																
KALLAROO RD																
KANIMBLA AVE																
KARINGAL PL													Y	0:20	1:47	0.30
KATOOMBA AVE																
KAWANA AVE																
KEERA CL																
KIAR RIDGE RD																
KOORINGAL AVE																
KYAMBA CL																
LADY KENDALL DR																
LADY LAUREL DR					Y	0:40	0:15	0.15	Y	0:40	0:20	0.18	Y	0:20	2:31	0.43
LAKE HAVEN DR																
LANA PL																
LANDHAVEN AVE	Y	0:40	0:20	0.35	Y	0:40	0:20	0.45	Y	0:40	1:00	0.53	Y	0:20	3:00	0.80
LAW PL																
LEMON GUM CCT					Y	0:40	0:20	0.39	Y	0:40	0:20	0.46	Y	0:20	2:40	0.74
LENOLA CR																
LIAMENA AVE																
LILY LANE																
LOCH CL									Y	0:40	0:20	0.20	Y	0:20	1:59	0.31
LONSDALE CL																
LOONGANA CR													Y	0:20	0:28	0.28
LOWANA AVE													Y	1:49	5:20	1.25
LYGON ST																
MAHENO AVE																
MARRI CL	Y	0:20	0:54	0.11	Y	0:20	1:15	0.20	Y	0:20	2:00	0.26	Y	0:20	2:00	0.45
MARSDEN RD													Y	0:20	2:07	0.71
MCCREA BVD																
MCKELLAR BVD													Y	0:20	2:43	1.59
MELIA LANE																
MENINDEE AVE	Y	0:40	0:20	0.26	Y	0:40	0:20	0.31	Y	0:40	0:20	0.36	Y	0:20	2:40	0.56
MERIMBULA PL																
MERINDA AVE																
MILLER CR					Y	0:40	0:20	0.31	Y	0:40	0:20	0.35	Y	0:20	2:40	0.72
MOALA PDE																
MOGO CL	Y	0:20	0:30	0.11	Y	0:20	0:20	0.13	Y	0:40	0:20	0.17	Y	0:20	1:31	0.30

Road Name	20% AEP Event (Wallarah Creek Bridge Gauge Level - 0.95 mAHD)				5% AEP Event (Wallarah Creek Bridge Gauge Level - 1.19 mAHD)				1% AEP Event (Wallarah Creek Bridge Gauge Level - 1.42 mAHD)				PMF Event (Wallarah Creek Bridge Gauge Level - 2.95 mAHD)			
	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)
MONA RD													Y	1:00	2:29	0.42
MOUNTAIN RD																
MUNMORAH AVE													Y	2:00	5:20	0.58
MURCHISON CL																
MURU CL																
MYALL CL									Y	1:00	0:40	0.31	Y	0:20	3:05	0.88
MYEE PL																
NAGLE CR									Y	0:40	0:20	0.24	Y	0:20	2:05	0.32
NAMBUCCA CR					Y	0:40	0:10	0.22	Y	0:40	0:20	0.27	Y	0:20	2:19	0.51
NARARA AVE																
NARRAN RD																
NELMES RD	Y	0:40	0:17	0.06	Y	0:40	0:20	0.08	Y	0:40	0:20	0.13	Y	0:20	4:00	1.10
NERIDA AVE																
NEWTON PL	Y	1:00	0:40	0.47	Y	1:00	1:20	0.81	Y	1:00	2:20	1.12	Y	0:20	6:57	3.53
NORAH AVE																
NYMBOIDA CT																
OAK RD																
O'HART CL																
OLNEY DR									Y	0:40	0:20	0.34	Y	0:20	3:40	2.45
ORARA LANE																
PACIFIC HWY	Y	0:40	1:20	0.42	Y	0:20	0:40	0.42	Y	0:20	2:00	0.42	Y	0:20	6:00	1.51
PACIFIC MWY													Y	0:20	6:40	1.74
PANORAMA AVE													Y	1:40	5:20	1.02
PARKSIDE DR																
PENGUIN RD									Y	2:20	1:59	0.40	Y	1:19	6:11	2.50
PEROUSE AVE																
PINE CT																
PINEHURST WAY	Y	0:40	0:20	0.35	Y	0:40	0:20	0.44	Y	0:40	0:39	0.53	Y	0:20	3:00	1.15
POPRAN WAY	Y	0:40	0:19	0.24	Y	0:40	0:20	0.26	Y	0:40	0:40	0.27	Y	1:00	4:00	1.51
POTTER ST													Y	0:20	0:55	0.28
RAILWAY - MAIN NORTHERN													Y	0:40	3:40	5.69
REEF WAY													Y	0:20	1:31	0.33
REGANZA ST																
REGINA LANE																
RESTHAVEN AVE																
RESTLEA AVE																
RICHARDSON RD																
ROPER RD																
ROSELLA CCT													Y	0:20	1:00	0.28
SCENIC DR																
SCRIBBLY GUM CL	Y	0:40	0:17	0.20	Y	0:40	0:18	0.22	Y	0:40	0:20	0.24	Y	0:20	2:40	0.44
SHEARER CR													Y	0:20	2:42	0.56
ST LAWRENCE AVE							0:00	0.18	Y	0:40	0:20	0.21	Y	0:20	2:07	0.36
STORM CR																
TALIA CT													Y	0:20	0:33	0.26
TANDARA CL																
TARONGA AVE																
THE ADA					Y	0:40	0:18	0.21	Y	0:40	0:20	0.24	Y	0:20	2:33	0.68
THOMPSON VALE RD													Y	1:00	3:53	2.17
TIMBARA CR													Y	0:20	2:03	0.53
TINGIRA ST																
TOOHEYS RD	Y	6:00	0:44	0.26	Y	1:21	1:35	0.55	Y	1:20	2:11	0.72	Y	0:40	6:19	2.53
TUSCAN PL									Y	0:40	0:20	0.16	Y	0:20	0:34	0.26
TWIN LAKES DR																
UNA AVE																
WAKOOL CR																

Road Name	20% AEP Event (Wallarah Creek Bridge Gauge Level - 0.95 mAHD)				5% AEP Event (Wallarah Creek Bridge Gauge Level - 1.19 mAHD)				1% AEP Event (Wallarah Creek Bridge Gauge Level - 1.42 mAHD)				PMF Event (Wallarah Creek Bridge Gauge Level - 2.95 mAHD)			
	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)	Access Cut?	Access First Cut (Hours:Minutes)	Duration Cut (Hours:Minutes)	Max Depth (m)
WANDEWOI AVE																
WARRIGAL RD																
WATERHEN CL					Y	0:40	0:10	0.15	Y	0:40	0:20	0.16	Y	1:00	3:39	1.38
WATERSIDE DR																
WAUGH CL																
WENTWORTH AVE																
WEONGA PL																
WHITE SWAN AVE													Y	0:20	1:20	0.43
WILGA CL					Y	0:40	0:17	0.24	Y	0:40	0:20	0.29	Y	0:20	2:34	0.42
WILLS RD																
WINDERMERE AVE																
WIRRIGA AVE																
WIRRUNA ST																
WONDABOYNE AVE																
WONGALA AVE																
WOODCUTTERS RD																
WOODS RD																
WOODVILLE RD																
WYEE RD																
WYNDORA AVE																
YURUGA AVE																

Appendix G

Property Inundation Information

Number of Properties with above floor flooding				
Location	**20% AEP Event (Wallarah Creek Bridge Gauge Level - 0.95 mAHD**	**5% AEP Event (Wallarah Creek Bridge Gauge Level - 1.19 mAHD)**	**1% AEP Event (Wallarah Creek Bridge Gauge Level - 1.42 mAHD)**	**PMF Event (Wallarah Creek Bridge Gauge Level - 2.95 mAHD)**
Allambee Cr	1	2	3	46
Apsley Ct	0	1	1	1
Belyando Cr	0	0	0	3
Birdwood Dr	0	3	26	166
Blueridge Dr	0	0	0	7
Brava Ave	0	2	2	10
Colorado Dr	0	0	0	13
Costa Ave	0	0	0	25
David St	0	0	0	7
Dunlop Rd	0	0	0	2
Dwyer St	0	0	0	8
Famata Ave	0	0	0	10
Jenkins Pl	0	0	0	9
Karingal Pl	0	0	0	2
Lady Laurel Dr	0	0	0	6
Landhaven Ave	0	0	0	2
Lenola Cr	0	0	0	2
Loch Cl	0	0	0	4
Marsden Rd	0	0	1	9
Mckellar Bvd	0	0	2	48
Myall Cl	0	0	0	2
Nagle Cr	0	0	0	5
Nambucca Cr	0	2	2	6
Nelmes Rd	0	0	0	15
Newton Pl	0	2	3	28
Olney Dr	0	0	0	25
Penguin Rd	0	0	0	10
Pinehurst Way	1	3	3	18
Popran Way	0	0	0	9
Scribbly Gum Cl	0	1	3	6
St Lawrence Ave	0	0	0	10
Talia Ct	0	0	0	4
Timbara Cr	0	0	0	8
Waterhen Cl	0	0	0	9
Weonga Pl	0	0	0	4
Description of Flood Impacts	Local overland flooding resulting in shallow inundation along local roads. Above floor flooding of 1 property in Pinehurst Way and 1 property in Allambee Cr.	Local overland and mainstream flooding resulting in shallow inundation along some local roads. Additional properties with above floor flooding near Penguin Rd. Roadway Access along Allambee Cr Namburra Cr and Pinehurst Rd cut	Local overland and mainstream flooding resulting in moderate inundation along local roads. Additional properties with above floor flooding near Pinehurst Way, Nambucca Cr and Allambee Cr. Additional roadway access near Scribbly Gum Cl, and Newton Pl cut.	Local overland and mainstream flooding resulting in high inundation depth along most local roads. 539 properties within Bluehaven experiencing above floor flooding. Many roadways cut including Colorado Dr, Waterhen Cl and Mckellar Bvd cut

APPENDIX H

PUBLIC EXHIBITION SUBMISSIONS

Wallarah Creek Floodplain Risk Managagment Study & Plan - Summary of Public Submissions & Responses

Submission Number	Summary of Comments	Response
1	Owns a property in Woongarrah and could not locate any site specific flood information to determine if there will be any planning implications for the site	Email was submitted which included flood mapping in the vicinity of the site. No changes to the report necessary
2	Observed that all flow in the local area drains down to the low point in Birdwood Drive and stormwater infrastructure at this location appears outdated/unable to cope. Water seems to often pool and flood the back of houses in Birdwood drive first	Flood mapping confirms that inundation of Birdwood Dr is predicted during relatively frequent floods. Flood mapping also confirms that inundation at the rear of the Birdwood Dr properties also occurs
	Half the street does not have gutters. If kerb and guttering was installed it would assist with the nuisance flooding	Regrading of Birdwood Drive is recommended for this area. Report will be updated to suggest that kerb and guttering in addition stormwater upgrades could be explored as part of these works
	King tides increased the impact of flooding during February flood. Suggested that upgraded stormwater infrastructure and dredging of The Entrance channel would greatly assist reducing the flooding problems	Dredging of The Entrance channel was not explored again as it was investigated as part of the Tuggerah Lakes Floodplain Risk Management Study. Council is currently preparing an Entrance Management Procedure and Decision Support Tool together with expert coastal engineers
	Suggested that raising the creek embankment at its lowest point would reduce floodwater overtopping and entering Birdwood Dr	Several structural options were trialled to help alleviate flooding in the area. However, the shear volume of water travelling along Spring Creek during large floods makes it difficult for structural options / topogrpahic modifications to make a meaningful difference
3	Submission noted that the Central Coast Regional Plan 2036 shows that many new developments are earmarked for the Central Coast LGA including within the Wallarah Creek catchment. This is in addition to the Doyalson RSL area where 45ha of additional development is proposed. The increase in hard surfaces from this new development will add to the flooding problems.	The Central Coast Regional Plan 2016 was not available when the draft floodplain risk management study & plan report was originaly prepared. Nevertheless, Section 3.4 of the report presents the outcomes of a "future catchment development" scenario which defines the potential impacts that future catchment development may have on the existing flooding problem. This confirms that future catchment does have the potential to increase the flooding problem and is the primary reason why several of the options were evaluated not only against the existing flooding scenario but also the future flooding scenario. No updates made to report.
	Wallarah Creek catchment is bordered by the Vales Point power station that generates and stores coal ash in an ash dam. Concerns raised over the integrity of the walls of the dam and the potential for leaching of coal ash leachate and further flooding issues that may include acid sulphate soil problems.	The Vales Point power station is not located within the Wallarah Creek catchment (it is located about 4km north, north-west of the catchment boundary). Although it is acknowedged that lechate does have the potential to cause environment issues, this facility is considered to have no impact on flooding within the Wallarah Creek catchment. No updates made to the report.